Interceptor

SPECIAL EDITION

THE F-101 AND PITCHUP

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FOR THE MEN RESPONSIBLE FOR AEROSPACE DEFENSE

Interceptor

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spotlight

A pitchup warning system, no matter how valuable, cannot be used as the final criterion of maximum "G" loading.

contents

Hq ADC Field Printing Plant
Ent AFB, Colorado

OUR COVER

Our artist has captured a critical moment in the life of an ADC aircrew. The way the picture is painted from here on is strictly dependent on the pilot.

memo
from the CHIEF OF SAFETY

INTRODUCTION

"Primary Cause: Operator factor in that the pilot inadvertently exceeded the critical angle of attack of the aircraft, resulting in pitchup at an altitude too low to permit successful recovery."

Does that sound routine? Is your attitude, "So what, it's the nature of the beast and it will happen again"? If so, read on, because this special edition of the INTERCEPTOR is dedicated to the proposition that pilot-induced pitchups in the F-101B are preventable; that it is a better performing airplane than most people give it credit for; that when it is flown with finesse within the design envelope it has proven its ability to accomplish the mission successfully.

During the first few years after the Voodoo began showing up on ADC flight lines, pilots in the Command were getting into pitchup at fairly regular intervals. Lack of knowledge, understanding, and training in the flight characteristics of the airplane, plus a natural desire to find out what the shiny powerhouse could do, led to a substantial number of accidents in the "wotta waste" category. As time went on, aircrews gained experience in the bird, sometimes the hard way, and induced pitchup became the rare rather than the common occurrence.

Meanwhile, difficulties arose in the reliability of the Pitch Control System and some pitchup losses were incurred because of equipment malfunction. The MCSL and PBI were installed as additional protective devices. The results were satisfactory.

Until recently, the problem looked like it had become a thing of the past. However, there are now strong indications that we may be approaching a situation not unlike the one where it all began. The attrition of experienced F-101B pilots to Palace Cobra and other personnel programs has, and will continue to significantly reduce the degree of expertise on the Voodoo. ADC is in turn receiving a large number of SEA returnees who have little or no experience in the aircraft. If past history is of any value at all, trouble lies ahead unless supervisors make it perfectly clear that the F-101B is not an F-4, F-105, or any other aircraft, and must be flown in the manner prescribed by directives and/or instructor pilots.

In the interest of aircrew safety and preserving the F-101Bs we have left, the INTERCEPTOR staff has reviewed all past issues containing articles on pitchup and the Voodoo. We can't improve on what has been written so well before by those who knew what they were writing about. Therefore, this special edition contains a series of articles worth their weight in gold for those who don't know all they should know about flying an airframe which is different, to say the least.

Colonel H. C. Gibson

Benedicto Escombro! or Holy Mackerel

Our thanks to McDonnell Aircraft and MAC test pilot Don Stuck, for making this story possible. They provided manpower, brainpower and flight time in support of this story.

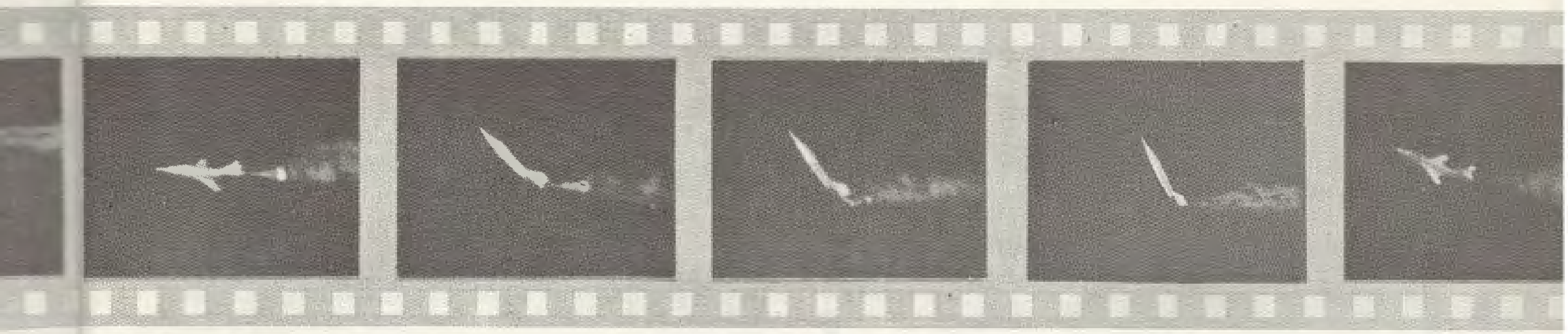
THE hottest subject on our F-101 ramps today is pitchup, and justly so: We've lost two aircraft to it already. If we play our cards right from here on in, we need not lose another. All it takes to beat this thing is an understanding of what causes pitchup; the means of avoiding it; and the proper recovery techniques in case it occurs in spite of us.

Pitchup is caused by one thing only—excessive angle of attack. There are no ifs, ands, or buts about it: if you exceed the angle of attack limits of this bird, she'll take matters in her own hands and put you to the pitchup recovery test! So, unless you care to test your skill in a recovery, you'd better develop your skill at staying out of it.

F-101 drivers can't afford to "feel" for flight limits as they used to do in the case of the conventional stall—the price of overshoot is too great. It takes more than a simple pop of the stick to recover. It is true that the horn boundary has taken the place of the pre-stall buffet, but it would be unwise to establish your normal technique around a mechanical limit such as this. If you did, the price of a mechanical malfunction would be pitchup. No—the answer here is to stay inside the stability limits through technique and understanding.

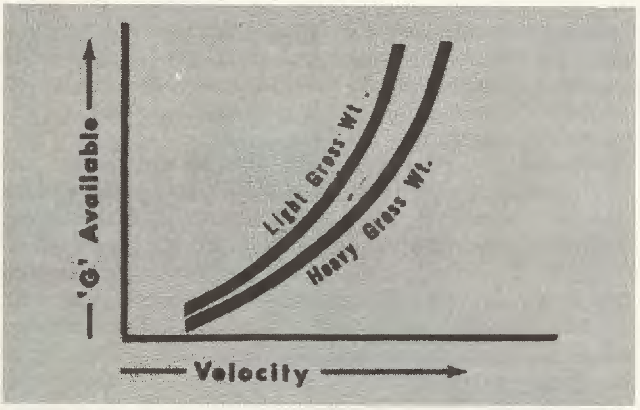
An angle of attack limit is not a common term to 101 pilots, because we don't have alpha indicators in the aircraft. But an angle of attack limit is really a lift limit, and we can read that as g. Since the requirement is set to one maximum angle of attack, the pilot must correlate this to lift at various airspeeds, or maximum g versus airspeed.

This is not as foreign as it first sounds. We have always flown by reference to our 1 g—airspeed limit; we called it stalling speed. We came to the point where we were also adjusting this limit for gross weight; the higher the gross, the higher the stall speed. Or, the higher the weight, the lower the allowable g. These computations are just as valid for two or more g's, because a limit angle of attack has a limit lift for any given airspeed. Fifty thousand pounds of lift could be



2 g for a 25,000 lb. airplane, or 1 g for a 50,000 pounder; it's as simple as that. Angle of attack times airspeed equals lift, and lift divided by gross equals available g.

So, when we plot limit g versus airspeed—or mach—we will have a different plot for each gross weight. There are several ways of plotting this; we use two. The dash-1 uses the block graph, which is good for precise calculation of any configuration in the spectrum, but is hard to read quickly for relative values. The high altitude plot contained in the 29-1 is more to our liking, since it is a curved graph which plots limit g versus airspeed under rather typical conditions. It affords you a good readable picture of the g boundary, from which you can extract key index points for use on your knee pad. Having studied the curve for the interpolative relationship, the key limits can serve as a basic guide in flight.

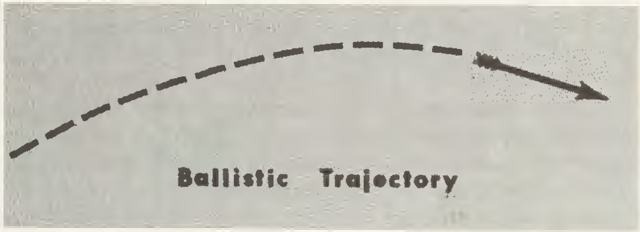


Notice that the curve does not stop at 1 g, nor even at critical 1 g speed, This leads us to the next subject—the zero-g theorum.

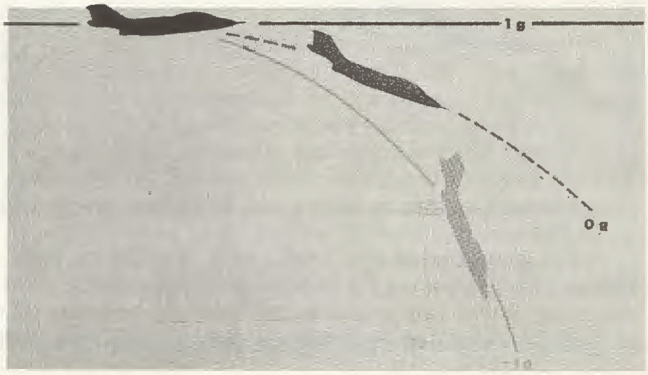
To understand the theory behind this "not really new" technique, let's consider the aerodynamics behind pitchup. We know that pitchup is an instability, caused essentially by the downwash effect which comes from excessively high angles of attack. It follows, then, that if you don't have a high angle of attack, there will be no pitchup. This is equally true of the stall in any other aircraft—no angle of attack, no stall!

Just what does happen to an aircraft if we reduce our angle of attack below that which will support level flight? The answer is elementary: If we are in straight and level flight, we go down. If we happen to be inverted at the time, we simply reduce the rate at which we are turning toward the ground!

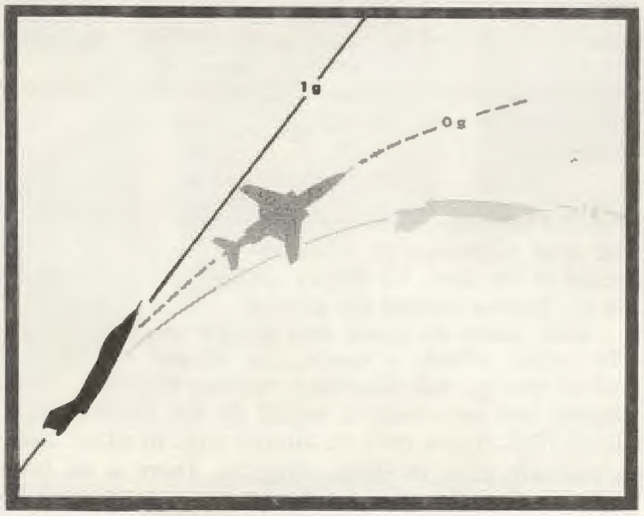
Let's shoot an arrow into the air on a 45° angle. The arrow, which is continually subject to the 1 g pull of gravity, will describe a ballistic trajectory. If an aircraft had no wings, it would do the same thing—right? Well, if you push an aircraft over to where there is zero lift, it is, in effect, wingless. There is no force present other than the force of gravity, so at zero lift the airplane will do exactly what the arrow does: whether right-side-up or upside-down.



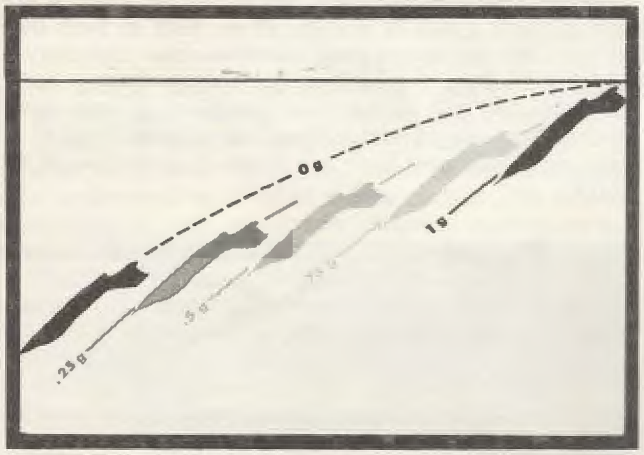
Consider the case of an aircraft which is flying level in perfect 1 g trim. Actually, the lift on the wings is offsetting the 1 g pull of gravity. If we were to push over to zero lift, we would push ourselves into trajectory—which is really a 1 g ballistic curve toward the ground. If we pushed still further—to 1 negative g—we would double this rate of turn toward the ground—right? In fact, we would now have a 2 g turning rate toward the earth.



All right, suppose we just roll over while trimmed for level flight. Doesn't this also give us a 2 g turning rate toward the ground? We took away 1 g of lift above trajectory and added it below.



Let's apply this to the vertical recovery. We will start from a climb with 1 g airspeed available. Once we roll over, we are in a 2 g turn toward the horizon, but we are also running out of airspeed. We don't want to try to hold the full g, because it would take more angle of attack to do it, and that means pitchup. So we push toward whatever fraction the chart prescribed for the speed. On our chart here you can see the lines representing turning radius for fractional g. Note that you are not pushing away from the horizon, but merely reducing the turning rate toward zero g, which is the basic 1 g trajectory. You are now making like an arrow, and we've never heard of an arrow that failed to come down.



Just how good is this? Well, Mr. Don Stuck, McDonnell's test pilot on the F-101B pitchup program, has been taking Air Force people over the top at from 110 to 140 knots in demonstration flights in the 101. Don assures us that there is ample stabilator control to hold zero g down to 90 knots or less. Remember, zero means there is no critical downwash to cause pitchup, and that's worth going into 1 g orbit for.

In case you're worried about actually going to zero airspeed, don't. You certainly should have had your nose down to 30° or so before reaching zero g. Here, the induced drag is literally zero also, so the full, or military, power you have on will preserve your airspeed beautifully. The thrust line is very close to the longitudinal axis in the 101, so don't be afraid to light those burners at the first sign of trouble in such a recovery.

One word of caution in pushing for zero g: The oil flow to the engine bearings stops with negative g, and 10 to 15 seconds is critical without oil. So, if you overshoot zero in the initial roll, be sure to apply an increment of positive g to get that oil back on the bottom of the tank. As you will note at zero g, your stomach neither rises nor falls at zero—it takes a little g in either direction to move it. Oil is like that too.

For those of you who can't—or won't remember limit g at the various airspeeds, the 101 has three gismos with excellent mechanical memories. They are: the Automatic Flight Control System (AFCS) with its Control Stick Limiter (CSL), the horn warning, and the stick pusher. The last two devices are part of the Pitch Control System (PCS).

The AFCS, commonly called the Auto Pilot, is designed to keep you just inside the horn boundary. It will do so, with one possible exception: Some of the "black boxes" have cams which allow horn penetration in the transonic region (.9 to 1.1 mach number), but this is nothing to worry about as long as you know about it.

The Auto Pilot knows all about zero g techniques and will reduce angle of attack as much as necessary to keep you within g limits, even at the low airspeeds which require less than 1 g.

There are two things you should know about the AFCS that can cause trouble. 1. If the pusher were to activate for any reason, it would automatically disengage the AFCS; and 2. The auto pilot can be overpowered. It takes 60 pounds of aft stick force to break loose in pitch. If you were to be pulling this kind of force and it did let go of you, you would induce a dynamic overshoot into pitchup unless you were mighty fast. So, if you disagree with the AFCS at any time, we suggest that you press the disengage switch on the stick and proceed with the knowledge that all you have left is the PCS.

When you do this, you should remember that the PCS has one important limitation also. It is a time delay in resetting for a second warning, due to a time delay relay which is included in the system circuitry.

It works this way: Once activated, the pusher will keep pushing until two conditions are satisfied: 1. the alpha vane must signal that the angle of attack has actually been reduced by a safe margin, and 2. the stabilator sends an O.K. when it has moved 2.5 degrees. When BOTH signals have been received, a TIME DELAY RELAY opens to deactivate the PCS. AFTER A .4 SECOND DELAY, the system is reset for the next warning cycle.

The way to pitch without warning here is to "ride" the pusher closely, and pull yourself into pitchup during the .4 second the relay is open. Even though it is impossible to rotate the bird this quickly, you can induce a rotation rate that the pusher will not be able to stop, so be careful!

That just about brings us to pitchup, in which case it will pay us to understand the recovery. So, here goes.

It is true that we've lost both aircraft that pitched so far, but we now have a good explanation for this fact—and some information that will help you be the first to recover successfully.

In the first place, both of our pilots lost their spin chutes in the early phase of recovery. One was twisted or torn—and jettisoned early, and the second burned away in a flash fire of an unexplainable nature. In light of the high reliability rate of the 101 chute, we must consider these two cases as unusual—for the time being at least.

Next, in view of McDonnell's success in pitchup recovery—over 150 with chute and over 100 without—we concluded that there must be something we didn't know about this recovery business. There was: RECOGNITION OF RECOVERY.

It is not enough to say "hold full forward stick until recovered," as it does in the dash-1, because recovery is not easily recognized. Furthermore, full forward stick can push the aircraft right into a new pitchup cycle if held too long. This difficulty is greatly amplified in the no-chute recovery, so let's concentrate on that.

Don Stuck recently flew a delayed deployment recovery test, in which he held full forward stick throughout—instead of neutralizing as the bird recovered flyable angles of attack. A study of the films revealed that he had "recovered" five times during the 35 second series, but that the recovery control drove him right into continuous pitchup cycles. Each cycle was about identical to the one preceding it. At the peak of the fifth pitchup, he deployed the spin chute and made a normal recovery.

Here is how a pitchup cycle goes—holding full forward stick throughout:

1. The pitchup—60 to 80° angles of attack are normal.
2. The rebound—so named because the nose comes back fast.
3. Recovery—meaning recovery of relative wind, not control.
4. Roll—induced by residual yaw. This is not good with negative angle of attack present, since roll will be very rapid and will couple to the pitch axis and cause pitchup—which begins the cycle all over again. Hence:
5. Pitchup—same as the first.

The answer to recovery, then, lies in bringing the cycle to a halt the moment the bird regains its relative wind. This means getting the stick back to neutral when you reach a flyable angle of attack.

Now we're not going to suggest that you are expected to see the relative wind, nor even feel your entry into it. But the first time you feel negative g, you'd best get that stick back to neutral, because you are then starting in the other direction. That's your key; negative g. Think it over; you couldn't get negative g unless the stabilator was working in the relative wind.

Hold on a second, now—it's not over yet. You will probably have to sit out a roll as the wings start to "fly" again. Besides, you may not have enough speed yet to actually fly out of the thing under full control. And, don't try to counter the roll with aileron either, because that's the quickest way into the steady state spin. Just sit it out until she settles down to a normal dive—then take control.

If it happens that you do overshoot into negative g on the first try, sit tight. The long term effect of neutral stick favors recovery.

This is the phase of recovery where Don Stuck's recent troubles began. Here's what happened:

The pitchup and rebound were as advertised. He recovered his relative wind and brought the stick to neutral on the first sign of negative g. As can happen, the yaw coupled to roll, and roll coupled to pitch—and up he went into a second cycle. Don used the spin chute at the peak of the second pitchup and recovered completely.

After jettisoning the chute, Don switched hands on the stick—and inadvertantly applied 3.5° up elevator. (Telemetery Data). This induced a second pitchup. Here, Don reached for his reserve chute—for the first time in earnest and accidentally hit the squib type jettison handle. He then pulled the proper handle, and the big chute took off—unattached.

This moment of confusion placed the bird in the incipient maneuver. He was unable to break this cycle.

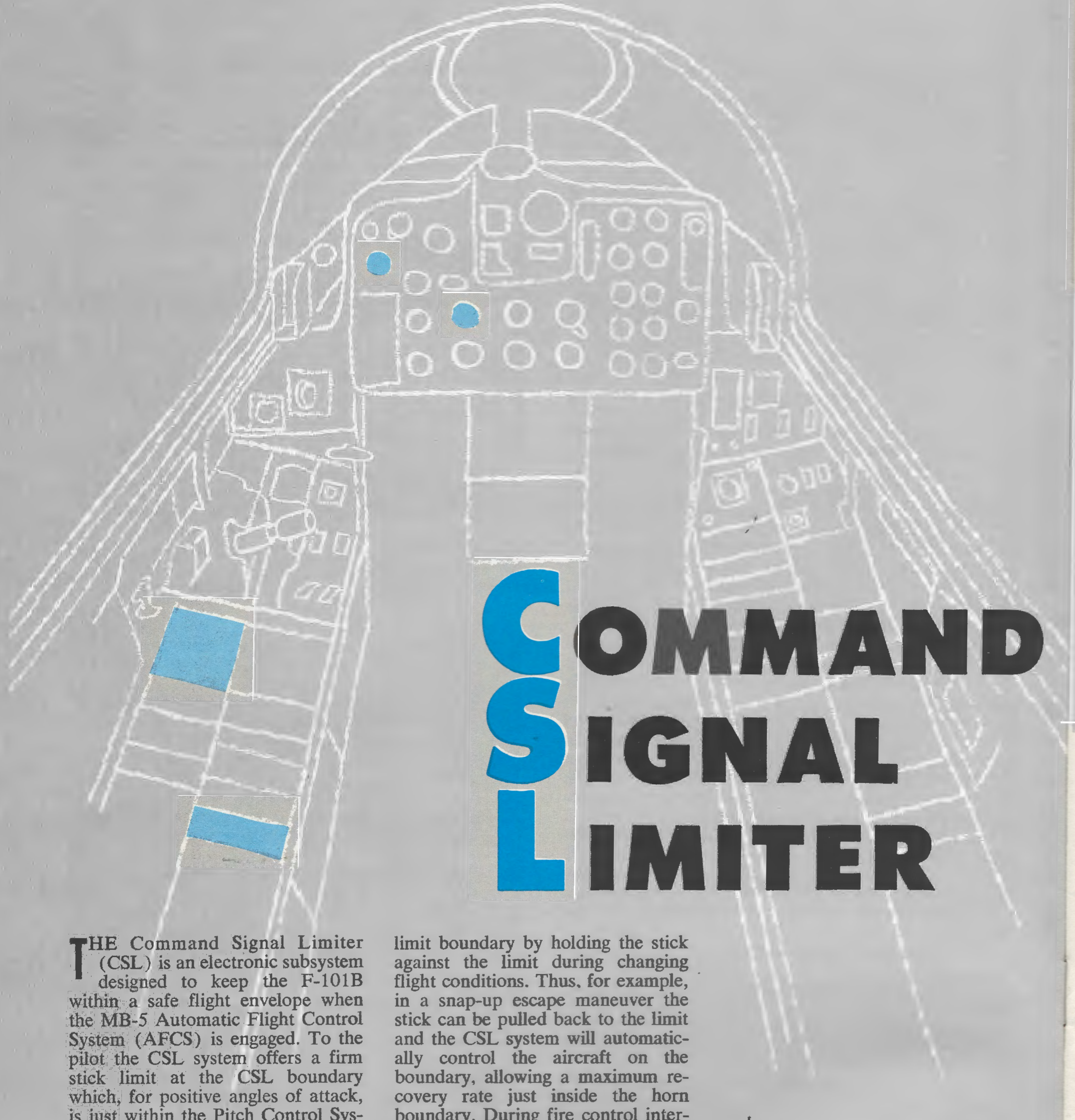
Don decided to leave at 16,000 feet, and it took over 10,000 to do it. He went through the canopy finally—with not much to spare.

The stick-free recovery trend was good, and the bird recovered its relative wind before it hit.

The point is made: The no-chute recovery can be successful—it has been! It can also become unmanageable—it has done that too!

All this applies to the no-chute recovery, which is the worst possible situation. With the spin chute deployed, all the wildness dampens out quickly. Even full forward stick won't preclude recovery—but it will aggravate the situation as the aircraft tries to regain its composure in the relative wind. So, when you feel negative g, bring that stick back to neutral—ride out the roll—and let her hang on the chute until she builds up enough speed to give you good solid control.

When it does, jettison the chute and go home. Then, sit down at your desk and write your story of success for the INTERCEPTOR. Good luck! ★

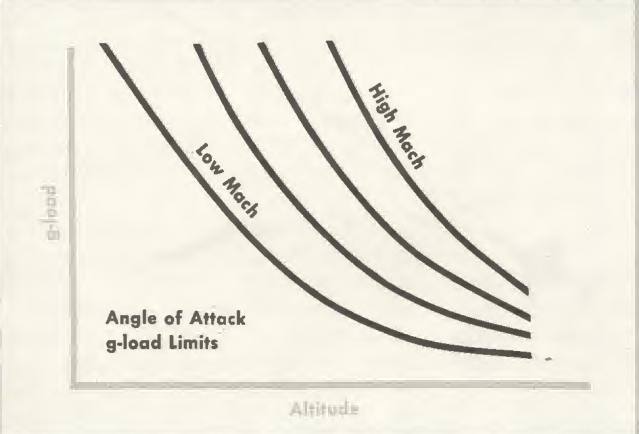


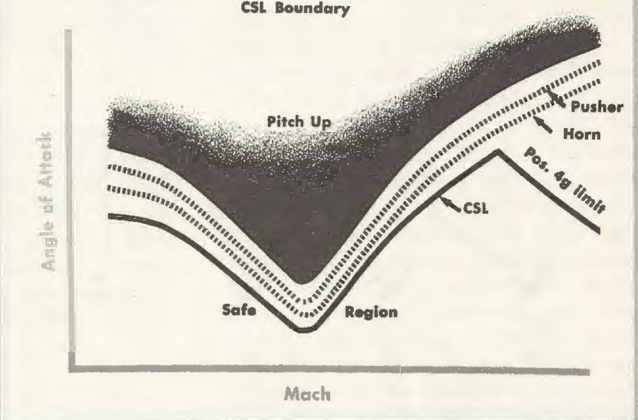
COMMAND SIGNAL LIMITER

THE Command Signal Limiter (CSL) is an electronic subsystem designed to keep the F-101B within a safe flight envelope when the MB-5 Automatic Flight Control System (AFCS) is engaged. To the pilot the CSL system offers a firm stick limit at the CSL boundary which, for positive angles of attack, is just within the Pitch Control System (PCS) horn boundary. A properly operating CSL during AFCS engaged operation will prevent the pilot or AFCS from commanding positive angles of attack which could cause pitch-up. It allows you to ride an automatically changing limit boundary by holding the stick against the limit during changing flight conditions. Thus, for example, in a snap-up escape maneuver the stick can be pulled back to the limit and the CSL system will automatically control the aircraft on the boundary, allowing a maximum recovery rate just inside the horn boundary. During fire control intercepts the AFCS can make rapid high rate corrections without exceeding the limit boundary, and it is largely due to the CSL system that the AFCS can make closer lock-on intercepts than can be accomplished on manual control.

by
CHESTER L. JOHNSON, JR.
Honeywell Aeronautical Div.

Basically, here's how the CSL system works: Angle of attack (α) is sensed by the aft vane on the right side of the aircraft nose. The vane's output signal is corrected as a function of Mach by the central air data computer to give wing angle of attack, and this corrected signal is then directed to the limiter black box and summed with stabilator rate for α anticipation. Within the CSL system a reference voltage is established and varied as a function of Mach over the operational Mach range. Whenever the angle of attack input from the vane exceeds the reference voltage by a predetermined margin, a limit condition exists and the CSL system controls the AFCS pitch servo to prevent the aircraft fom exceeding that limit. Only positive angles of attack are limited, since this represents the operational condition which normally causes pitch-up. The CSL boundary figure shows a typical angle of attack boundary and the PCS horn and pusher boundaries.





An angle of attack limit is really a lift limit which can be read as a g-loading. Since only a g meter is available in the cockpit, limit points must be determined as g-loads to check the angle of attack boundary. T.O. 1F-101B-2-10A gives these g-limits for specific Mach numbers and fuel loads at 35,000 and 40,000 foot altitudes and should be consulted for specific check points. A couple of these points should be memorized so that a fast check of CLS operation can be made at any time. These limits will increase with airspeed, and decrease with an increase in altitude or fuel load.

A maximum 4 g positive and a negative .5 g limit is also established. The positive g limit will be effective if the angle of attack boundary reaches or exceeds it and, as is shown on the CSL boundary curve, angle of attack boundary does exceed the positive g limit in the high Mach region.

During flight, six to eight pounds of stick force per g are required to reach the CSL boundary. If you wish to ride the boundary, pull only enough force to become firmly established on the boundary. Greater stick forces will not alter the limit point unless the servo is overpowered, which should be avoided except in case of a malfunction.

If it is desired to overpower the CSL system, it may be done at any time by an aft stick force of 60 pounds or greater, or a forward force of 30 pounds. If the system is overpowered in the aft direction, it is possible to overshoot and pull through the PCS pusher boundary into the pitch-up area. A .2 to .4 g margin does exist between the CSL and pusher boundaries, and the aircraft can be controlled in this region by overpowering the servo. However, if the pusher boundary is reached, the AFCS, including the CSL system, is automatically disengaged. The firm stick feel is removed, and the force being applied will be released abruptly. Since less stick force is required to overpower the pusher, the released stick force could easily result in an overshoot of the pusher boundary.

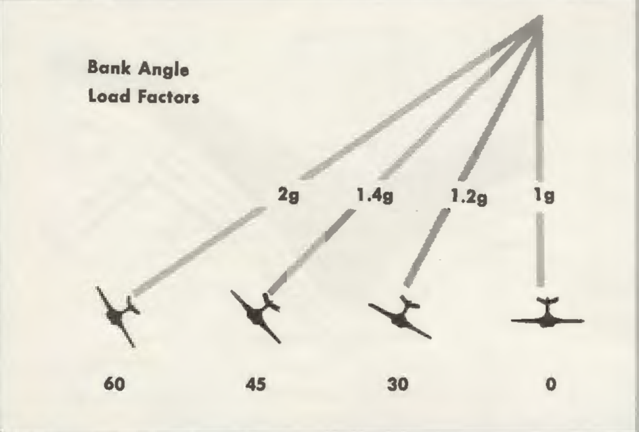
A good way to flight-check the CSL boundary in the subsonic region is by banking the aircraft to increase g loading. With the AFCS engaged, fly to 35,000 feet at about .86 Mach. Make a slow turn with increasing g loading until you reach the boundary. You will feel a firm stick limit in pitch, and g loading will not increase with further pressure.

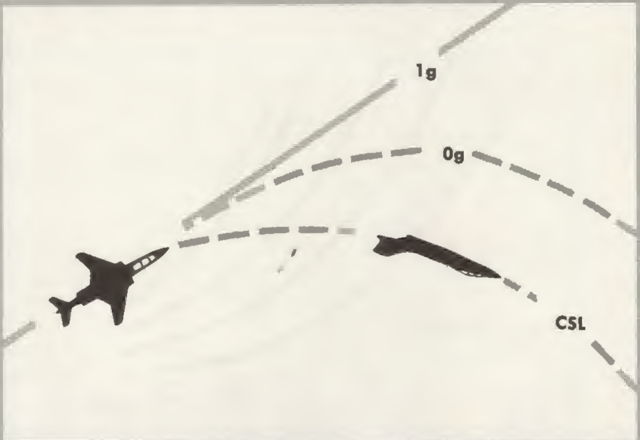
To check the boundary at higher speeds, climb the aircraft to an altitude above 40,000 feet. Accelerate the aircraft into a banked turn at 40,000 feet and supersonic speed, and increase g loading until you feel the CSL boundary. By holding the stick firmly against the boundary and allowing airspeed to bleed off, you will note a decreasing g reading on your meter. This is what we call "Riding the CSL boundary." It is a unique feature of the CSL system, whereby the aircraft is automatically controlled on the boundary as limit conditions vary. Large sections of the CSL boundary can be checked by this method during one run.

Some overlap of the PCS horn boundary will normally occur in the transonic region (.9 to 1.1 Mach) and the horn will beep intermittently during this region. If the horn boundary is reached at any other points on the CSL boundary, misadjustment or malfunctioning of one or both of the boundaries is indicated, and caution should be exercised.

When you ride the CSL boundary in a banked turn, it is necessary to control the bank angle if your reference altitude is to be held. The g's at which the CSL limits becomes the bank angle load factor, and this factor determines the correct bank angle for constant altitude. As airspeed bleeds off, the bank angle should be decreased. If the bank angle is held, or if it is increased more than that required to reach the boundary, the aircraft will lose altitude—and this brings up a couple of good points.

Suppose you're using the AFCS "altitude hold," and the aircraft is banked for a turn by roll stick force. At high bank angles an angle of attack greater than that allowed by the CSL boundary may be required to hold the altitude. Since pitch stick control is locked out and controlled by the AFCS during "altitude hold," you will not be able to feel a limit or know when the CSL system is limiting. If the CSL boundary is reached as a result of bank angle g-loading, the aircraft may be allowed to lose altitude, and this is normal. As soon as the bank angle is decreased sufficiently, the AFCS will attempt to regain the lost altitude.





During an Automatic Ground-Controlled Intercept (AGCI), a similar condition may result. Bank angles up to 45° can result, and if the aircraft is being flown at 35,000 feet, subsonic speed, and high gross weight, the CSL boundary may be encountered at less than the required 1.4 g for a 45° bank level turn. In AGCI, roll stick control is locked out, and the roll axis is controlled by the AFCS. Pitch stick control is allowed, and you will be able to feel the CSL boundary when limiting occurs.

The CSL system is absolutely essential during automatic fire control intercepts. After lock-on, large corrections may be necessary in both azimuth and elevation. Sixty to 70° bank angles may result, and you are almost certain to encounter the CSL boundary. Concurrent with high bank angles, a high dot condition may exist, also requiring an increase in angle of attack or lift. In these cases the CSL functions automatically, allowing full AFCS maneuverability to, but not exceeding, the CSL boundaries. This means that many late lock-on out-of-position attacks can be safely and successfully completed by the coupler-CSL which might not be possible with manual control.

Even more noteworthy is the performance of the CSL system when it is used in a snap-up escape maneuver. By inverting the aircraft and riding the CSL boundary, a relatively simple and safe maneuver can be made. The CSL gives a firm stick boundary in contrast to the continuous search for the safe edge of the changing horn boundary on manual control. By holding the CSL boundary and the 180° roll attitude, the aircraft will follow a 1 g trajectory course, plus an automatically increasing angle of attack boundary, and this will get you down safely and in a minimum of time.

Remember, any time you are flying with the MB-5 AFCS engaged, whether you're using control stick steering, altitude hold, or making automatic fire control intercepts, the CSL system is in operation. It takes only a couple of minutes to check it out, and when operating correctly, it will give you a controlled limit boundary representative of maximum safe flight conditions. With the fire control activation program well under way at most bases, you will probably be using the AFCS more in the future and the CSL system will help to make your mission a safer, more effective one. ★

ABOUT THE AUTHOR

Chet Johnson spent three years in the Air Force in the CBI Theater during WW-II. Shortly after graduating from the Univ. of Colorado in 1950 with a BSEE degree, he joined Honeywell's Aeronautical Division. Since then he has maintained close contact with the Air Force in the field of automatic controls. His present position is Systems Development Engineer for the MB-5 AFCS at Minneapolis-Honeywell.

SEEING IS BELIEVING!

HOW would you like to roll your Wonder in or over and pull her in to maximum turning performance every time? With no "feeling," "groping," or anticipations about where the horn is, or whether or not it's even there?

You will soon be able to do so. The Pitch Control System Boundary Indicator is here, and will, in the coming months, be installed in all F-101B's.

With this jewel, you will be able to reverse a tedious task of the past. Instead of pulling to a mentally computed G that varies with IAS, you will be pulling to a visual alpha limit, and will be able to see your rate of approach and margin to boundary at all times. You will be able to pull within a hair of the horn boundary, and sit there confident in the knowledge that you are perfectly safe, and further, that you are getting maximum performance as long as you hold it there.

The mental gymnastics presently required in selection of G for maximum performance can be relegated to a backup procedure. Because G is the product of alpha x IAS, hold optimum alpha, and you get optimum G. As we see it, this meter will emerge as the greatest comfort and convenience of the century. It will raise the technique level of the "greenie" to that of the pro on the first day out.

The "snap-up" and recovery will be pleasureful practice of optimum performance, free of anxiety about angles and speed. Certainly, you will still need airspeed with which to fly—but you will know from the start that you will be drawing the last ounce of performance from every knot. You will know this, because *seeing is believing!*

The official title, "Pitch Control Boundary System Indicator," will undoubtedly, through usage, be shortened to Alpha Meter or PBI. During our discussion PBI will be the standard term, with Alpha Meter being used only as necessary for comparison.

A true Alpha Meter is designed to indicate actual wing angles of attack, and requires pilot knowledge of specific angles for all configurations of flight, in order to be used effectively. One function of the PBI closely parallels that of the Alpha Meter, and is presented to the pilot by an "Alpha Wing" (∝W) or wing angle of attack needle. The second function continuously shows horn and pusher boundaries for any conceivable flight parameter, and is registered by the "Boundary Indicator" needle.

Individually, these two functions provide accurate and useful information as to aircraft performance. However, the sum of their indications continuously calculates references and limits to which the pilot can safely and effectively extend his aircraft.

PBI will, as advertised above, provide a pilot with reliable and usable information. However, we know that system dependability stems from proper calibration and operation of its individual components. Therefore, it is necessary to delve into the gadgetry behind our new system.

The hardware that causes PBI to tick and the forces that determine how fast, by design include a little each of aerodynamics, electronics, and mechanics. In order to establish a basis for all subsequent discussion, we must first consider an aircraft in flight.

We know that the airborne F-101B is affected by the factors of thrust, lift, drag, and gravity. We presently establish best cruise by selection of an altitude and mach based on total aircraft weight. What we are actually doing is calculating the optimum lift/drag ratio, which is, in effect, the optimum wing angle of attack. Vary this selected mach by changing thrust or altitude and you lose performance and range because of an unbalanced lift/drag relationship, which stems from an inefficient wing angle of attack.

Optimum ∝W remains constant for all aircraft weights and altitudes, as long as thrust is varied to maintain a constant mach. For each aircraft configuration and for each phase of flight, to include climb, cruise climb, descent, and final approach, there is one specific value of ∝W that represents most efficient aircraft performance. Establish this known ∝W with reference to a preselected mach or airspeed and the desired cruise, and rates of climb and descent are automatically established.

By what process does PBI relate these actual ∝W values to the pilot? Enter aforementioned mechanics and electronics factors. The Horn Angle of Attack Vane provides PBI with the basic ∝W signal. Since airflow patterns at various points on the aircraft vary as to specific direction and speed, it follows that the aircraft wing and the horn vane, due to physical separation, are subject to slightly different airflow patterns. Changing mach establishes new flow patterns which result in further differences in actual wing and horn vane angles. The deviation is least in the transonic region (.9 mach), and increases at a predictable rate as we increase or decrease from this range. In the normal operational airspeed envelope of the F-101B, this angular deviation averages out at 1.6° Horn Vane Angle for each 1° ∝W.

This average is then locked up in the system to provide a constant 1 to 1.6 relationship between actual ∝W and indicated ∝W.

This factor leads to the use of the term, "Units of Alpha." These are,

Since the sensing vane and wing angles of attack are not identical through the full range, boundaries are programmed into the pitch control system. By these means, the PBI can continuously present indicated Alpha (α_w) versus limit Alpha (boundary flag).

in fact, the increments seen on the PBI indicator face. It follows, then, that PBI αW indications, since read in "Units of Alpha," as opposed to degrees αW, will be the criteria for establishing and publishing specific optimums of aircraft performance.

Now that we have developed the basic input signal, we apply it directly to the αW needle for our "Units of Alpha" reading. We must, however, further modify the same signal to achieve the desired "Boundary Indicator" reading. This signal modification continually takes place in the PCS Horn Mach Scheduling System, and results in a visual presentation, in Units of Alpha, of the Horn and Pusher Trigger points.

Reliability of both PBI indications should equal or better that of the PCS Horn System, in that neither function is affected by stabilator rate sensor malfunctions and only the "Boundary Indicator" is subject to mach scheduler malfunctions. The αW needle should be especially honest to the pilot, but for those instances where the Horn Vane has been dinged out of shape or alignment. The Boundary Indicator is more apt to fib to the pilot, only because of the greater complexity of its electronic system and calibration procedures. Basic calibration and alignment procedures go hand in hand with those of the PCS system, and require the same high degree of precision on the part of both maintenance man and test pilot.

Those malfunctions that occur as a result of internal power loss will be obvious to the pilot through built-in warning devices. Loss of, or a specific decrease in, either 28V AC or 28V DC will cause the "OFF" flag to appear, and both indicator needles will return to minus 5 units of Alpha (also Power Off) reading on the gauge. When the Boundary Indicator alone fails, it will align with, and thereafter move with, the αW needle.

We have met good old PBI, are beginning to understand and like him, but we're not quite sure exactly why.

Maximum appreciation and understanding of the system will not be realized for some time to come; i.e., application of PBI in the achievement of optimum performance in such phases of flight as cruise, cruise climb, loiter, descent, and final approach can, and we hope will, be established through further flight test. In the meantime, quite possibly all of you F-101B jocks will have the opportunity to run your own personal evaluation of PBI. If you, through your past experience in the big bird, are relatively sure that you can establish optimums of performance for a given flight phase or configuration (cruise, loiter, final approach, aerodynamic braking, etc.), then the αW reading that you see when you attain a computed optimum should ever after provide you with a quick and ready reference as to desired aircraft performance.

You are all familiar with the optimums that we discuss, and use them on a daily basis. They are, to mention a few, computed airspeed for final approach, best cruise at a given altitude, the resultant aircraft attitude during Gate and Buster climb at a specific mach or IAS, and the standard attitude for takeoff.

Two indicated optimums are relatively firm and could be used effectively when you find yourself boxed into a hazardous corner. First, best cruise at *any altitude* is achieved by setting up 5½ units of Alpha, so when you're heading for home plate with busted instruments dictating low altitude to stay VFR, trust PBI to set up best miles per gallon. Second, when you're heading steadily uphill, not quite sure where terra firma is, and "oops," a 160 knot IAS causes a momentary clutch, rely on PBI — establish between 0 and 5 units of Alpha until you get your attitude sorted out, then proceed with a normal "snap-up" recovery procedure.

A word of caution concerning your evaluations and subsequent hangar flying sessions: Remember that you are dealing in "Units of Alpha," and not true angle of attack, so should therefore eliminate confusion by thinking and speaking in terms that all F-101B jocks will see and become familiar with.

Your personal familiarity with the aforementioned PBI-established optimums is a side benefit to the real purpose of the system. The prime reason for system development was to add a visual indication to already presented audio and sensory indications of aircraft performance. These latter two signals (Horn and Pusher) have undoubtedly prevented countless numbers of pilots from straying into pitchup, and yet are limited as to the information that they provide him with —limited because of their inability to tell the pilot his current relationship to their hidden boundaries until he actually reaches them. PBI does show us the rate at which we progress toward these boundaries as we honk into a turn; does prompt and permit, as we near the boundaries, relief of stick pressure to maintain a constant and desired maximum turning capability anywhere within the horn region.

We reiterate that these functions are constant and reliable, regardless of flap or gear position, regardless of aircraft weight, of IAS, or any other normal configuration variables that might be possible.

A couple of additional facts and figures are worth mentioning before we rack up our pencils and head for the barn.

We currently have smart fighter oriented types in high places that are pressing for an in-service flight test, so that exact αW indications for various optimums will be published for your use. These same people will insure that PBI's position in the F-101B instrument panel is conducive to a natural inclusion in the cross-check. They also strongly recommend that the PBI circuit have a separate "ON/OFF" switch. Current plans show it wired through the horn switch. A shorted and constantly beeping horn is cause for turning the switch off, and in this case PBI would also be eliminated.

We have here presented some facts and some healthy theories for your edification. Facts remain status quo, whereas theories are eventually proved or disproved. We don't get the opportunity to bat about the sky in the 101 proving our theories so much any more, so we'll leave it up to you straight-shooter squadron types. And when you do finally firm up the why's and wherefores on PBI, drop us a line so that we can pass the straight scoop to the Johnnie Come Lately troops. ★

AN ANALYSIS

THE title illustration is significant. It appears that too many folks have difficulty in analysing situations involving stability. Specifically, we've seen two accident boards very nearly stumped in their effort to analyse the events which began as a gate climb and ended with ejection from F-101's.

The key misleader — we believe — is the term "Pitchup." Throughout both accident reports there is a persistent search for an explanation as to how an aircraft can go from stable flight into a spin, without passing through the classic characteristics and/or warnings of pitchup. Although some individuals came close — the records were closed on a note of mystery.

So, let's begin by defining the stability characteristics of the F-101 as they relate to the old-fashioned term "spin."

To do this, let's consider the natural free-fall characteristics of the configuration. We say "configuration," rather than "airplane," because most of us still liken airplanes to darts—which have lead noses and feathered tails. They always fall nose-first. And, while virtually every aircraft up to the Centuries invariably did just this, the situation is different today.

Were you to drop an 101 in the manner illustrated, it would (normally) remain essentially horizontal — and fall to the ground in a listless spin. This is a classic flat spin, known in the F-101 handbook as the "steady state spin mode."

Why it happens is a pure matter of drag and c.g. analysis.

If you took a yardstick and put feathers on both ends, you would not expect either end to point down every time—would you? You realize upon sight, that the c.g. is dead center, and that the feathers on the front offset the feathers on the rear. You realize that there is a net balance of drag on the pitch axis of the configuration.

If you were asked to describe what the yardstick would do, if dropped in a horizontal attitude, you would likely say it will oscillate on all three axes — probably rolling frequently; rotating slowly on its vertical axis; and possibly even diving and zooming on occasion.

In the steady state spin mode, the

101 can be likened to the yardstick. The free fall drag forward of the c.g. is very nearly equal to that aft of c.g. Actually equilibrium will be found with the nose somewhere around 30° below horizontal. In the free fall state, that means equilibrium at an angle of attack some 60° to the relative wind.

How do you get out of such a state? You add a 16 ft. diameter feather at the tail end — the spin chute.

How do you get into such a state? There are several ways — all quite complicated.

The only pure and positive way to go directly from stable flight into steady state spin mode is to point her straight up — a 90° climb angle — and run her completely out of airspeed. You will then enter a free fall state. But even this is complicated, since you are not yet horizontal. So let's discuss this a bit.

In a T-33, you would brace for a whip or hammerhead stall under these conditions, and you'd get it. Not so for Century series birds: The even spread of fore and aft drag dampens out the whip tendency. These configurations would likely flop softly toward the horizontal.

To be completely correct, we must acknowledge that there may be a gyration or incipient spin mode between fallout and steady state.

Nevertheless, the 101 will end up falling upright at true angles of attack in the 60° neighborhood. Even if you were to begin the fall inverted, it will roll upright every time, and this rolling moment will couple to the pitch axis and increase the angle of attack.

Remember now, we're analysing a non-flying configuration here; we "dropped" the bird from 30,000 feet, so to speak.

The only way to reach the same state from controlled flight is to first pitch up — or down; then fail to regain control over the pitch axis (with the chute). This puts you in the incipient spin mode. Now, if you aggravate this mode with aileron or rudder, the resulting rolling moments — which always couple to the pitch axis — may convert the gyrations into the steady state mode.

PITCH CONTROL SYSTEM

The pitch control system was designed to keep you from exceeding critical alpha limits. The alpha vane will "fly" accurately down to speeds below 100 knots — that's a matter of record. The accuracy has been established down to 92 KIAS. Don Stuck reported on this subject in the July 1960 MAC *Field Service Digest*.

Nobody knows at what speed the vane stalls out and "drops," but we are very much concerned with this subject when we discuss high angle climbs. We are concerned, because the horn and pusher cannot be expected to protect you from spinning out of a high angle climb.

To begin with, it takes less than one g of lift to hold any climb angle. Specifically, the g required decreases as the cosine of the climb angle. At 30°, it takes .866 g; at 45°, .707 g. In a 60° climb, ½ g is all you need, and to go straight up — 90° — no g at all.

What, then, is your "stalling" speed in these high-angle climbs? More correctly, of course, what are the horn warning speeds?

You won't find them in your dash-one; you aren't supposed to need them. For your information, Don Stuck found the horn at 128 knots at a steady angle of 30°. And, although he got a beep at 125 in a 45° angle, he held her there and reached 110 knots without hearing it again. From this condition, he pushed over and rolled into his recovery maneuver — and went over the top at 92 knots. Naturally, he never heard a horn here, because both the wings and the vane were "flying" at near zero angles of attack!.

Why don't you need the PCS here? Because you're not pulling g in a climb — you are further away from pitchup than in level flight, and you have no reason to approach it. Who would deliberately hold a 60° pitch attitude at less than 200 knots?

NOW — THE ACCIDENTS

We had two aircraft abandoned in the soup. Both started as gate climbs. We'll discuss these accidents as the Northern and Southern cases — specific identification serves no purpose.

The northern bird should have needed about a 33° climb angle to hold 400 — the one down south, about 37°. It was cooler that day.

Up north, the pilot thought he had everything pretty well under control. He recalls seeing 380 knots, and pushing on the stick to increase it a bit. The R/O only recalled one airspeed reading — 450 knots True. He recalled the initial g lightening also — considered it normal for airspeed correction in gate climbs.

Shortly after that, things fell apart fast. The R/O reports that he felt the bird "snap roll" — to the right, he thought — so he ejected. Yes, without saying one word, he ejected.

The first apprehension the pilot had was one of feel. He didn't think the nose was responding properly to his pushover. He too felt a rolling moment, he thinks, but he never really interpreted it. He heard an explosion, and was suddenly confused. He tried to orient on the meters, but couldn't. He remembers seeing the left engine oil pressure gauge fluctuating between zero and something. He pulled her out of afterburner. Deciding to eject, he noticed that the canopy was gone. He than assumed that the R/O had gone — so he went.

Some Facts:

- Both chutes opened immediately — automatically. This puts them below 15,500. The R/O said he went shortly after passing through 12. Cloud tops were known to be 17-18,000.
- The pilot, though second out, was below the R/O, and had him in sight — in the soup. So he went out shortly after the R/O.
- Witnesses said the aircraft was in a diving turn when it came out of the 7,000 foot overcast.
- The bird did travel approximately 10 miles beyond where both crewmembers landed — and they were 10 miles out from the corridor mouth. In all, then, the aircraft traveled about 20 miles, and must have topped out at about 16,000 feet.
- The aircraft turned about 180° in its final dive, crashing on a heading reciprocal to the corridor.

The case down south was different in many respects. This pilot entered the soup very low — did his rotating on instruments. He first noticed an overspeed — 420 knots. So he increased his pitch attitude. He was also combining a 180° turn with his climb.

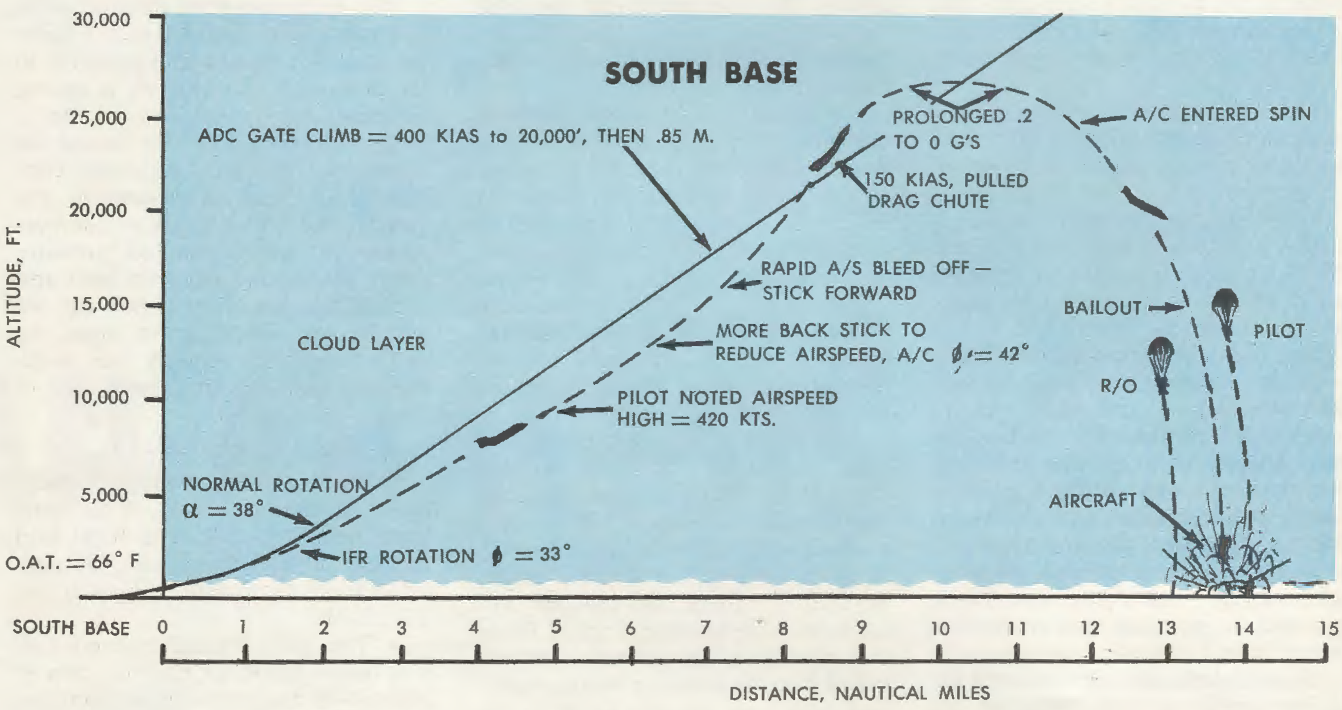
His next impression was that he

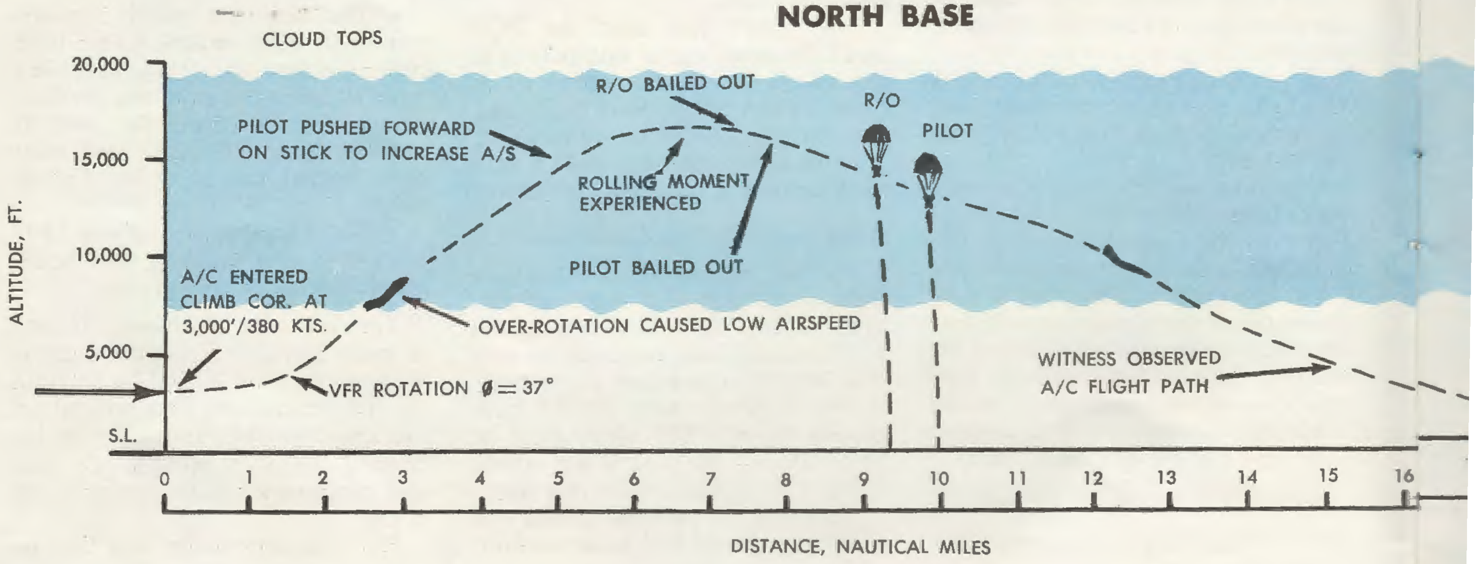
was trying to lower the nose to regain speed, and the R/O verifies the g lightening. Both descriptions suggest zero or slight negative g before any spinning sensations.

The pilot recalls seeing the airspeed meter go through 200, and on down to 150. He pulled out of afterburner and deployed the drag chute. From here, both crewmembers clearly remember periods of relative calm and violence. The pilot thinks he saw a speed of 350 later — but they had fallen from 25,000 to 15,000 by then; so they ejected.

This time, the pilot — last out from a falling bird — saw his R/O below him in his chute. The R/O reported a definite delay in opening, however, so that is explainable.

The pilot heard the aircraft hit and explode, and also watched the R/O land in his chute. So, it is pretty well established that the bird was spinning; they parted company at 15,000, and all came down in the same area.





By analysis, this aircraft accelerated straight ahead to about 380; was rotated for climb in IFR conditions; reached a peak altitude of 25,000 feet; accomplished a net course change of only 40°; and came to rest in a very flat attitude just 15 miles from the end of the runway. This sequence of events and the distances involved check out pretty well with handbook predictions.

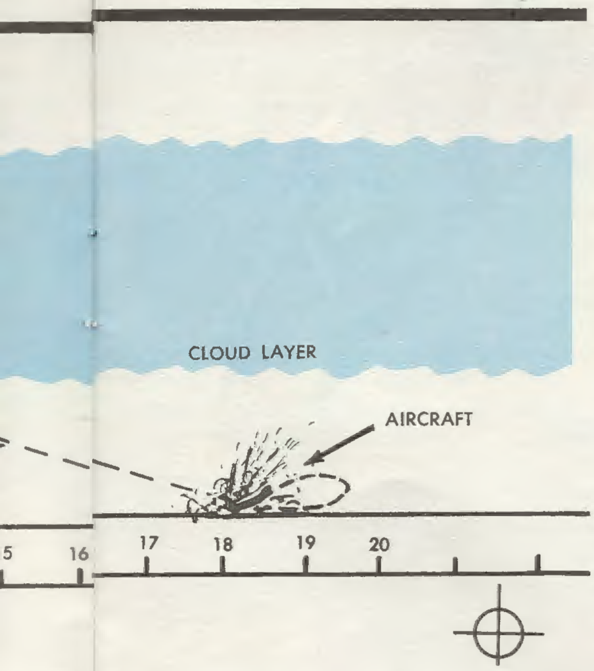
Incidentally, neither pilot got any horn or pusher before losing control.

As investigators, it is our job to make an educated guess as to what happened in each case. We have the advantage of comparison — a benefit that neither board had when they reached their conclusions.

So, let's plot a cross-sectional view of the flight paths — we think this is the key to this analysis. Then we deduce and opine. We will base our distances and angles on modified handbook figures, since they are for .85 MN climbs, and these pilots used 400 K.

DID THEY SPIN?

One aparently did — one apparently did not. The basis for the conclusion is the fact that, even in the case of an accelerated pitchup entry into a spin — say at 350 knots — the speed is immediately snubbed to 150 or less. So, unless you have evidence of still lower speeds, you can assume 150 indicated to be the greatest horizontal component present at the beginning of the spin maneuver.



From there, you would strike a curve representing the falling trajectory. You will find that the fall of a spinning aircraft is not far from the curve of a falling body or man in chute. (The chute is affected more by wind, of course.)

Now a conclusion based on history—F-101's have not been known to recover stickfree and fly 10 miles after ejections. Even if one did, normal trim would hardly make good the 10° average dive angle that is evidenced here by the 10 mile distance (the case up north) from only 16,000 feet.

In our diagram, we see that the aircraft that was known to have run out of speed — and was ridden through 10,000 feet of gyrations — did follow the path expected of a spinning bird. Furthermore, although under control for a greater length of time (in soup from 300 feet to 25,000 feet), it traveled substantially less distance in flight.

In the first case, the accident board did a fine job of exploring pitchup entry, and they were not convinced that it occurred. They closed the case as undetermined — a wise conclusion to a baffling case. Here is the way it stacked up.

If the airspeed readings were correct — 380 KIAS and 420 KIAS — there was no pitchup, because both crewmen were sure that the necessary 3½ + g was never applied.

If the aircraft did spin, it slipped into it at a very low speed — perhaps as described in our opening analysis. To justify this thesis, however, you must accept a trapped airspeed reading of 380, and assume an overrotation to 60° or higher pitch attitude. In a subsequent test flight of this theory, the test crew assumed a 60° climb angle from a duplicate corridor entry at 3,000 feet. The airspeed bled fast; 300 at 9,000; 200 at 12,000; and topped out at 17,000 and 165 in the recovery maneuver. This does suggest that the lost bird would have popped out, at least momentarily, before the vertical speed would come to zero and the fall begin. However, the pilot did chop the A/B's when he thought he was in trouble.

The board dwelt on jet wash in their investigation. The weather was reported as stable, but three 101's had departed 45, 30, and 30 seconds ahead of this one, so the jet wash turbulence was a valid suspicion.

The only factor we can add to the investigation is the flight path analysis, diagrammed here. The distances involved — horizontal versus vertical — make it very difficult to account for a spin.

To begin with — if you plot a simple triangulation from the point of rotation to a point 16,000 above where the canopy and crew landed, and then back down to where the aircraft landed, you find yourself looking at a very shallow angle for average climb and dive. Only a 12½° climb and 15½° dive are indicated.

It is very difficult to crank a spin into this geometry. If you crank him up to a 60 or 60° climb angle right after rotation, you can kill off the speed and spin all right; but this shortens the time in flight and the ground speed component to a point where the spin occurs some three or four miles from the corridor mouth. We would then expect to see the canopy and crew land considerably shorter than 10 miles out.

On the other side of the ledger, we have both crewmembers attesting to the presence of good speed — 420 knots true — plus the evidence of 20 miles traveled with very little climb accomplished.

By injecting such testimony as no severe g at any time; a prolonged period of slight negative g — actually, something ranging from .5 positive to perhaps .2 negative; no drag chute deployed; and an aircraft that was described by several witnesses as being in a shallow diving turn — any investigator would be led to the conclusion that this aircraft was flying all the way—from start to finish.

This leaves us with a very distasteful conclusion: That a flying and flyable aircraft was abandoned without evidence of good cause. Such a finding is more difficult to explain than prove.

Your editors have no reason or business to go any further in this case. Our objective was to provide a few hints on investigation and analysis. We hope that we did so. ★

man, machine and the

Pilot and PCS/CSL systems both play leading roles in the pitchup story — but in the end pilot actions decide the outcome.

WILD rides continue in the Voodoo, and though an increased percentage of riders are returning safely from pitchup, neither they nor the second guessers have been too sure exactly where they'd been — or why. As a result, some reports reaching the field have in fact clouded the issue, rather than adding to our catalog of experience and knowledge.

We don't claim to have all the answers on the why's and wherefores of pitchup, but we do know some common aerodynamic laws that can't be argued with. Add this to the known constants of F-101B performance, and we see that some things said to have happened could not have happened.

In '62 to date we've had three pitchups — two of the pilots recovered and flew home. The third aircrew had taken the correct actions following pitchup, and was waiting the bird to recover, but ejected when notified by a wingman that they were on fire.

Of these three pitchups, all warrant a long look and a discussion of some points not covered in earlier INTERCEPTOR articles.

Before going into a point-by-point analysis, let us say that our pitchup/crash picture for '62 could have been much better or much worse — the bird that crashed should never have pitched up. On the other hand, techniques used by one of the pilots who recovered could have spun the aircraft all the way to the ground.

Incident No. 1.

In executing an auto snapup from angels 35 to 41, the pilot noted that the coupler was not centering the dot in elevation. So he pulled in to the CSL limit in order to get the "MA." At fire signal he had 300 KIAS and elected to make a 90° breakaway, rather than the inverted recovery. Still on the CSL limit, he initiated a hard port turn. After rolling 50° port, the aircraft snapped back to the right and simultaneously pitched up. Full nose-down stick was applied, burners were chopped, and the drag chute was deployed at 140 knots. The pilot eased the stick to neutral at first sign of negative "G" and the bird smoothed out, to recover straight and level at 24,000. You'd say good show and congratu-

FINAL OUTCOME

late the pilot. We feel the same way. This jock was cool, knew and followed his procedures, and came home in a breeze.

There were, however, two questions about this incident that cropped up:

(1) Did this pilot really experience full scale pitchup, or did he catch it early enough to fly out of the critical area?

(2) If pitchup did occur, why were the PCS and CSL systems caught napping?

In answer to Question No. 1, we think he did reach full scale pitchup, and here are the reasons why:

IAS dropped from 300 to 140 KIAS in a matter of seconds. From the pilot's statement, the aircraft went in a flash, but since we didn't have a stopwatch on it, we'll have to estimate the time involved. To pick a figure on the slow side of the pilot's approximation, we'll use five seconds.

The 160 knot loss in a five-second period would equal a 32 knot per second bleed rate. If we take a 101 in gate at 300 knots, honk it clear in to the pusher boundary (2.40 G in this case), the highest bleed we can get is about 6-7 knots per second. Here are the calculations that bring us to this figure:

1. Acft wt (42,000 lbs.) x 2.40 G = 100,800 lbs., effective aircraft weight.

2. The required lift is therefore 100,800 pounds.

2. A quick and dirty method of deriving drag is:

Lift x sine α (angle of attack). Since we know that α for .91 mach at the pusher boundary is 12.5°, we have all the elements for approximating the total drag.

Drag = L x sine α
= 100,800 lbs. x sine 12.5°
= 100,800 x .216 = 21,772 lbs.

4. When we compare the thrust available (Ta) at 39,000 feet and .91 mach to the drag (thrust required), we see a discrepancy of over 5,000 pounds:

Drag = 21,772 lbs.
Ta = 16,000 lbs.
5,772 lbs. Thrust Discrepancy.

5. This adds up to slightly more than a 1/G deceleration. In terms of airspeed, this is a bleed rate of 6.5 knots per second. Compare this rate with our approximation of the actual bleed rate (6.5 KPS vs 32 KPS) and it is obvious that the bird made like the proverbial "barn door," i.e., did pitch up.

Now to the second question — how come the PCS/CSL systems got fooled into letting a pitchup sneak by? We don't have a positive answer, and haven't been able to get one out of the Voodoo experts. A couple of points we are pretty sure of, though — The PCS/CSL systems were in calibration both before and after the incident, and the pilot didn't break through pusher or CSL limits to cause the pitchup.

So process of elimination leaves the "yank and bank" maneuver as a prime suspect. Combined "G" loads and high roll rates have hit the headlines before. Many a bird has come home from the ground gunnery range with wing or tail surfaces sitting on the bias.

The forces that cause this bending of aircraft parts are hidden from the pilot. They don't register on the "G" meter, or at "seat of the pants." For this reason we lower the T.O. "G" limit for rolling pullouts.

The key word here is "rolling," even though high "G" must also be present. In a roll the inside wing develops an increased angle of attack while the opposite wing α decreases. Picture the wings of your bird as the feathered prop of an airborne recip. The prop (wing) angle of attack is at or about 0°. Now motor the dead engine over, and the angle of attack increases. This resultant increase in α is a component of the forward and rotational directions and speeds of the prop. For example, with the bird sitting still, prop rotation would cause a 90° angle of attack. Airborne, with aircraft forward speed equaling that of prop tip rotational speed, tip angle of attack would be about 45°. A similar increase in wing angle of attack during an aircraft roll greatly increases the lift, sometimes to the point that structural limits are exceeded.

Trouble can begin well below a point where hardware starts bending, though — the troops who have scared themselves gray when this same increase in angle of attack brought a wing stall and dish-out during an on-the-deck roll can attest to this. What we're concerned with in the F-101 is pitchup and the effect rolling has on the stability envelope.

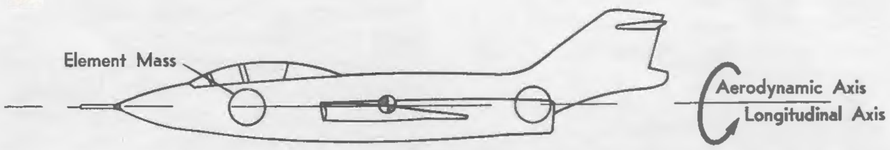
We'll have to throw out three possibilities here, because we don't have a firm answer. One: The boundary "G" roll increases wing alpha to the stall point, and the resultant maneuvering in roll, yaw, and pitch couples to induce pitchup. Two: as the wing α increases on the inside wing, the center of lift or pressure moves forward . . . magnitude of the wing tip vortices increases and moves inboard with the approach to C1 max. Greater stabilitor downwash results. These factors combined produce a nose-up moment sufficient to push the bird into pitchup. Three: Combined roll and "G" induce inertial coupling sufficient to cause pitchup.

First to define inertial coupling. Take a 101 in flight and draw two lines through the aircraft CG — one, the longitudinal axis of the aircraft, and the other the aerodynamic axis (actual flight direction of the aircraft). If the two lines coincide or are close to parallel, we have a minimum alpha, and negligible inertial coupling would result from a roll. But let's pull CSL boundary "G", in this case about 10° alpha. Now the longitudinal axis line diverges from the flight path line at 10°. Wings level, this means that the nose is 10° above and the tail 10° below the actual flight path line. Now we stick in a high rate of roll. Remember that the aircraft rolls around the aerodynamic axis.

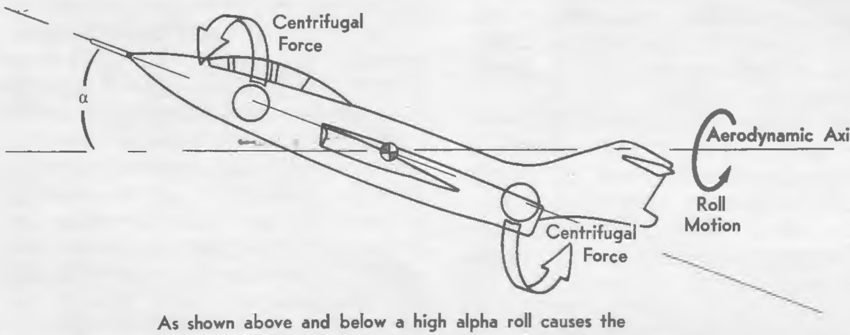
If boundary "G" is maintained, the nose and tail describe circles around the aerodynamic axis, with the CG being the pivot point. The nose and tail masses, orbiting, so to speak, around the CG pivot point, are subjected to centrifugal force. As the roll continues, the centrifugal forces tend to throw the nose/tail masses into an even larger orbit. This increases the angle between the longitudinal and aerodynamic axes or, in basic terms, increases the angle of attack. This, simply, is inertial coupling. It increases alpha, perhaps to the point of pitchup.

One of these three factors probably caused the pitchup — maybe a combination of two, or perhaps all. The point to remember is that you do have unusual forces acting on your bird during the "yank and bank" maneuver. Also remember that these forces are not always registered accurately by the PCS/CSL sensors that are located close to the longitudinal axis, so if you tend to "yank and bank," don't depend 100% on the warnings that these systems provide — they may come too late.

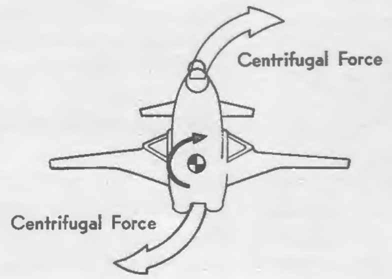
INERTIAL (ROLL) COUPLING



Here the nose/tail masses and CG are aligned with both axes, therefore inertial forces are slight.



As shown above and below a high alpha roll causes the nose/tail masses to be thrown outward by centrifugal force.



Incident No. 2.

This is the one that could have augered because of pilot technique. Here's the way it went:

Everything progressed well through the coupled attack on a 50,000 foot target. At fire signal IAS was 240 knots, and altitude was an estimated 46,000 feet. The pilot unloaded and rolled inverted into his recovery maneuver. The horn beeped, pusher activated, and the bird pitched up. Why we don't know, but determining blame in this case isn't the important issue, anyway. What is important to look at is the pilot's recovery technique.

Initial recovery actions went pretty well by the book — A/B's out, chute deployed, rudders neutral, and stick full forward. To make a long, horrible story short, the bird finally got levelled off at 5,000 feet. This adds up to a loss of something like *41,000* feet in recovery. Wow! Shades of the 1960 pitchup, spin, bailout series.

The problem in this incident, as in our early failures to recover, was one of control technique. Failure to neutralize the stick when negative "G" was sensed gave us fits then, and almost repeated ancient history in this case. The pilot knew the proper T.O. procedure, but didn't neutralize stick, because, as he put it, the "G" forces varied so much it would have been difficult to catch the negative "G" and move the stick to neutral quickly or accurately enough.

We'll say again that it is imperative that the stick be returned to a position close to neutral when negative "G" is first sensed. If not done, the pilot is asking for trouble.

Here, briefly, are the factors involved: The negative "G" is the first indication that the bird is starting to recover. Up to this point the main force working at getting the bird flying again is the drag chute. As the chute straightens the bird out into a diving attitude, the relative wind is quickly regained. As a result, the full nose-down stabilator becomes effective and pushes you over into some negative "G". Your only clue to regaining the relative wind is this negative "G," so action must be taken right then.

If the stick is neutralized to maintain between 0 and .5 "G", the bird starts flying again and you're on the road to recovery. If you continue to hold the stick full forward, you push right on into a negative stall and a new pitchup cycle.

This second pitchup may not be recognized as such, because the nose doesn't zoom rapidly skyward. At this point, the bird doesn't have enough dynamic energy to cause a radical rotation. Also the chute has a damping effect on pitching movements. But just the same you've pitched up again, and will return again to the negative "G" part of the cycle. Be ready to catch it the first time, but if you don't, be waiting and take action on the second. Handle the stick gently — it will try to drive to neutral of its own accord. Keep the light seat-of-the-pants feeling by maintaining between zero and .5 "G".

Remember, at zero "G" you've got zero lift and zero angle of attack, so the bird can't stall. It's making like a falling arrow and from this point on is going to pick up dive recovery speed rapidly.

Incident No. 3.

This one didn't get home to roost. Here's what happened. The aircraft was flying a snapup from angels 30, target at 42,500 feet. The crew had "no joy" at 20 miles, so the pilot started a 10° climb. Airspeed at this point was approximately 350 knots.

Contact was made at 14 miles, "judy" at 12, and snapup mode was selected. "B" time came at approximately eight miles; simultaneously the pilot checked airspeed, saw 280 knots indicated, and moved to light burners. He never got there.

At this point the nose came up "smoothly and rapidly" into pitchup. The pilot used both hands to jam the stick full forward. The nose either "continued up" or "came up again." Some wild gyrations followed, and the drag chute was deployed. Then the calls about fire that prompted the ejection.

Later it was strongly suspected that the fire was an abnormal amount of torching from the vent system. We have no quarrel with the witness wingman's evaluation of the situation. He saw fire and sounded the alarm. The aircrew acted in the only logical manner, i.e., made hurried exits. The chain of events that led to this point is another story.

We must take exception to the reported cause of the initial problem, the pitchup. It was theorized that the aircraft "backed into pitchup," and that specific blame lay with the inability of the PCS/CSL systems to warn or protect against unhealthy angles of attack during low airspeed, high pitch angle conditions of flight.

We agree that limitations of the PCS/CSL systems might allow the F-101 to "back into pitchup" without warning, but only by flying at indiscriminate extremes of pitch attitude and airspeed. Taking a note from the MAC low Q PCS evaluation, we see that the combined extremes of 45° pitch attitude and 110 knots could set up the situation where CSL/PCS systems might trigger too late to allow sufficient airspeed for recovery.

Such was not the case prior to the pitchup we're discussing. We know that the pitch attitude was not abnormal (about 20°) and are reasonably sure that the airspeed was well above the minimum safe limits. From the pilot's statement, it appears that "B" time, the airspeed check at 280 knots, the move to light burners, and the pitchup all occurred in too short a sequence to bleed more than a few knots' airspeed. Also supporting this line of thought is the target aircrew's statement that, upon hearing the "20 seconds to go" call, they both immediately sighted the oncoming fighter and noted that it was already in pitchup.

Neither of these statements gives any hint of a time period sufficient to bleed the airspeed from 280 knots down to the 150 knots minus that it would take to back into pitchup. So what actually happened?

From the information available we can't be 100% positive, but there are a couple of real good clues in support of our theory. We're of the opinion that the pilot caused the pitchup. Here are the factors and facts that figured in arriving at this conclusion:

(1) This particular aircraft had a short previous history of horn and pusher activations that, as the aircrew put it, "felt different." Also the bird had been written up for being dangerously nose-light on a previous takeoff. Both the pilot and R/O were aware of these previous discrepancies and had discussed them. Another pilot had also warned this pilot about the nose lightness.

(2) The "G" forces felt by the aircrew after pitchup was recognized were not representative of the forces normally expected; i.e., the pilot pushed the stick forward with both hands and noticed a *sharp negative "G"*. The R/O, head in scope, felt a slight positive, and then *negative "G"* which caused him to come out of the scope. At this point he realized that they had pitched up.

This second factor, though seemingly irrelevant, is a pretty ironclad clue. The fact that negative "G" resulted when the stick was jammed forward suggests that the aircraft had not pitched up yet. As Mr. Don Stuck will tell you, the negative "G" means stabilator effectiveness, and this means that pitchup has not been reached.

Our theory on how this pitchup did occur is this: The coupler, in flying the pass, first centered the dot in elevation (15° to 20° nose high), then, as the dot drifted starboard, the coupler established a 45° right bank. This caused CSL limiting, and the nose dropped to about 5°. As coupler recaptured the dot in azimuth, the wings rolled level and coupler started a rapid pullup to catch it in elevation.

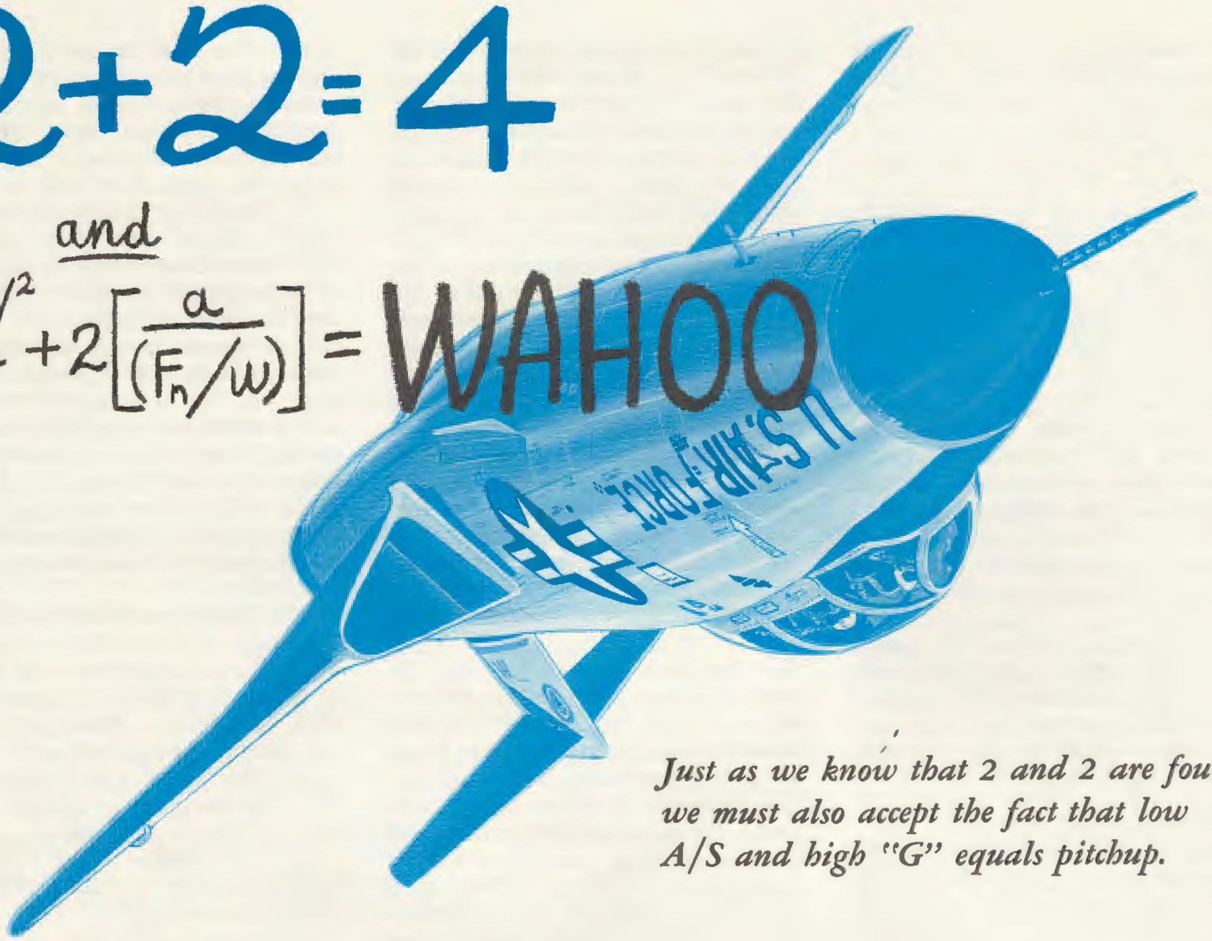
This is the action that we suspect the pilot interpreted as pitchup. His past knowledge of the aforementioned nose lightness and PCS problems may have fostered some anxieties. At any rate, he drove the stick forward. With airspeed sitting in the 280 knot region, full down stabilator was very effective and drove the aircraft to an excessive negative angle of attack. The resulting negative stall caused violent wing drop or snap roll, and this brought coupling into pitchup.

As you should have gathered from this discussion, pilot actions or reactions are more important in the overall picture than the mechanical devices. We have now proven more than a dozen times that pitchup or negative spin entry can occur in spite of devices. Acknowledging this fact of operational life, it becomes imperative that 101 drivers really understand the nature of the incipient spin — and the means of effecting a recovery. It is a fact, after all, that spin entry itself does not make a crash inevitable. It is the actions within the cockpit that determine final outcome. ★

2+2=4

and

$$\frac{\frac{1}{2}\rho V^2}{4}+2\left[\frac{a}{(F_n/W)}\right]=\text{WAHOO}$$



Just as we know that 2 and 2 are four, we must also accept the fact that low A/S and high "G" equals pitchup.

In September of 1962 we discussed via an INTERCEPTOR article, those pitchups that had occurred in the preceding six months. During that period we'd had three pitchups, and two recoveries, for a 66% success rate. In just the six months since that article, we've logged four more pitchups with only two recoveries. The success rate is down to 50%, and even more discouraging is the loss of two pilots.

The manner in which these last two pitchups occurred is of much importance, but the fact that pilot factor was involved is more so: The well supported conclusion is that some of our people just don't understand, and aren't hacking, high performance flight in the F-101. The words "high performance" are used here, because it is fact that the majority of our pitchups have occurred in flight conditions well below maximum limits of the aircraft. In other words, pitchup mostly occurs at speeds, attitudes, etc., that are known to many as everyday requirements of the mission.

The answer? Well, it doesn't lie in restricting the aircraft to a set of arbitrary maximums or minimums—the record proves that all altitudes, airspeeds, and flight attitudes can be hazardous, if the pilot doesn't understand his bird or is heavy-handed. Conversely, the pilots who know their aircraft and know how to fly it will rack up MA's in regions far beyond those at which our pitchups occur.

The answer — there must be knowledge of how to fly the aircraft and to what maximums it can be flown. Across-the-board development of these two qualities is a must, because without them, even with all of our antipitchup systems, some people are going to get themselves in trouble.

Several programs are now going on that will help bring pitchup into better focus and clarity. Our Combat Crew Training Squadron at Tyndall is doing an excellent job of building confidence, knowledge, and technique, both in classroom and in the cockpit. Our manuals are being changed to require greater supervisory and instructional emphasis on ground and flight training. The new Dash-One will cover the problem much more comprehensively.

Our assessment of F-101 pilot capabilities may seem to be overly critical. True, it is a criticism, one that is by no means aimed at the majority of our people, but all the same a valid one, that can be backed up by reading through reports of some 21 pitchup accidents and incidents.

Since any critic that is worth his salt should follow criticism with something constructive, we'd like to cover several points about pitchup that we suspect aren't pegged down too tightly in some people's minds.

IN a good percentage of our past pitchups, it seems that the ole 101 took bit in teeth and stampeded right into pitchup.

During climbs, turns, breakaway maneuvers, and even in the landing pattern, the bird is supposed to have gone "Able Sugar," and jumped into its famous "Wahoo" maneuver, much to the amazement of the pilots involved. Admittedly, there have been several pitchups that are suspected or known to have resulted from system failures. The remainder, however, occurred when all systems were reported to be "A" O.K., and generally on missions that required performance well short of maximum. On top of this, they happened at an average indicated airspeed of around 230 knots.

Now, to those people who consider that anything below 250 knots is "skating on thin ice," 230 might seem to be a logical point to expect pitchup. But the bird itself doesn't have the foggiest idea that it might be in trouble — in fact it will keep on flying right down to 120 knots and below. Witness Don Stuck's 88 knots minimum during the Low Q PCS Tests.

The point we make is that the F-101 is capable of longitudinally stable flight throughout a wide A/S range, and that there is no magic airspeed figure at which a "Wahoo" occurs. It can be pitched up, from straight and level flight at 600 knots IAS or, conversely, it will fly through a snap-up recovery very nicely, from a stability standpoint, at 130-140 knots.

The secret to success is one of ANGLE OF ATTACK. As long as the critical angle of attack is not exceeded, the bird is happy — go beyond and it will pitchup, regardless of airspeed, attitude, or color of the pitot boom.

PCS and CSL most of the time do a good job of keeping alpha within limits, but they are not infallible. We also have PBI to help maintain safe angles, but this too is subject to error. So the final responsibility for keeping alpha within limits rests with the pilot.

Exactly how a pilot does this is pretty simple most of the time. He heeds the warnings and indications of PCS, CSL, and PBI. He recognizes and takes action when he gets airframe buffet or wing drop. And he is, as a rule, pretty discrete about how forcefully he wobbles the stick around.

Over and above these things, a pilot should have an understanding of the angle of attack/IAS/"G" relationship, because when systems fail or are fooled, this is all he has left. To lead into a discussion of this relationship, let's refer back to a phrase mentioned earlier, i.e., "critical angle of attack." This is the factor that limits the aircraft or establishes its operational performance envelope. It is the angle of attack which, if exceeded, will put us into pitchup. Since it does vary some and can't be seen, felt, or smelt, it is easier to use a couple of things that we are all very familiar with, i.e., indicated airspeed and "G" loading.

We all know that high IAS means that we can pull a lot of "G" and vice versa, low IAS means that we ease off on back pressure. So to maintain a constant safe alpha throughout the aircraft speed range, "G" must slide down the scale along with a decrease in IAS. This relationship can be backed off very safely to such extremes as 120 knots if the proper "G" is being pulled (about .5 G at 120 knots, dependent on aircraft weight).

You might be beginning to wonder why all the talk about airspeeds that we seldom, if ever, reach. Our purpose is to hammer home the fact that there's nothing to get shook about, if just after fire signal you see airspeed creeping downward to, say, 180 knots. You simply unload toward zero "G" and smoothly roll at a moderate rate (4 seconds recommended) to the inverted position.

As the 90° bank point is passed, the forward stick pressure is being eased off, and as you hit the inverted attitude, available positive "G" should be pulled. This may only be +.2 to .5 "G". However, even this small figure will cause the bird to get headed downhill much faster than by holding the zero "G" that some people advocate.

Pulling the "G" could be extremely important if you found yourself recovering from a 60° or higher climb angle with A/S bleeding rapidly. Positive "G," however small, will get you headed downhill and accelerating, whereas the zero "G" method, which provides a relatively slow turning rate, might leave you with nose still not down through the horizon and A/S bled off to a critical point.

So again it's up to the pilot, the bird itself being willing and able to hack much more than the normal mission requires.

All this discussion of matching "G" loading to IAS doesn't mean that we expect pilots to cross their eyes to keep one each on "G" meter and A/S indicator. Far from it, and impossible to use anyhow, because of the variables caused by gross weight, instrument error, parallax, etc.

The "G,"/IAS comparison is, however, available to us in a manner which is more reliable and does not require lightning cross-check or calculation. This is airframe buffet or approach to stall, and it provides us with warning throughout the transonic and supersonic ranges — the ranges, by the way, in which all of our pitchups have occurred.

Now, somebody is going to say that in process of a mission we get or fly in buffet all the time. True, we do — but we know just how far to go with it, wing drop generally being the max. The one thing that some people don't seem to realize is that the onset of buffet is a good warning that we are approaching max alpha, clear down to the 120 knots that we mentioned before. So there is no need to start breathing hard at any time, even on those max performance missions — getting shook makes people start taking unusual and hurried actions to eliminate the cause — and recovery from low speed, high angle, climbs is no time to develop spastic tendencies.

So far, we've talked about the need to maintain the proper "G" loading and a very tender touch. The lack of these on the part of a new troop is what caused ADC's last pitchup. This pilot completely disregarded warnings, from horn, severe buffet, and the R/O, to "over-G" the bird, of all places, in the landing pattern.

Our traffic pattern pitchup was a pretty straightforward case of the "G" factor in the "G" vs IAS relationship growing too big, because of a strong arm.

Another factor that must also be considered, along with "G" and IAS, is roll rate. An improper balance of these three factors pitched up and augered a 101 and pilot just the day before the one mentioned above. Let's use this last case as an example.

The bird was snapping up at a 20-25° pitch attitude. Fire signal came at about 240 knots, at around 40,000 feet. If you detect the weasel words "about" and "around," it's because the R/O had to estimate these figures — because the pilot had gone in with the bird. Anyway, the situation as indicated doesn't sound too hairy, but yet, pitchup. Well, he had tanks on, and as a result had a heavy fuel load at time of fire. True, but tanks only cause a slight amount of parasite drag at low A/S, which in turn causes A/S to bleed off a little faster.

Anyhow, he had about 240 knots at fire signal, so tanks and their effect on bleed rate don't figure in this one. How about the additional weight due to the amount of fuel remaining? Yes, this is a factor too, but in our 240 knot case easily compensated for. We know that a heavy gross weight means less "G" to stay short of critical alpha. Your PCS and CSL also know this and, therefore, limit you earlier when you're heavy. Likewise, the bird itself provides warning earlier. At a specific airspeed, say our 240 IAS, the wing tips stall at a lower "G" and old airframe buffet is felt.

All this means that at the higher weights we either pull a little less for a given airspeed, or have a little higher A/S if we want to pull a specific "G". In our example, the pilot had 240 knots and a CSL-limited 1.4 "G" available, both more than ample for making a snap-up recovery maneuver from a 25° climb. In fact, his A/S could have bled down to the the 150 knot minus region, and he could have successfully recovered, if the aircraft were unloaded to the proper "G" during roll and pull-through.

On the other hand, even at 240 knots, holding 1.4 "G" on CSL and rapidly rolling, he could get in trouble. This last condition, we strongly feel, is what caused this particular pitchup and also several in the past.

So the problem is still one of too much "G" for a given A/S, with an added factor — roll rate. Roll gets into the act with a combination of forces which are mentioned below.

- As the aircraft is rolled left, the angle of attack of that wing is increased. Conversely, right wing alpha decreases.

If, as in our example, the wings are already pulling max "G" (i.e., developing max lift), an increase in alpha due to a fast roll increases the left wing loading to the point of wing tip stall. As the stall works its way inward on the forward slanted wing, it concentrates the area that is still producing lift farther forward, so we get the forward shifting of the center of lift. Another factor is also present. This is downwash caused by the wing's high angle of attack, and strengthened by increased wing tip vortices.

This combined flow, at high angles of attack, submerges the stabilator and decreases its effectiveness as a control plane. So the total result is a nose-up pitching moment, which, by itself, probably won't cause pitchup, but which, when combined with the other forcing effect, can produce a "Wahoo."

The second force is simply an extension of the first. If roll and "G" are "pressed on," the stall which started at wing tip progresses to stall most of the wing, and a snap roll results. The snap is what we started with — a high rate of roll.

From here on out the bird can go either way. If at the start of a snap, the pilot unloads and can keep from putting some adverse control in during the gyrations, there is a good chance that the bird will stabilize out and fly away. But, if the pilot keeps the back pressure in, or starts booting controls to counter the snap roll, he is compounding the problem — to the point of pitchup.

A third major force stemming from the high "G" rapid roll is inertial or roll coupling. This is probably the most difficult to put into words, so we'll also diagram it out after the written explanation.

Roll coupling gets its name from the fact that, when we roll with "G's" applied, we get a certain amount of activity in the longitudinal axis also. In other words, we get a coupling of the pitch axis to the roll axis without any help from pitch controls (i.e., stabilator).

The key to the amount of roll coupling we get depends primarily on "G" loading, rather than rate of roll. For example, in a fast "show type" aileron roll we automatically unload as we start the roll. Backing off toward zero "G" decreases alpha to a minimum, so we don't slop around the sky, but rotate the bird smartly on a point. No roll coupling in this case.

Now, if we hold max G and whip the aileron over, it's a horse of another color. The high "G" means high alpha, and this combined with a roll tends to further increase angle of attack.

Here's the reason: In a roll, the bird rotates about its aerodynamic axis, that is, a line drawn through the center of gravity along the flight path. If we have minimum "G" and alpha, the longitudinal axis and flight path line are almost one and the same, and we have the case of that snappy aileron roll. But with more "G," the flight path line and longitudinal axis diverge by, say, 10-12°. If this angle of attack is maintained during a fast roll (remember we always roll about the flight path line), then centrifugal force gets into the act and tries to sling the nose and tail into a larger circle. If the circle made by the tip of the pitot boom gets larger, due to centrifugal force, it means that the angle between the longitudinal axis and flight path line increases. This, in other words, increases angle of attack — so, if you started a roll at max alpha and increase it due to roll coupling, you can overshoot critical alpha.

So these are the forces that have helped splatter over half a squadron of F-101's around the countryside. The straight over "G" or too much "G" with the addition of the combined rolling effects has been the final cause of all of them. No matter what the initial problems were, or what or who caused them, too much "G" and, therefore, too much angle of attack, is the answer.

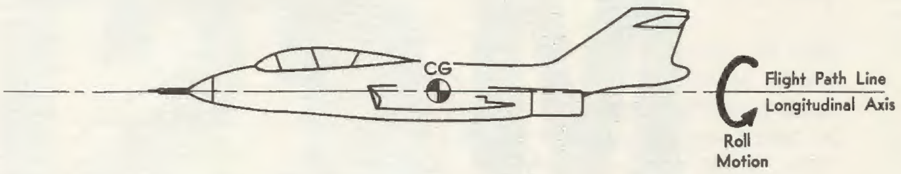
For example, we've had three nosedown stick forces that took the bird to negative stall — the most recent, just last month at Minneapolis Honeywell on a test bird. The pilot couldn't break the system-applied nosedown force, nor could he do anything about the resulting snap rolls that followed negative stall. The snap roll brought on roll effects and pitchup.

The one before this came when a pilot created his own nosedown force by jamming the stick full forward in the 280 knot vicinity. The results were the same as those faced by the M-H test pilot, but our strong-armed friend came home by chute, whereas the M-H pilot flew the bird back minus only a drag chute.

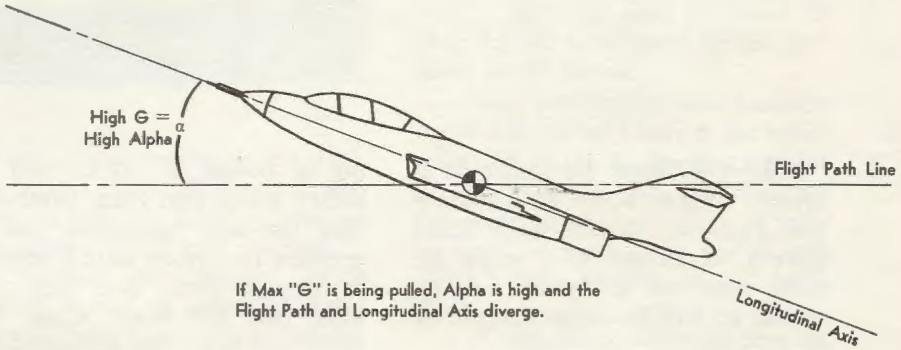
No matter how a pitchup starts—too much forward or aft stick, too much aileron, too great a rate of movement of either — the final result is too much alpha. And in those where the systems are blameless, the pilots are the reason for the too much of everything.

This is a fact of life. The proof is there in our accident/incident file. It seems that we continue to blame tanks, bleed rates, and strange and unknown forces for pitchup. We are in fact, only using these causes as a crutch for our own inabilities to fly the F-101 in a manner which the bird is fully capable of doing without us. ★

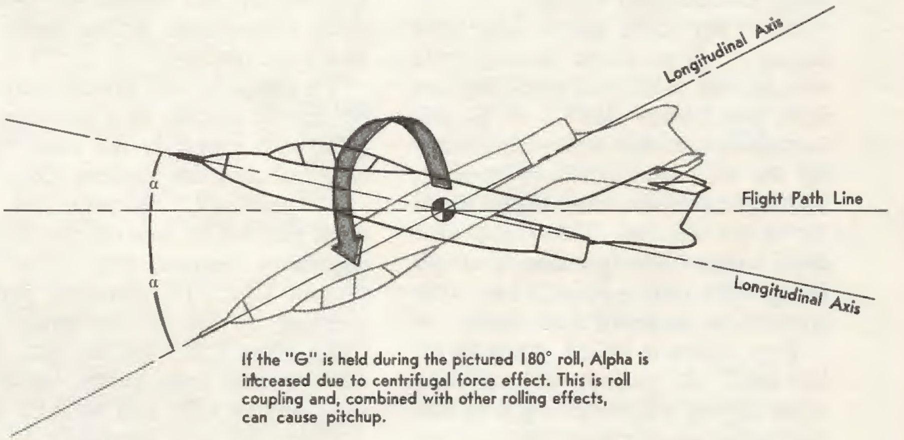
INERTIAL (ROLL) COUPLING



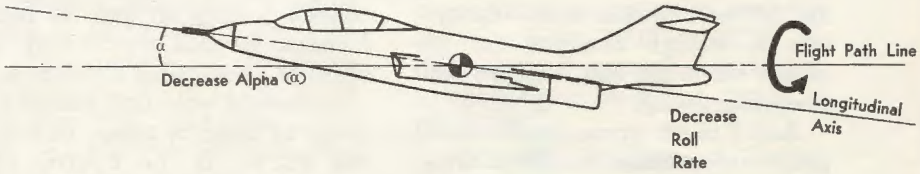
When Flight Path and Longitudinal Axis are aligned during a roll, no coupling results.



If Max "G" is being pulled, Alpha is high and the Flight Path and Longitudinal Axis diverge.



If the "G" is held during the pictured 180° roll, Alpha is increased due to centrifugal force effect. This is roll coupling and, combined with other rolling effects, can cause pitchup.



The answer is to unload "G" to decrease Alpha and to roll at moderate rates.

MCSL

“m” is for manual

“Major—Please! I’d rather do it myself!” These words or a reasonable facsimile thereof were heard quite a bit around ADC when the word went out to fly all F-101B attacks on AFCS—either coupled or on CSS.

The reason for this directive was to have CSL standing by to do battle with “Ole Debbil Pitchup.”

Now, for those pilots who have strong feelings about letting little switches do their stick-wobbling, we have a solution—MCSL. With this forthcoming gadget a pilot can hand-fly the bird to his heart’s content, and still have command signal limiting when needed. There are also some other nice goodies that go along with this system, but we’ll cover those in detail a bit later.

First, when is MCSL going to hit the field? At present, it looks like some of you will be seeing it in late September or early October.

You might ask why INTERCEPTOR is getting all trembly and verbose about MCSL, when every one knows all about CSL already. The difference is more than just adding an “M” to a familiar term—the system is enough changed, for the better, we might add, that it’s well worth discussing.

And if in our discussion we sound pretty expert about the whole thing, it’s because we’ve gotten all of our poop from some experts. They were: Mr. Joe McDonald, Senior Systems Engineer at Honeywell, who figured big in design of MCSL and Jim Bailey, Chief Test Pilot, Honeywell, who test-flew, squawked, and re-test-flew the system until it achieved its present form. And then there were two AF types, Capt. Tom Mack and Capt. Bob Linsay, AFLC test pilots from Hill AFB, who flew the acceptance flights and who stopped by last month to give us some enthusiastic words about the new system.

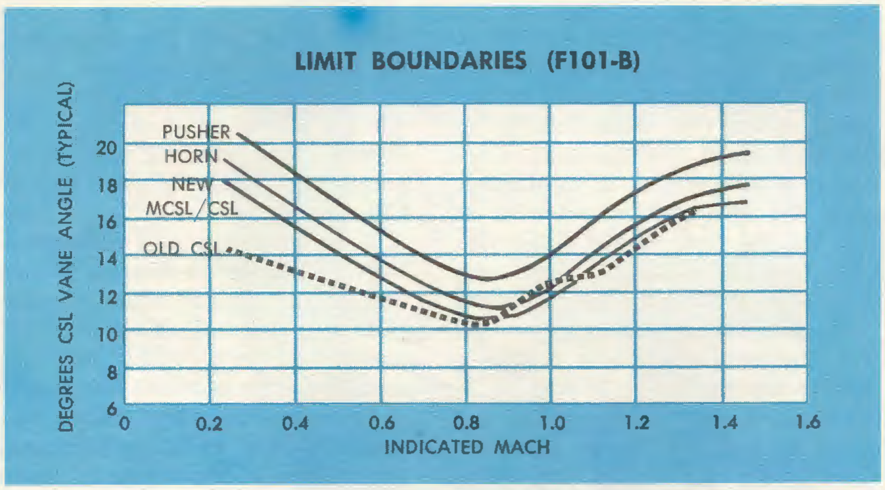
To call it a new system may not be exactly proper, as it provides the pilot with generally the same functions as does the present CSL. We say “generally,” because for the most part MCSL extends the aircraft capability beyond that under the present CSL. To eliminate further garbling by use of the terms, Old CSL, New CSL, MCSL etc., let’s mention the two prime areas of similarity of CSL and MCSL.

First, the limit boundary of new CSL and MCSL will, though actuated by different switches, be a common system and will, therefore, be identical. Another similarity is the emergency overpower force—still 60 pounds aft and 30 pounds forward. Beyond this, MCSL is a horse of a somewhat different color.

Externally your bird will look the same, as angle of attack pickoff for the MCSL is the CADC vane. Your only indication of MCSL installation will be an “ON/OFF” switch and amber “MCSL OUT” light on the center pedestal next to the ILS/TACAN switch.

Now to the hidden goodies that come with this installation:

- MCSL has a new limit boundary, reshaped to closely parallel the PCS horn boundary. You can see in the accompanying boundaries diagram that MCSL and new CSL should eliminate the intermittent horn beep normally heard in the .9-1.1 mach overlap range. Also note that the new boundary makes considerable more alpha and “G” available in the low mach range.
- While on the subject of “G,” MCSL has no 4 “G” limit as does the CSL, so will allow “G’s” appropriate to indicated speed. So, if you’ve gotten up a real head of steam, the MCSL boundary will really let you bend the bird around. (In tests at Ogden, Bob Linsay got up to 5½ “G’s” at 500 KIAS.) MCSL does, however, have a negative “G” limit which deenergizes the system if for some reason it goes ape and drives the stick forward to the tune of 1½ “G’s.”
- MCSL was designed to provide continuous backup for the existing limiter/inhibitor systems. For example, the switch once placed to “ON,” stays on until switched “OFF,” the AFCS C/B is pulled, or power failure occurs. This means that you can turn the switch on at your 5,000 foot check climbing and more or less forget about it. Going to AFCS for a coupled run or one on CSS relegates MCSL to an inert



backup position. Later, if AFCS is turned off, crumps and drops out, or is cut off by a pusher activation, MCSL comes alive to provide a limit boundary.

- There are also a couple of other things that will temporarily cut MCSL out. One is the paddle switch, which deenergizes MCSL only during the time the paddle is squeezed. The other is the gear cutout circuit which deenergizes MCSL when gear is extended. If a go-around is made and gear is retracted, MCSL becomes active again.

- Another MCSL feature that will seem new to the pilot is its reaction to pitch rates. We said "seem," because these same pitch rate capabilities have always been a function of CSL, but were not generally felt or noticed because of the stick damping present when flying on AFCS/CSL. So, when you're happily hand flying the bird, with MCSL switch on, and all of a sudden, haul back hard and fast on the stick, this is what will happen. MCSL will anticipate an excessive pitch rate and will limit you a tad below static boundary and will then, when the excessive rate has been controlled, ease the stick back to solid on the limit. Since MCSL also limits on aircraft pitch rate (by looking at rate of vane angle change), flying in turbulent air will cause some excessive rates to be sensed, and if you're on the MCSL boundary you'll notice very slight fore and aft movements of the stick. This action is MCSL sensing and acting on the very slight bobbles in pitch caused by the gust loadings.

- Another arrangement which the pilot should be aware of is the gear interlock circuit which prevents MCSL deactivation if you should ever be pulling on the MCSL boundary when gear is lowered. This circuit should very seldom be used, but if you're courageous enough to try to beat Shehi's pattern time, you can lower the gear while on the boundary, and it will give protection until you ease off—then it drops out. NOTE: This is not recommended, nor is it in our estimation a wise practice.

- Another important point—Do not hold on either MCSL or CSL limit while switching to the other system. There is a quarter-second delay in getting relays, etc., of the newly selected system closed, which will leave you without a limit during transition to that system.

- A portion of the system that we are all very concerned with is the monitor circuitry which tells us the system is reliable or is kaput, by shining an "OUT" light in our face. This portion of the system looks at practically all of the MCSL components that could cause system failure. In addition to telling us when a system failure has occurred, the light also comes on when:

1. The switch is "OFF."
2. The paddle is depressed.
3. AFCS C/B is pulled.
4. When utility hydraulic system failure occurs (actuated on a drop to 1500 PSI).
5. When you're pumping the stick fore and aft rapidly during a test flight rate check, the light may flash on during the forward movement of the stick—this because MCSL anticipates a negative 1½ "G" at the rate the stabilator is traveling, so actually cuts out and turns the light on before the limit "G" is reached.

NOTE: The light does not come on when MCSL is dropped by the gear down cutout circuit.

- One completely new function which CSL doesn't have is the availability of MCSL in the rear cockpit of the two-stick birds. The system has identical characteristics in both cockpits, with only the switch and "OUT" light missing in the back chair.

- A last small point of interest is the test circuit. This is wired through the existing PCS test switch and allows ground test of the system through a bypass of the gear down cutout.

Now that we've got a general idea on MCSL's insides let's see how everything works during a flight.

As we're strapping in, we see the large amber light glowing down on the center pedestal, so we reach down and flick the adjacent switch on. The light still glows, because we haven't started and have no hydraulic pressure.

After the start and PCS and AFCS/CSL checks have been completed, check out MCSL this way:

First be sure the AFCS switch is "OFF," because you recall CSL has priority when both systems are on. Next turn MCSL on. The light should go out. If it doesn't, MCSL is out for some reason, so don't use it during flight. NOTE: MCSL has duplication of most primary circuits, so should give us a high degree of reliability.

Now, with the light out, depress the PCS test button, pull the stick back and have the CADC vane rotated from the full down position, clockwise to the up position. The stick will drive forward. Depress the paddle switch—the stick will stop and the MCSL light will come on. Release the paddle, and the forward drive will resume, and the light will go out. You may note that the stick drive is much slower than with the old CSL check. This is not a malfunction. It is a characteristic of the new system *during the ground check only*. Once airborne, the MCSL will, if necessary, decrease stabilator angle at the rate of 25° per second.

During climbout, turn on MCSL at the 5,000 foot check, and note that the light goes out. At leveloff, you can check out both MCSL and CSL simultaneously, by making the check on AFCS. You probably won't get a rate check on CSL because of the stick drag caused by AFCS damping, so if you want to specifically check out this function, turn AFCS off and hand-fly the bird. Since MCSL senses rate from four separate sources, i.e., stabilator rate, CADC vane pitch rate change from the rate gyros, and angular acceleration it won't take much of a honk to get a rate MCSL.

You might at this point figure that MCSL is too sensitive in rate and will therefore restrict you. Not the case at all. When MCSL senses an excessive rate, it moves out to meet the stick, slows it down to an acceptable speed, then continues to ease the stick back at that speed to solid on the proper boundary limit.

Continuing on with the mission, we can hand-fly all the way and have MCSL available, regardless of what pusher, horn, or fire control system do. Remember, pusher does not knock MCSL out as it does with CSL. Also, neither the fire, abort, or minimum range signals have any effect. If, on the other hand, we're running it automatic all the way, CSL will have the honor, with MCSL standing by if CSL drops out for any of the reasons mentioned above. At this point, we emphasize again: Do not switch back and forth from CSL to MCSL, because you lose the boundary limit for about a quarter of a second during the changeover.

During the remainder of a profile mission, MCSL or CSL will function generally as you've noted in the past—except that, while hand-flying the bird, you'll probably rapidly develop a new feeling of confidence over the feel and effectiveness of MCSL. At low speeds, like over the top of a snapup, you can snug the stick into the boundary with just finger pressure, yet get the tightest, smoothest recovery you've experienced.

If you're really cooking along and wind up having to make a conversion to the tail, MCSL will allow smooth high "G" maneuvering just a smidge short of horn, clear from V max right down to target speed. One point at which you'll note some horn beep is the .8-.9 mach region —this because on MCSL boundary you don't have the damping that is present with CSL, so the buffet is a little more pronounced and will cause the intermittent rate horn.

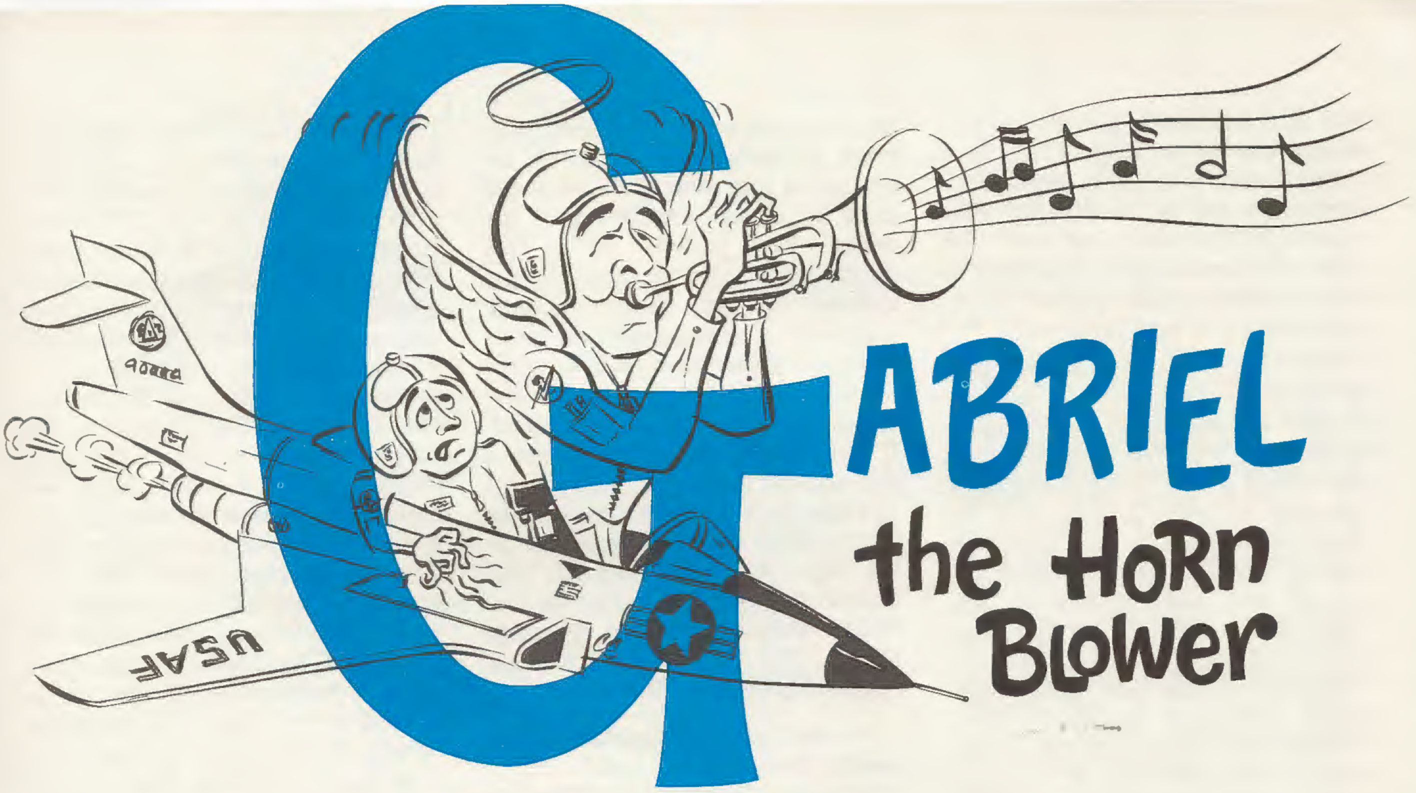
Back to that rapid buildup in confidence with MCSL. Our test pilot friends from Hill were very enthusiastic. In fact, the above words on flying the bird are pretty much as they said it. But they also had a word of caution. It was this: You always know you're on AFCS because of the way the stick feels. Likewise, you would know by change in feel if CSL should drop out. But hand-flying the bird is just the same, MCSL or no, until you hit the boundary. So, should MCSL fail or should you forget that you've turned it off, there is no change in feel to warn you. For this reason we stress the continued need to fly the bird smoothly at all times. You don't need to be a pussycat, but should use a constant level of aggressiveness, both with and without CSL.

If you yank and bank with MCSL "ON," it's liable to become a habit that can't be stopped with the system "OFF" or failed. Normally you won't even turn MCSL off after switching it on at 5,000 feet, except during specific test hop checks. You should leave it on through recovery and approach. As the gear comes down for landing, MCSL will be cut out. This is not true of CSL, so you can land with AFCS/CSL on. And in some cases this is very advantageous. When experiencing control problems due to a feel bellows leak, viscous damper problems, etc., going to AFCS will make the bird straighten up and fly right, and with the new MCSL/CSL boundary and a flat approach, you've got plenty of back stick available to round the bird out.

Well troops, that's MCSL from the aircrew's standpoint. It's designed to increase the bird's capability, to be highly reliable through redundant circuits, and in addition to be easy on the maintenance man. For the "do it yourself" stick wobblers, it's just what the doctor ordered.

And, last but not least, it'll make straight shooters out of a lot of us that would otherwise be wrestling with pusher at a second to go. ★

The geardown cut out switch mentioned at various spots in our article will not be hooked up in the initial MCSL modification. This would require dropping an engine to route the necessary wiring and would therefore require many extra manhours. However, all black boxes will be installed, and individual squadrons will be required to route the wiring the first time an engine is dropped. This situation will require an interim procedure to insure MCSL is "OFF" for landing. As it stands now, we understand that the initial checklist will specify turning MCSL "OFF" at 6,000 feet, only when approaching to land. It should not *be turned off if on an intercept mission below 6,000 feet.*



GABRIEL the HORN Blower

GABRIEL is the greatest fighter pilot in the Air Defense Command, to hear him boast at the bar on Friday afternoon. He is an excellent T-33 pilot but the F-101 is really his piece of cake. No other jock can put his body through all the contortions as he explains the maneuvers with his arms and hands. Anytime the conversation gets around to pitch-up, Gabe just shrugs it off as "no sweat, only a real hamhand would pitch-up".

Actually, Gabe was not one of the smoothest jocks in the squadron. The R.O.s had tabbed him "THE HORN BLOWER" because he was so spastic on the controls he usually gyrated the bird in and out of the horn boundary. Most R.O.s did not like to fly with him. When the flying schedule was being posted and they were looking for someone to fly with Gabe, all of a sudden the R.O.s were busy — sick kids, wife in labor, overdue reports, and projects that needed immediate attention.

The squadron had their nose to the grindstone preparing for the recheck on the ORI they failed a few weeks ago. The Ole Man had said the hack rate would improve, regardless. Everyone was cocked and ready to go as soon as the team arrived.

Early Saturday morning, after a blast at the club the night before, the squadron was notified to implement their recall plan.

The crews were assigned aircraft as they arrived at the squadron. When Gabe showed up there was no R.O. available, so he waited for the next one to report to the squadron. When this unsuspecting back seat gunner arrived and saw he was paired with the horn blower, he developed a backache and a sinus block. The flight commander detected these psychological symptoms and ordered the R.O. to go with it.

After they were set up in the aircraft, they returned to the alert shack for a cup of java. Everyone was anxious and eager for the scrambles to get started except for the R.O. with Gabe. He was nervous and tense and was trying to think of an excuse to get off the schedule. After a short period the scramble horn blew and Gabe and his reluctant gunner were scrambeld.

After level-off, they were committed on a high altitude target. The R.O. released the hand-grips long enough to get locked-on and they began the snap up. Intent on aggressive dot steering, Gabe did not notice the airspeed until it was dropping below 200 knots, but he pressed on because he had to hack this intercept. At fire time the airspeed was below 150 knots. "Horn Blower", knowing that the escape maneuver would be graded, slapped the control stick over to get the aircraft on its back. As the bird approached the inverted position, the nose came down abruptly and she snap rolled. After a few terrorizing moments, Gabriel realized the situation. Now, let's see, what is the pitch-up recovery procedure? Stick full forward, neutral ailerons and rudder, out of A/B and deploy the drag bag. The nose pointed toward terra firma but she was still rolling and yawing. She began to pick up speed and the bag ripped off at 240 knots. Gabe, pale and sweaty, began his pull out with tender, loving care. All the way back to home patch our nervous gunner did not say a word, but he was thinking about plenty to say when he got on the ground. Gabe was also in a hurry to get the bucking bronco on the ground — pronto.

Pitch-ups have been decreasing the past few years, but we continue to lose a few airplanes due to this aerodynamic characteristic. ADC has recorded twelve aircraft lost primarily due to pitch-up. There have been several losses that were probable pitch-ups. We have logged many pitch-ups that have been recovered and your guess is as good as ours as to how many pitch-ups and recoveries have not been reported.

We believe that we can decrease or eliminate these wahoos and loss of men and machinery by education of the aircrews. We have discussed the causes and recovery methods of pitch-up in seven articles over the past five years. You may think that we are placing too much emphasis on this one problem, but we continue to have the wild gyrations and it is not always the new troop in the squadron. There are undoubtedly some field grade command pilots flying around today who don't fully understand their aircraft or their own abilities. In most cases this is a more severe case than with the new pilot. How does an old timer admit he doesn't know some very basic information without losing face? In contrast, how does the new boy admit it while trying to impress everyone that he's progressing faster than his compatriots? Ego and pride are human traits that are completely acceptable, but don't let it drive you to destruction.

All of us Voodoo pilots are familiar with the aerodynamics of the F-101, especially the bit about gross weight, indicated airspeed and "G" forces.

Disregarding the warning gadgets, here is the rule of thumb to remember: the heavier the aircraft, the less "G" we can pull for a given indicated airspeed, or the slower the indicated airspeed, the less "G" we can pull for a given gross weight. Another variable that enters into the picture is altitude. The Brown Shoe pilot will tell us that for a given gross weight we can pull so many "Gs" for a given indicated airspeed *regardless of altitude.*

The experienced Voodoo pilot will tell us this is not true. We can pull more "Gs" at 300 knots at sea level than we can pull at 300 knots at 40,000 feet. Why? As we climb, holding a constant indicated airspeed, our mach is increasing. As mach increases we lose some of the available angle of attack, until we pass the critical mach region (.865). This critical mach region is caused by the airflow over the wings becoming supersonic. The supersonic air forms a vertical shock wave, which causes lift to be decreased and disturbs the airflow over the horizontal stabilizer. If the airspeed is increased above this region, the shock wave begins to angle back and move toward the trailing edge of the wing; therefore we begin to regain our lift and smooth out the airflow over the stabilizer. Remember, when operating in the .865 region, we have less angle of attack to horse with.

Another problem we encounter is inertial overshoot or rate. With a slow smooth increase in "G" the onset and build-up of the warnings will occur at a rate that can be interpreted and acted on by the pilot. If the "G" is increased at a rapid rate, the warnings will be compressed into a shorter duration and may not provide adequate warning prior to exceeding critical angle of attack. Rapid aft stick rates may cause pitch-ups even though back pressure is released prior to the critical point. The Voodoo is a heavy bird and once we start it moving, it wants to continue to move even after the control stick is neutralized. When flying at high angles of attack we should handle the control stick smooth and easy.

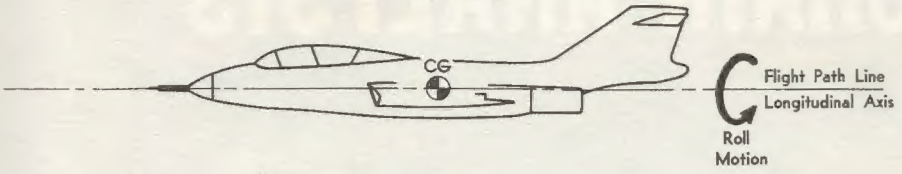
Climb angle also effects our "G" loading. Let's take a hypothetical situation—we are in a 45 degree climb unaccelerated flight. Our wing loading in this case would be .707 "Gs". We are not dependent on the wings for all the lift because the thrust of the stoves helps keep us airborne. This rule holds true for all angles of climb. The greater the climb angle the less we depend on the wings for lift. If we are in a vertical climb, the wings are producing very little, if any, lift. Actually, we can climb slower than we can fly straight and level. This is not as noticeable in most birds as it is in the Voodoo. This is especially critical when we do not maintain proper climb speed or during a snap-up maneuver. At a 45 degree climb with 200 knots airspeed the airplane is still far from pitch-up but the margin is narrowing quickly. If we hold this attitude too long we find ourselves in a situation where we practice our pitch-up recovery procedure. How do we get out of this position? Naturally, the best way is not to get in this predicament to start with, but if we find ourselves here, we must get the nose down to pick up some airspeed. The simplest procedure would be to execute the normal escape maneuver.

The Voodoo will continue to fly down to 90 knots provided the wings are not overloaded. (Practically a ballistic curve.) Below 90 knots the bird loses its stability even at 0 degrees angle of attack. The crux of the matter is being able to detect these critical situations before we paint ourselves into a corner.

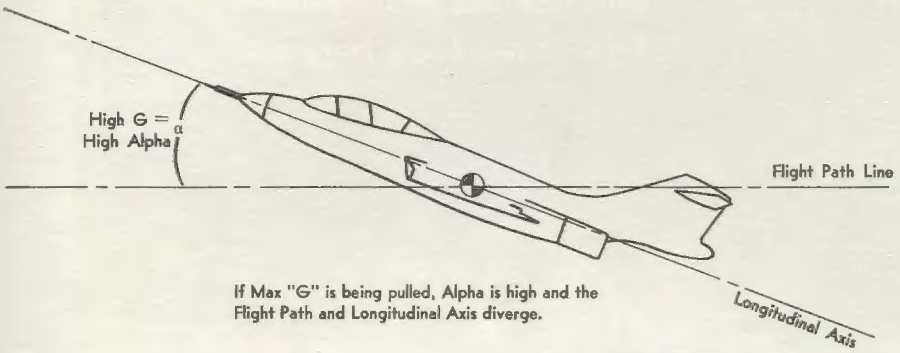
Finally, the big culprit — inertial (roll) coupling. This is the bug that bit Gabriel and caused our last two recorded pitch-ups. The first pitch-up was caused by consecutive aileron rolls at low altitude. This is the reason the good book states that more than one consecutive aileron is a prohibited maneuver. The other pitch-up was caused by the pilot banking from one side to another, looking for the target.

What causes inertial coupling when we roll? When the aircraft rolls it does not roll around its longitudinal axis but around the aerodynamic axis. If we were at 0 degrees angle of attack (ballistic trajectory) then the longitudinal and aerodynamic axes are identical so inertial coupling is no problem. Now let's pull to 10 degrees angle of attack. The longitudinal axis diverges from the flight path at 10 degrees. Wings level, this means the nose in 10 degrees above and the tail 10 degrees below the actual flight path. At this angle of attack we initiate a roll, the nose and tail roll around the aerodynamic axis at 10 degrees. The faster we roll the more centrifugal force is created by the nose and tail. This centrifugal force causes this

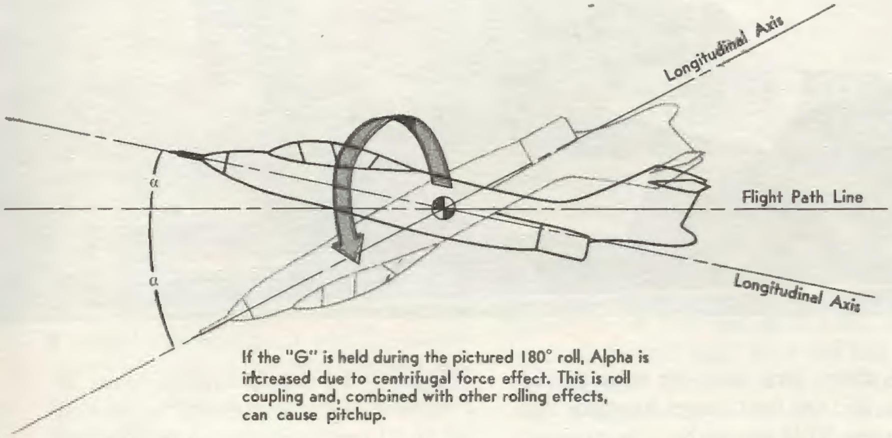
INERTIAL (ROLL) COUPLING



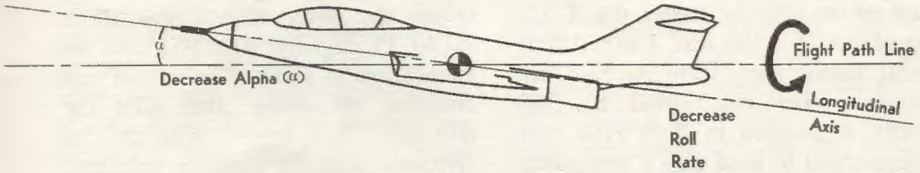
When Flight Path and Longitudinal Axis are aligned during a roll, no coupling results.



If Max "G" is being pulled, Alpha is high and the Flight Path and Longitudinal Axis diverge.



If the "G" is held during the pictured 180° roll, Alpha is increased due to centrifugal force effect. This is roll coupling and, combined with other rolling effects, can cause pitchup.



The answer is to unload "G" to decrease Alpha and to roll at moderate rates.

initial 10 degree angle to increase and it is possible to exceed safe limits and place the bird in an excessive angle off attack position — pitch up. Another nasty feature is this increase in angle of attack may not be registered by the warning devices because of the disturbed airflow over the angle of attack sensors. In essence then, with the pitch warning devices operating normally, we can pitch-up without warning from these warning gadgets or the autopilot. When operating at high angles of attack, we should reduce angle of attack (unload the wings) before initiating a roll.

At the present time Minneapolis-Honeywell is performing a test program to design a new pitch control system. They have proposed to remove the angle of attack transmitter vanes from the nose and place an angle of attack sensor probe on the pitot boom. This would correct the error in the PCS curve caused by the installation of the IR seeker head, but would not correct the errors caused by the inertial coupling. This is only a test program and at the present time has not been bought.

The Voodoo can perform any maneuver that any other aircraft is capable of, but we must know its limitations as well as the characteristics and limitations of the Wonder. The mission does not require over the top maneuvers to be performed; therefore, the boss has restricted these maneuvers, i.e., loops, Immelmanns, etc.

We might not like the way our airplane was designed and we might all fancy ourselves as being able to do a better job than those civilian and military "pros" responsible for it, but it all boils down to "We're stuck with it and it's worth our life to know how it functions — good and bad." The one-o-one is a good, proven weapons system. There are a lot of good things going for it from its high rate of climb to its high hack rate. As long as we admit to its one bad aerodynamic characteristic, pitch-up, and fly around it, we will continue to get our fair share of hacks in the 101 for a long time to come. ★

ARM CHAIR ANALYSIS

F-101 Destroyed.
Both Crew Members Ejected.
Undetermined Board Findings.
What Could Have Happened?

SHORTLY after becoming VFR, I started to move out and make my lanyard, pusher and MCSL check. Just after level off, the lead asked for a recheck of the lanyard, pusher and MCSL. I called each off, "Lanyard disconnected, pusher on and MCSL on." After this we turned the wing tanks on and the fuselage switch to gravity. After checking that the wing tanks were feeding, we checked the data link and I noted that we were paired. The first pairing lasted only about three frames, and then the pairing was broken. The wing tanks empty light came on and the wing tank switch was turned off and the fuselage switch was placed back to the normal position.

A short time later we were paired on a 35,000 foot target heading 360 degrees. This was to be a front snap-up on a T-33. I dropped back to about a 2½ to 3 mile chase position behind the leader so that I could watch him start up. Lead never got a good paint on the target and drove straight under the T-33. At about 15 miles out, I noted that while falling back from the lead my airspeed had diminished to 350 knots. I plugged in both ABs and commented to lead that I was going to use ABs in the snap-up.

At 10 miles, airspeed of 380 plus and about 9000 pounds fuel remaining, I asked the RO if he wanted me to start up. He said, "Roger—10 nautical miles." Just as I started a gentle pull-up, he locked on and I centered the dot in azimuth and elevation. At this time I coupled the auto pilot and informed the RO I had coupled. The attack turned out to be more of a climbing attack than a snap-up. With the dot in the center the pitch attitude was about 20 to 25 degrees. The RO said we should fire at about 5 miles and was counting off range. Just after the RO said, "5¼ miles", with the dot centered and the coupler engaged, the nose of the aircraft came swiftly up about 30 to 40 degrees and felt like it had begun a snap roll. Immediately I started a pitchup recovery, pushed the stick full forward and grabbed for the drag chute handle. It took about two tries to get the chute, as I was being thrown around the cockpit violently. I then grabbed the throttles and brought them out of AB. I could hear the RO saying, "Stick forward—stick full forward." I said, "Roger, and I have the drag chute."

About this time the gyrations stopped and the nose of the aircraft was about 20 degrees below the horizon. The aircraft started to swing gently from side to side and I pushed the mike button and transmitted, "I've pitched up and in recovery". I heard someone say, "Mark the spot on the scope, mark the spot on the scope." I checked the altimeter and airspeed. The airspeed was going through 230 knots and building, and the altimeter was descending through 24,000 feet. I told the RO to watch the altimeter.

At this time the aircraft started to react violently, and I was thrown against the left side of the cockpit. Prior to these last violent maneuvers, I was holding forward stick and waiting for an indication of negative G. I felt none. After the second uncontrolled gyrations started, I checked the altimeter and saw it going rapidly through 20,000 feet. I told the RO to eject twice, and then started to go for my left handgrip while looking at the altimeter. It was going down through 17,500 feet as I pulled the handgrip and squeezed the trigger. I felt the canopy go sometime before I got my handgrip to the top.

When the seat fired I was lying against the left side of the aircraft but evidently I cleared the aircraft cleanly. I tumbled once or twice, noted that my seat was gone, and then assumed a position for opening shock. I saw the parachute come by my right side and then felt the opening shock. It was a fairly sharp shock. I checked the canopy — found it to be okay, and then I noted that I had lost my left glove and right boot. At this time I started to prepare for the landing. The first thing I did was deploy the survival kit and raft. This seemed to set up quite a bit of oscillation. At times the raft would be about 45 degrees out to the side. I wrapped my left leg around the lanyard and was able to slow the oscillation a little. After this, I pulled my LPU cords and fastened the LPU together in front, as I was in the weather and didn't know whether I was over a lake or not. I had some difficulty doing this, as my left hand was quite cold and my fingers were getting numb. I then placed my left arm through the left riser and grabbed the right riser with my left hand. I then unfastened the safety release on my left riser and continued to the ground in this manner. At about 2000 feet I broke out of the overcast and spotted the RO for the second time. I had seen his chute briefly just after mine had opened. I watched where he would land and then started to concentrate on my landing.

I struck the ground, drifting backward with about a 10 knot wind in my face. I attempted to keep my right foot above the left one as I didn't have a boot on that side. I hit on my left foot and rolled backward on my left calf and left buttock. I had my right index finger through the quick cable release as I touched down and immediately pulled the cable. The chute dumped. I was not dragged, but rolled over to see the RO land. He was still about 50 to 100 feet in the air. His landing looked fine, so I got out of my harness, took two heavy socks and two mittens from the survival kit, placed them on my bare extremities, and started for the RO.

At no time during the entire pitchup was the horn heard by the pilot, nor was a stick limiter or pusher felt.

As usual with a major bash of this type, the wheels got together to decide what happened and why. They visited the crash scene to inspect the crater and bits and pieces of metal scattered over the area. The aircraft was completely destroyed upon impact with the ground from a near vertical dive. Although all major flight components and control surfaces were accounted for, the impact damage precluded further cause factor analysis of the normal and automatic flight control components. Without the actual hardware to inspect, the board had to rely entirely on the statements of the two crew-members. The board was unable to determine the actual cause of this accident. With the limited amount of information available to them, we cannot argue with their findings.

As we sit here at the puzzle palace reading the accident report and discussing possibilities, we come up with some rather interesting points that may be worth bringing to your attention. Keep in mind that we have been reading and talking about this for two weeks where the pilot had to react in two seconds. To aid us in our Monday afternoon quarterbacking, we have read many articles, booklets, done an enormous amount of research and strapped the Wonder to our butts many times.

First, what caused the aircraft to increase the pitch angle 30 to 40 degrees just prior to fire time. If a malfunction had occurred in the coupler, autopilot, trim, or any of the pitch control devices, it would have been reflected by control stick movement. A pitch increase of that magnitude would have been noticed by the pilot with his hand on the control stick. The only possibility here is for the control linkage to fail. In our opinion this is a remote possibility because it requires a double malfunction.

Another possible cause was inadvertent flap extension. The pilot states that he had to ask the leader for a little power on takeoff. If he forgot to retract the flaps they would have retracted automatically at 290 knots. Later during the snap-up, when the airspeed decreased to the 290 knot region, the flaps would automatically extend. This would not have increased the pitch angle, but it would give the pilot a sensation of pitch increase, especially when you add the element of surprise. There would be no aft stick movement here. If anything the stick would move forward to compensate for the balloon tendency and the increase in lift.

Could it be possible for a pilot with over 1100 hours in this aircraft to forget the flaps? It is possible and has happened to other pilots with equal amounts of experience, especially during formation takeoffs.

The squadron ran two test profiles simulating the attack pattern, airspeeds and pitch angle. On the first profile, both burners were lit prior to the rotation for snap-up. The airspeed at the fire time was 340 knots, which is above the airspeed switch limits. If these speeds were true, then the flap theory is all wet. The second profile was flown and the afterburners were lit. at the time of pull-up. The airspeed at fire time was 265 knots, which is well below the airspeed switch limit. If the speed was somewhere between these two profiles, then the flap theory could have some merit.

Something caused this aircraft to perform some type of unusual maneuver. Was it pitchup? The crew experienced no aircraft buffet, wing drop, pusher, CSL, or warning horn. The pilot did not check his airspeed to see if it was below 150 knots. Because of the absence of all these indications, there is some room for doubts that he had actually entered pitchup.

When this unusual maneuver occurred, regardless of what may have caused it, the pilot executed the pitchup recovery procedure. When he shoved the control stick full forward with the aircraft still flying, he may have stalled the aircraft from negative angle of attack and snap rolled. This snap roll could have caused the crewmembers to be thrown against the left canopy rail.

If the above were true, then the drag chute was deployed above the maximum drag chute speed; therefore, the chute canopy ripped away. The afterburners were not terminated until the drag chute had been deployed. If this had been a full scale pitchup the engines would be in a stalled condition and the afterburners would be torching. This would have burned the chute away. This probably was not a factor in this bash, but it is worth pointing out.

The nose of the aircraft was now pointed below the horizon and the speed was going through 230 knots. The pilot, still holding the control stick full forward, was waiting for the negative "Gs" called for in the procedure. This could have caused the aircraft to stall the second time from negative angle of attack. Because of this, the board recommended that the pitchup recovery procedure should be reviewed and possibly rewritten or explained in greater detail. We agree.

We have talked to pilots who have encountered the wahoo and recovered. Some of them were able to determine when they were in a negative "G" condition and others said they were never able to tell the difference between negative "G" or just being thrown around the cockpit.

Initially on pitchup entry the control stick should be placed full forward. This will allow you to take advantage of any control still available from the stabilizer. After the drag chute has been deployed and the nose is below the horizon, the control stick could be turned loose. In full scale pitchup the stick will be full forward. There is very little pressure in the ram air bellows to hold the balance assembly erect. This allows the balance assembly to tilt forward and place control stick forward, i.e., parked on the ramp. When the aircraft begins to fly, the ram air pressure in the bellows begins to increase, erecting the balance assembly, and returning the controls to the trimmed neutral position. With the artificial feel system working for you, it is not important to wait for that negative "G" condition. Keep in mind this is not a change to the good book's procedure, but just a little discussion on this problem area. Continue to use the procedure in the Dash one until it is officially changed.

Another area that needs to be discussed is the recognition of pitchup and the recovery by the numbers. It seems that we are beginning to lose several airplanes again due to this undesirable maneuver or other maneuvers interpreted as pitchup.

The Wonder pilots have been drilled so intensely on pitchup that any unusual move by the airplane is too often interpreted as a wahoo. We are so spring-loaded and have the recovery procedure so well memorized that when we decide we are in a pitchup, one, two, three, four — the recovery procedure by the numbers. Actually this is good if our first decision is correct.

Pitchup is a restricted maneuver and therefore, we do not practice it. The only way we can recognize it is by correlating what we have read and heard with the way the aircraft is reacting.

There are some basic reactions the aircraft will perform before it enters a full scale pitchup. Disregarding the warning devices, below .9 indicated mach the airframe will buffet and then one wing will drop. The length and intensity of these warnings depend on the aircraft speed and the rate of rotation. If we are hell bent to pull beyond this natural warning, then the nose will begin to come up on its own. The natural reaction at this point is to move the control stick forward to push the nose down. If the nose of the aircraft continues upward with the control stick full forward, then the aircraft will enter full scale pitchup. Regardless of entry speed, after a full scale wahoo the airspeed will be 150 knots or lower. If the airspeed is much higher than this, the aircraft is still flying and there is no need for the recovery procedure at this time.

The bird will not enter pitchup below .9 indicated mach without going through these natural warnings. If everything doesn't add up take two seconds and analyze the situation before executing the recovery procedures.

This bash will probably never be explained, but we have tried to take some interesting theories and discuss them with you. We can scratch one Wonder from our fleet and we would like to gain some knowledge from this loss. ★

T IS FOR TROUBLE

Putting the horizontal stabilizer on top of the tail does have some design/weight advantages. However, as all F-101 pilots know, it also presents some aerodynamic disadvantages.

WE were scheduled to fly a test hop in the F-101 after it had completed a periodic inspection. Aircraft forms were in order and the walk around inspection revealed no discrepancies. Cockpit checks were accomplished and the engines started. Both engines were slow to accelerate to idle. The left generator did not come on the line and I made several tries to get it reset before it finally came on the line. Then I turned the right generator off to check the voltage on the left generator. Voltage checked out so I reset the right generator. All ground checks were performed with the PCS and a autopilot checking out properly.

An afterburner takeoff and climb to 15,000 was made. Wing tanks were turned on and a military climb was continued to 35,000. The wing tanks fed out just prior to level off.

First check of the pitch control system was made on the horn and pusher. This check was accomplished at .9 mach with 9500 pounds fuel. The check was satisfactory but we thought the horn might have been induced by rate, so we reaccomplished the same check. The system checked out perfect again. We now had 8000 pounds fuel remaining. Our position at this time was 60 NM out at sea. (We had been airborne about ten minutes). We turned to a westerly heading to accomplish the autopilot CSL check. The aircraft was straight and level at 35,000 feet and just below .9 mach. I then tried to engage the autopilot. Several attempts were made, all unsuccessful.

Because I could not get the autopilot to engage, I turned the MCSL on and tried to engage the autopilot again. About this time (1½-2 seconds after engaging the MCSL) the bird began to nose over. I was thrown against the canopy. The RO inadvertently raised his handgrips about half way before he turned them loose. He grabbed the bottom of the instrument panel and pushed the seat handles down with the other hand.

After the aircraft nosed over I depressed the paddle switch in an attempt to get the MCSL off the line. The MCSL off light came on but the forward stick force was not released. I pulled both throttles to idle and opened the speed brakes. I tried to pull the AFCS circuit breaker when the aircraft entered a negative pitch-up. I didn't get to the circuit breaker because of the negative Gs and the position of the throttles.

I saw the airspeed dropping through 200 knots so I deployed the drag chute. The bird felt as though it was about to recover at this time, but then entered into a snap roll and pitched-up again. I saw the altimeter passing through 20,000 feet and made the decision to bail out. I told the RO to bail out but received no response. I called him again and tried to position myself in the seat for ejection. I accidentally jettisoned the canopy when I pulled myself down into the seat. I held on to the seat to maintain my position and tried to contact the RO again. I still received no response so I bailed out.

When the canopy left the aircraft the RO lost his helmet and mask immediately because he did not have his chin strap fastened and his head was almost out in the slipstream. He could not reach the seat handles until he pulled himself down by pulling on the instrument panel. He was able to get hold of the right armrest and squeezed the trigger. He was against the left side of the cockpit and about three or four inches off the seat with his feet straight out in front of him when he ejected. (Actually the pilot ejected before the RO.)

I tumbled violently in the air, so I extended my arms and legs. This did not stop the rotation. I had the impression that I was very close to water, so I pulled the rip cord to open my parachute. I looked around and saw the aircraft below me and to my left. It appeared to hit the water in a sharp left turn. I looked to my right and saw the RO in his parachute slightly below me. I again looked to my left to see the impact point of the aircraft, but the smoke was drifting away.

I waited until I was close to the water before I deployed my life raft and survival kit. I released the parachute canopy as I entered the water and climbed into my life raft.

The RO tumbled after ejection but he deployed the life raft as soon as he was squared away and this helped dampen the oscillation.

All personal equipment and survival gear worked as advertised even the RO losing his helmet. Neither crewmember was hurt except for minor abrasions on the body and legs from the parachute harness. Both boarded their rafts with little difficulty, however neither one remembered to stow their sharp objects and discard their personal leads until they were in the raft. This caused the pilot to puncture a small hole in his dinghy. He ended up holding his finger over the hole until rescued some four hours later.

This flight had begun with a VFR local area clearance with flight following being filed with the Hot Room. After getting airborne the first of the pilot's problems cropped up. He was unable to make contact with the GCI site. This inability to make contact would not abort the mission, so the pilot pressed on with the test hop. When the control problems were encountered later in the flight, no transmissions were made over the UHF. The initial failure to set up communications and the lack of a transmission before bailout resulted in a delay in beginning the search for the crew. In fact no one knew anything had happened until they were overdue on return to the home air patch.

After the search was initiated, a pair of F-101s were scrambled and vectored to the test area. The Voodoos were flying about four miles in trail. The downed crew saw the lead aircraft and set off a smoke flare. The smoke was seen by the crew of the second aircraft. Because of so much yakking on guard channel neither aircraft was able to home on the URC-11s. The Voodoos vectored an HU-16 to the scene and the rescue aircraft dropped smoke floats. This smoke was spotted by a submarine in the vicinity and they made the pick-up. Four hours had elapsed since the crewmembers had climbed in their dinghies. Later they were transferred to a helicopter and flown to home base.

The aircraft was lost at sea and was not recovered. This made the investigation very difficult and about all that could be done was to speculate. After taking a close look at all the available evidence the board came up with a malfunction of the pitch control system or the MCSL as the primary cause.

While discussing the F-101 pitch control problems here at the head shed, we consulted our maintenance people and the safety analysis branch. Here are some of our findings:

The Voodoo has a history of nose down stick forces beginning with its introduction into the inventory. Because of the longitudinal stability problem encountered in the test phase, a pitch inhibitor system and an autopilot limiter were placed in the aircraft. (This instability problem is common to all "T" tail birds from the F-104 to the C-141 and the English BAC-111. This wild phenomenon is not the sole possession of the Voodoo, although most of the publicity has been pointed its way). Later, MCSL was installed to give the pilot the option of using CSL limiting without basic autopilot being engaged. These electronic devices were designed to prevent the pilot or autopilot from flying into a wahoo.

All of us who strap the Voodoo to our rears for a living have heard about pitchup more often than we care to remember. Our introduction to the wahoo came early in our transition phase and continues right down to today. However, not too much discussion has been given to the opposite of pitchup - push down. As we all know the bird is full of gimmicks to prevent us from pitching-up. All of them make the nose go down. So it then becomes obvious, since the bird is gimmicked to go down when we approach instability, it can go down inadvertently because of a malfunction.

There are several components that can cause these nose down stick forces. Here is a discussion about some of the problem areas:

Stabilator Power Cylinder

The stabilator power cylinder cannot cause a nose down stick force unless:

- The manual input valve has a stray input.
- This valve becomes binding due to hydraulic contamination or other sources.
- The control valves separated or stick. These abnormal linkage problems would appear in manual operation, both before and after the incident and are therefore unlikely. In addition, the basic mechanization of the longitudinal control system, feel system, and power cylinder of the F-101 is the same as used by MAC in the F-3 and F-4 airplanes which do not have a history of nose down stick forces. Although many of us have had problems with the stabilator power cylinder, it is not a major cause of nose down stick forces.

Artificial Feel and Trim Assembly

The feel system consists of a bellows unit, viscous damper and balance assembly (bob weight) with associated trim motor. The bob weight is actually the trim motor and assembly that is pivoted off center to give five pounds of stick force per "G". There have been problems with ruptured or leaking diaphrams in the bellows unit, but this cannot cause a hard over stick force. The viscous damper has caused us more headaches than any other unit in the artificial feel system. These problems have resulted in sloppy control, but not the hard overs. The feel system can be eliminated as a primary cause factor in instances of high nose down stick forces, even if the trim actuator runs full nose down at maximum airspeed, the force reflected to the stick is only 26 pounds. The stabilator rate resulting from a hard over trim actuator is 2.5 to 3.3 degrees per second.

Pitch Control System (PCS)

In the absence of adequate aerodynamic warning at supersonic speeds, a pitch control system was installed in the airplane. This provides an automatic warning of the approaching pitchup and initiates the necessary action to return the airplane to a noncritical angle of attack. The pitch control system consists of both electrical and hydraulic components.

PCS is triggered by signals which depend upon the airplane mach, local angle of attack, and the stabilator rate. Separate sensing units and black boxes are provided for the horn and pusher system. When the stabilator is moving the pitch control system will trigger below the normal boundary to give us plenty of warning. This early warning feature is present for both the horn and pusher. Since many of us move the stick very fast during the landing approach, the pusher is inoperative when either the flaps or main landing gear are extended. In this configuration the horn operates on angle of attack only to prevent us from accidentally getting the horn on rate. Further, the horn is completely cut off when nose gear strut is compressed.

The horn is strictly a passive warning device which has no effect over aircraft control. It is impossible for it to cause a nose down stick force. If the horn should malfunction, the pilot can turn the system off and get rid of the irritating noise.

The pitch boundary indicator (PBI) is an instrument that gives the pilot a visual presentation of the local horn angle of attack vane and the computed horn curve. If the horn switch is in the "off" position, the PBI is not operating. Like the horn, this system cannot affect aircraft control; therefore, it is not associated with nose down stick forces.

The pusher, when energized, hydraulically drives the control stick forward with 25-30 pounds of force, over and above the stick force produced by the feel system and bob weight. The pusher should disengage when the angle of attack falls below the pusher boundary and the stabilator has moved at least 2.5 degrees toward recovery. However, if the angle of attack, due to overshoot, is not below the boundary after the 2.5 degree movement, the pusher will not disengage. It will continue to push forward until the stabilator moves 2 degrees in the airplane nose down direction with speed brakes closed and 3.5 degrees nose down with the speed brakes extended. We can disengage it by pushing the control stick forward faster than the pusher through the 2.5 degree stabilator increment. If the angle of attack is reduced below the boundary, the pusher will disengage. If we disengage it by this method, a time delay will prevent the pusher from engaging on stabilator rate for 0.5 seconds.

The pusher can be disengaged by depressing the emergency paddle switch on the control stick. This disengage circuit is cold until the paddle switch is depressed, then 28VDC is routed to the pusher bypass valve solenoid. This valve ports the pusher cylinder to the return line and simultaneously removes hydraulic pressure from the Number 1 and 2 pusher control valves. If this electrical circuit breaks contact, there is no warning to us until we get into a bind and try to disengage the pusher with the paddle switch. Then we find out too late that is does not work. This has caused a lot of pucker time that we know about and could have caused some of our undetermined bashes.

In a complex system such as the pusher system, a multitude of failures could cause inadvertent pusher operation. This system contains many black boxes and electronic gremlins, but most of these component failures can be found by ground testing. Many of the other failures such as intermittent shorts, sticky rate potentiometers, and faulty wheel well test switches, may be tough to find during ground testing. If an inadvertent pusher engagement should occur, ice in the by-pass valves might cause us to have an extremely high overpower force and the paddle switch will not remove this force. This would be almost impossible to duplicate on a ground check. The pusher has probably caused more nose down stick forces than any other single system.

AFCS

The Voodoo has one of the most complicated autopilots in operation today. This is necessary because of all the coupler modes and the airframe limitation requiring a mechanism that will not allow the autopilot (or us jocks flying by control stick steering) to fly the airplane into the unstable region. This mechanism is called command signal limiter (CSL).

The CSL is composed of many electrical circuits and a hydraulic servo. When the autopilot flies the aircraft to the CSL boundary, it takes 60 pounds of stick force for us to overpower it with back stick pressure, and 30 pounds to overpower it with forward stick pressure. The CSL will limit the autopilot to four positive "G"s and 0.5 negative "G"s. If the system malfunctions and allows the aircraft to reach 4.5 positive or 1.5 negative "G"s, it will disengage the autopilot. The autopilot has many protective circuits that will not allow the AFCS to be engaged if it has erroneous signals or an internal malfunction.

With the AFCS circuit breaker in, the autopilot is supplied with electrical power regardless of the position of the AFCS switch. Pulling the AFCS circuit breaker removes electrical power from the autopilot. Depressing the paddle switch causes the AFCS switch to move from the normal to the standby position, but does not remove all electrical power from the autopilot. There have been recommendations to place an autopilot master switch in the circuit so that all electrical power can be removed from the AFCS without pulling the circuit breaker. We may see this soon.

MCSL

The manual command signal limiter was installed in the aircraft to give us the option of using the command signal limiter without the autopilot being engaged; however, the autopilot must have electrical power and utility hydraulic pressure. At this same time, four changes were made in the basic autopilot:

- The CSL curve was redesigned to allow more maneuvering at low airspeeds and take the overlap out in transonic region.
- The abort disengaged circuit was installed. This will disengage the attack coupler when a radar abort signal is received during the attack.
- The bank angles were changed during AGCI mode. This made it compatible with the tactics, i.e., subsonic is 30 degree bank and supersonic is 45 degree bank.
- Redesigned the rudder engage circuit to eliminate the rudder kick at autopilot disengagement.

When MCSL switch and autopilot are both on, the MCSL is a backup and is available in case the AFCS is inadvertently disengaged. The MCSL switch will not drop off unless we physically turn the switch off or remove electrical power by pulling the AFCS circuit breaker or turn the generators off. The MCSL is cut out when the landing gear is extended unless we are against its boundary at the time. In this case it will cut out as soon as the aircraft leaves the boundary.

MCSL protection is provided in both cockpits of F model aircraft while autopilot and CSL are available only in the front cockpit.

The MCSL limits in positive angle of attack only and with the same overpower force; however it uses the same negative "G" disengaging force (—1.5G). It does not have the 4 "G" positive limit nor does it have the 4.5G positive disengage feature.

It does not have some of the critical protective circuits like the AFCS. Therefore it is possible to engage the MCSL when an erroneous signal is present. This is probably what happened to the pilot in our introduction. Because of this, Safety Supplement T.O. 1F-101B-42 was published. In essence it says to check the AFCS prior to engaging the MCSL. If the autopilot will not engage, DO NOT ENGAGE MCSL.

The paddle switch, when depressed, should move electrical power and hydraulic pressure in the system. Here again we can have electrical problems which can give us some headaches.

As long as we have these complex protective systems we cannot completely eliminate the nose down stick forces, but we should try to improve the system and our procedures to make the system as safe as possible. These systems are over ten years old in electronic design and they are hard to maintain. In a recent four month period there were over 9000 true maintenance actions on these systems in ADC. If we compute this in dollars and cents, this system costs us several million dollars a year to maintain.

There are two ways we can solve this problem without redesigning the complete airframe. One way would be to install a completely new system, but this takes time. The other way is to improve our present system. Some of these improvements could be:

- Positive disengage feature through the paddle switch.
- Relocate AFCS circuit breaker or install a master switch.
- Provide CSL/MCSL disengagement when CADC AC power is lost.
- Reduce the CSL/MCSL 60 pounds stick overpower force.
- Improve the reliability of hydraulic shutoff valve.
- Reduce the negative "G" disengage valve.

As long as we put the horizontal stabilator on top of the vertical stabilizer (T-tail), we are going to have stability problems. To counter these problems we are forced to install controls which create headaches of their own.

In order to fly these aircraft we have to live with these problems. The best way to minimize them is through aircrew understanding and good maintenance practices. ★

BEYOND THE FEATHERED EDGE

THE FREQUENCY of the feared Voodoo maneuver, pitch-up, has been on the decline the past few years. But just when you think a problem area has been whipped, it shows its ugly head again. Here is a brief of our latest wahoo.

After spending the night at the dispersal base, two crews were scheduled to intercept a high-flying U-2 in the local area and then recover at home station. Both aircraft had a single drop tank installed on the right hand side and the second bird had an MSR on the door.

They were briefed for front snap-up attacks against the 60,000 foot target. The drop tanks would limit their speed to 1.3 mach. Even though tactics calls for a lesser speed, they were briefed to attain as near the 1.3 mach as possible. The snap-up would be initiated from 45,000 feet.

The preflight, start, and takeoff were normal. When they were passed from FAA to the SAGE controller, they were informed that data link was inoperative and the mission would be continued by voice. Both aircraft leveled at 33,000 feet at cruise speed with the second bird about 50 miles in trail. After external fuel was transferred, CSL/MCSL limiter checks were performed satisfactorily.

At a range of about 110 miles from the target, the fighters were commanded to accelerate to combat speed and climb to 45,000 feet. The first fighter was unable to complete the pass because the radar would not maintain lock-on. The second fighter got a radar contact at 35 miles on what appeared to be a beautiful frontal attack. With speed set near 1.3 mach at 45,000 feet, they began a manual snap-up at 17 miles range. As the pilot was pulling up, the radar observer obtained a lock-on at approximately 16 miles. The radar momentarily broke lock and relocked automatically.

At about this time during the intercept, FAA advised the controller to turn the target to provide separation with another high-flying aircraft. The controller advised the U-2 to turn twenty degrees to the left.

After the pilot manually centered the steering dot, he engaged the autopilot coupler. The coupler maintained the dot within 1/16 inch of the steering circle until a range of seven miles. At this time the armament door rotated and the steering dot began a rapid movement up and to the right with the coupler going after the dot. As the coupler banked the aircraft to the right, the pilot noticed the airspeed passing through 220 knots with a 25 degree pitch attitude.

The pilot decided to discontinue the intercept. He depressed the emergency paddle switch to disengage the coupler and continued to roll the aircraft to the right. As he reached about 120 degrees of roll, the bird snap-rolled back to the left and began compressor stalling. After the pilot realized that the aircraft was in pitch-up, he came out of afterburner, deployed the chute, and pushed the control stick forward. The aircraft snapped a few more times and entered what appeared to be a steady state spin.

The aircraft continued in a left spiral and did not respond to any recovery action by the pilot. As they passed 30,000 feet, the pilot noticed the EGT above 900 degrees Centigrade and retarded the throttle to idle position.

At 17,000 feet, still out of control, the pilot gave the order to eject. The R.O. blew the canopy and ejected with the pilot not far behind him. Both egress systems worked perfectly.

As the R.O. was descending, he saw that the drag chute falling at about the same rate of descent as himself. He also saw the pilot in his chute and the aircraft crash site below him.

The bird impacted the ground from a near vertical dive at high speed. It was almost completely destroyed. About the only things of any value in the wreckage were an EGT gauge, which showed 970 degrees Centigrade, and the tail section. Inspection of this section revealed that the lower jaw of the drag chute latching assembly was broken, allowing the drag chute to separate from the aircraft.

Like most of our accidents this year, this bash is extremely complicated. The biggest question in everyone's mind is, "Why did this experienced crew pitch up?" Most people have their own answer, but we believe it is a combination of several factors.

One of these factors was target altitude. The crew was briefed and had planned the mission for a target of 60,000 feet. Investigation after the accident shows that the target was several thousand feet higher than they thought. It was barely within the maximum engagement altitude for a tank configured Voodoo.

In discussing some of the other factors, let's talk about the three variables explained in the movie on pitch-up: airspeed, gross weight, and "G" loading; and apply them to this incident.

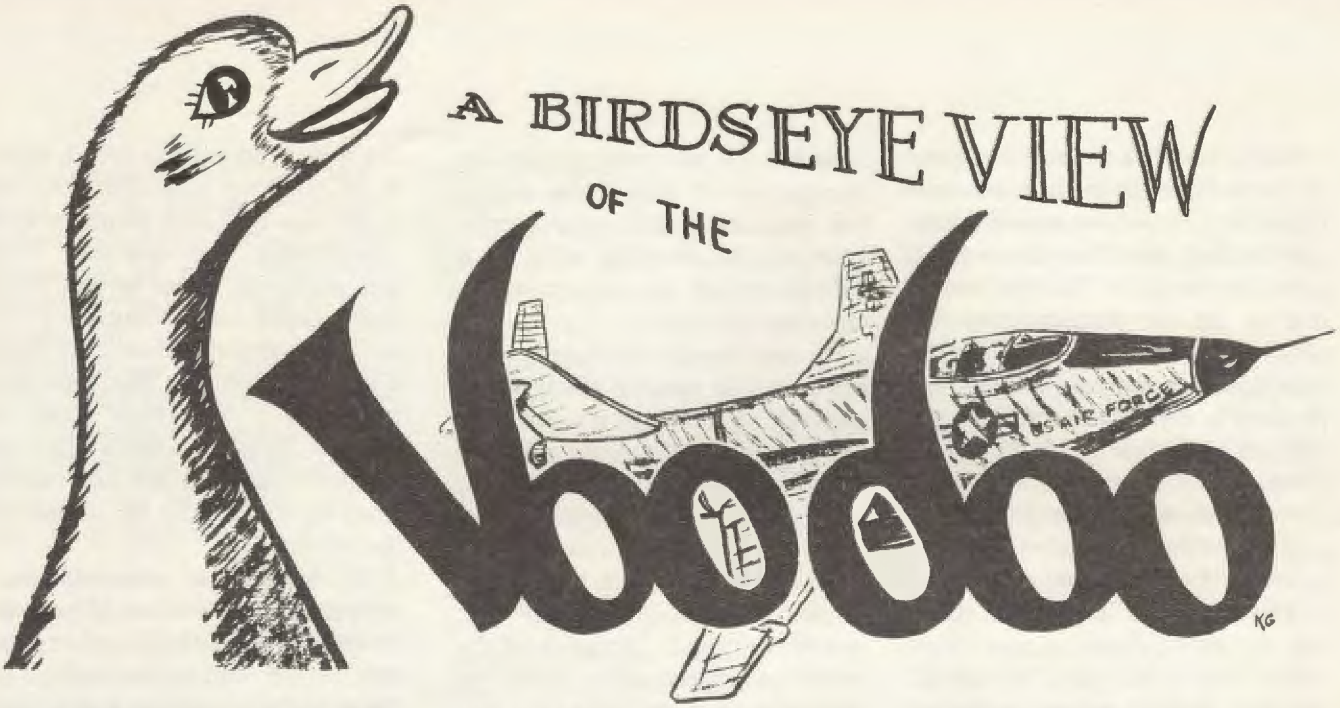
A tank configured aircraft is limited to 1.3 mach which causes us to start our 20,000 foot snap-up attack below a desirable speed. This attack is possible if everything else is perfect, but the airplane is placed on the feather-edge of the performance envelope. If a deviation should occur, the attack would probably have to be abandoned before firing time or wahoo. In this case, a deviation did occur at the final stage of attack. The dot movement could have been caused by a radar malfunction, but was most probably caused by the turning target.

The 230 knot minimum airspeed was directed to prevent aircrews from overextending themselves during a snap-up attack. Normally, this airspeed has a large safety margin built in, but this depends on the amount of wing loading encountered. The bird can be flown at 150 knots or lower, but there is very little left for maneuvering. The fact that the recovery was initiated ten knots below the recommended speed should not have caused the problem without additional factors.

Aircraft gross weight and "G" loading have the same effect. The wings produce a certain amount of lift at a given indicated airspeed. The heavier the gross weight, the less lift is available for "G" forces. Tanks themselves do not add much weight to the aircraft, but the additional fuel adds several thousand pounds. This allows the pilot to initiate the first attack at a heavier gross weight than with a clean airplane. This heavier gross weight and low airspeed during the escape maneuver limits the maneuvering potential even more.

At this critical point, the pilot had to initiate the escape maneuver. Even though he unloaded the aircraft, one wing has to have some loading in order to roll. The amount of loading placed on that wing depends on the rate of roll—roll coupling. If too much loading is placed on one wing, it will stall and cause the airplane to snap-roll in the opposite direction. Operating at such close tolerances with other interferences such as door rotation and airspeed bleed-off, 55,000 feet at 25 degrees pitch attitude, it probably didn't take too much in the way of wing loading to cause it to snap roll.

A BIRDSEYE VIEW OF THE Voodoo



The F-101B has been in the ADC inventory for about ten years now. And to say that during this time it has developed a praiseworthy reputation among all pilots and RIO's who have flown it would probably be slightly in error. It isn't too difficult to locate a Voodoo driver who will relate all the details concerning the dark spells cast by the beast. Matter of fact, you can even find jocks who have never flown it speak with authority on the evil ways in which it treats its handlers. But then all superstitions breed wild, exaggerated rumors and instill fear in the hearts of the fearless. It's no wonder that old and young heads alike squirm in their boots at the thought of an assignment to a "One-Oh-Wonder" outfit. And that's no wild rumor. It's been the cause for many to start off on the wrong foot before entering the cockpit for the first time.

The widely publicized characteristic known as "pitch-up" is at the root of all supposed evil in the Voodoo. There's no denying that it will rattle your cage if you get into it. But let's get serious and put things in the proper perspective. A certain delta series is also at the mercy of the gods once the 18° angle of attack is exceeded. The subsequent ride is no less hairy; the outcome no less in doubt. However, it's cautiously referred to as "post stall gyration." No matter what label you put on it, the F-101B is not the only victim of some form of aerodynamic witchcraft. So, the pitch-up phenomenon is not in itself the cause for alarm.

The reason that most people get excited about pitch-up in the 101 is the relative ease with which it can be entered. A long fuselage, with skinny wings halfway down the middle, and a high stabilator at one end produce good see-saw action.

A tendency to porpoise is not unusual for pilots during checkout, or later on. Control is sensitive to the touch, and the yank and bank specialist can't bury the stick in his lap or slam aileron without getting into trouble. This doesn't mean that the Voodoo won't perform with the best of them. Check the energy-maneuverability charts for the lower altitudes and compare the -101B against, for instance, the F-104C. And it was there all the time! Now up where the air is rare, everybody has problems, and top speed capability makes the difference.

You don't feel performance in the -101. The cockpit and fuselage are not the wrap around variety. The sensation is more like being strapped into a locomotive than an airplane. But don't be fooled. The -86D/L felt the same way and yet it could give the -86H a tough run for its money. To compensate for lack of feel in the bones, a lot of Tiger Types try to swing the Voodoo around a corner in heavy buffet. It's a waste of time. Subsonic, riding the fringe edge of the buffet gives the best you are going to get in any maneuver. Supersonic, the "G" vs airspeed rule of thumb is generally the best and safest guideline. Ask any old head who knows what he is talking about. There's not enough additional performance left between these guidelines and loss of control to make the risk worthwhile. What is more important is how you use what you've got.

Since the F-101B has been in service, sixteen known and three probable aircraft have been lost due to pitch-up. Only eight recoveries have been reported. At first, the recovery rate doesn't look too good. But you have to consider that some of the losses occurred at low altitude, like in the traffic pattern, where the chances of success are slim. Some occurred in weather where again the odds are bad. Of the rest, statistics indicate that with high altitude pitch-up, the time margin between recovery and the steady state spin is narrower than at lower levels. Also entry into pitch-up through excessive negative "G" appears to lessen the time available for recovery even more. All this adds up to is that when pitch-up is recognized, no time should be wasted in applying the correct recovery technique. It will work as advertized, if given the chance.

Flight tests have proven that the 101 is controllable down to approximately 90 knots. An experienced, delicate touch is required to keep the aircraft unloaded and ballistic in this extreme flight condition. But there's no reason to get into this tight spot, even if you should suddenly find the airspeed approaching 200 knots and going down fast with a nose-up attitude of 30-35 degrees. Fear and superstition may urge immediate drag chute deployment for a starter. Or a little voice may call for a rapid half roll and pull through. In either case, haste will put you behind the eight ball. If, instead, a slow and gentle half roll is executed together with a gradual unloading of "G" to a point just short of separating man from seat, the airspeed should bottom out between 130-140 knots. Keep the faith and before the nose passes through the horizon, the bird will be accelerating, especially with afterburners in operation. During the recovery what you don't need is airframe buffet and, if it's encountered, it means that the half roll is too rapid or not enough "G" has been unloaded. Control movement must be slow and easy. Although the maneuver seems to take hours, it works and beats the pitch-up ride for comfort every time.

With the Voodoo, more than any other aircraft, it's absolutely necessary to know the limits of the flight envelope. As some pilots have found out the hard way, there are certain things you just can't get away with. Also, there are a lot of things which can be done easily and safely but only after receiving sound instruction on the proper techniques. Anyone who impatiently tries to experiment with the 101 is headed for trouble. It's healthy for a pilot to want to know exactly what his airplane can or cannot do. It eliminates unknown quantities which can create confusion and instigate the wrong action at the wrong time. This makes good pilots and saves airplanes. The smart approach is to learn the score from an experienced pilot, preferably by demonstration. Listening to wives' tales just won't hack it.

In the subsonic region, the 101 has good, solid stall approach warnings. Even supersonic, they can be recognized as the nose begins to get light. Accident files indicate that overcontrolling or abrupt control pressures have resulted in pitch-up in those cases where malfunctions or impossible maneuvers were not factors. Because of built-in sensitivity, it's easy to stick rate into a full stall and bypass the normal span of warning characteristics. The slower the speed the less muscle is necessary. Equally disastrous is the inclination to "pop the stick forward" during anxious moments. The bird will pitch just as easily from negative forces. It's bad practice to pop the stick in any direction for any reason. Additionally, combine some fast aileron with moderate back stick pressures and roll coupling will result in a beautiful unexpected stall. So you've got to watch your combinations as well.

For convenience and protection, artificial "black box" devices have been installed between the pilot and the control surfaces. Once they leave the loving care of experts at the factory and get into the field, there is one thing that can be said about them with certainty. They are generally reliable, not foolproof. Numerous manhours and flight tests are required to keep them in operation, and they still malfunction. This wouldn't be of too much concern except that these devices are capable of taking aircraft control away from the pilot. When this happens at a critical phase of flight, the result can easily be the loss of an aircraft. Four such cases are recorded. Any pilot who sits back with his arms folded during a coupled attack is out of his hard hat.

The same goes for any 101 driver who flies the airplane with complete dependence on the pitch control system. Among other things, it may not be there when it's needed most. If it activates when least expected, it gives the nervous system a pretty good jolt and has caused more than one pilot to apply too much corrective action too hastily. There's no substitute for knowing your aircraft and flying it accordingly. But, if warning devices are desirable, as they are in the F-101B, the question arises as to the prudence of installing a type which can take aircraft control away from the pilot through malfunction or otherwise. It would seem more reasonable to pursue a visual/aural system which would provide the pilot with sufficient advance warning to knock off whatever he's doing and fly right. The stray volt danger would be eliminated in a system of this kind. We know we've lost four aircraft through malfunctions and suspect a few others. It might be worthwhile to take a second look and re-evaluate the cost/effectiveness of updating, instead of replacing, old concepts. No sense in throwing good money after bad. ★

DOWN and out

Pitchup Review

1959—Two aircraft lost due to Pitchup.

- An evaluation mission was scheduled for the purpose of obtaining data on maximum available "G" loading above 50,000 feet. The maneuver called for a simulated snap-up and fire signal, a 180° roll, and then pulling a specified number of "Gs" or to the warning horn boundary — whichever came first. As the aircraft passed 46,000 feet, the nose was rotated to a higher pitch angle for the final portion of the maneuver. At the highest point above 50,000 feet, a 180° roll was performed and back pressure applied. Almost instantly the warning horn blew and the pusher activated. Back pressure was released and then re-applied slightly. The aircraft pitched up; no horn, no pusher. The drag chute streamed and the aircraft remained in what appeared to be an incipient spin condition until the crew ejected at 15,000 feet. Failure of the warning horn and pusher to reactivate at the second application of back pressure was undetermined. This permitted the overshoot into pitchup.

- The second pitchup in 1959 occurred at 30,000 feet. An attempt at recovery was made. However, the drag chute burned off, probably due to afterburner operation. Accident files on this and some other early F-101B accidents are not available because of disposition procedures which call for destruction after a specified period of time. The cause of this accident was determined to be pilot error.

1960—Four aircraft lost due to pitchup.

- Intending to perform an Immelmann, the pilot lit afterburner, picked up 450 knots, and started a pullup at 22,000 feet. At the 60° point, with about 380 knots and 2.8 "G", the pilot felt what he described as a sinking sensation. Whatever it was, he assumed it was pitchup and initiated recovery. He pushed the stick forward and got substantial negative "G". He then deployed the drag chute at about 300 knots and promptly lost it. As the aircraft nose approached the horizon, he noted 200 knots. Shortly afterwards, the aircraft snap-rolled to the right. Following this, the airspeed oscillated between 0-150 with the nose in a 40° dive. At 15,000 feet, both crewmembers ejected. The primary cause was pilot error.

- During an MB-1 firing mission, the pilot was cleared to launch the weapon under IFR conditions. He was at 30,000 feet and 380 knots and flying the aircraft manually. Dot excursion resulted in a slight hump course, so the pilot lit both afterburners. At about 20 seconds to go, he followed the dot up and to the right, then down and to the left. Just as he leveled the wings, the weapon fired. He started his turn to breakaway heading, but received no control response. The aircraft fell out of the cloud deck at 25,000 feet in a fully developed pitchup. Recovery procedures seemed to be working, but because the altitude was below 15,000, both crewmembers ejected successfully. The cause was undetermined, but most probably the pilot allowed his speed to become marginal so that when the weapon fired, either rocket blast or inadvertent pilot response caused pitchup.

- The pilot had been briefed to fly locally at 30,000 feet while the radar observer operated a television camera. After performing several maneuvers, the pilot engaged the autopilot and activated the altitude hold mode. He started a 40° bank and turned to look over his shoulder. He felt the aircraft nose up sharply, and quickly forced the stick full forward with both hands. However, pitchup had developed fully. Recovery attempts were made until the aircraft passed through 14,000 feet, at which point both crewmembers ejected safely. The cause was undetermined. However, the most probable cause was believed to be malfunction of the Command Signal Limited function of the automatic flight control system.

- Beyond the fact that a pitchup occurred, the aircraft was lost, and the cause undetermined, records are not available to indicate what occurred in this accident.

1961—One aircraft lost due to pitchup.

• During a day scramble, a gate climb to 35,000 feet was directed. Weather was reported 500 broken, 12,000 overcast with tops at 40,000 feet. After takeoff, a right climbing turn to departure heading was initiated. At 25,000 feet, slight back pressure on the stick was applied to correct mach from .92 to .85. Shortly afterwards, increasing negative "G" forces were felt by the crew. The pilot terminated afterburners and observed the airspeed dropping below 200 knots. He deployed the drag chute and the aircraft appeared to recover momentarily, then went into a tumbling tight maneuver with severe oscillations. The pilot could not regain control and the crew ejected at 15,000 feet. The pilot did not hear the horn or feel the pusher. The primary cause was listed as pilot factor in that he failed to maintain aircraft control during an instrument departure.

1962—Three aircraft lost due to pitchup.

• During snap-up training, the aircraft pitched up after 20 seconds to go. This accident is covered in detail by the article entitled, "Man, Machine, and the Final Outcome," which is contained in this special edition.

• Aircraft pitched up during escape maneuver. This accident is covered in detail by the article entitled, "2+2=4" which is contained in this special edition.

• The pilot was on his fifth transition mission with an instructor R/O. The flight was uneventful until the beginning of the 360° overhead traffic pattern. The pilot broke and pulled into the horn and heavy buffet. The R/O told him to ease off, which he did momentarily. The pilot again pulled into the horn and severe buffeting. Just before rollout on downwind, in an apparent attempt to regain lost altitude, the nose came up 30°-40° with an almost simultaneous roll to the left. At about 1,000 feet altitude, the aircraft pitched up and the R/O ejected. His chute just barely opened in time. The pilot did not eject.

1963—One aircraft lost due to pitchup.

• During a Tac Eval upgrading mission, the pilot initiated a rapid breakaway after fire signal which resulted in pitchup. It was a low level intercept and there was insufficient altitude remaining to effect recovery. The cause was pilot error.

1964—One aircraft lost due to pitchup.

• The pilot completed a normal intercept mission and made a practice instrument recovery. At the completion of a low approach, he contacted the tower and advised that he would remain in the local area for five minutes. Shortly thereafter, he was observed at about 1500 feet, high speed, performing a series of rolls which ended in pitchup from which the aircraft was not recovered. Both crewmembers were fatally injured because of a delayed decision to eject.

1965—Three aircraft lost due to pitchup.

• During a snap-up attack from 20,000 on a target at 35,000 feet, the pilot initiated a manual pullup in afterburner prior to lockon. As the pullup was begun, lockon was accomplished and the pilot centered the steering dot. He then engaged the attack-mode position of the autopilot. Just prior to fire time with the airspeed about 290 knots, the nose of the aircraft rose rapidly to about 40° and both crewmembers were thrown violently against the left side of the cockpit. The horn, pusher, and CSL did not activate. The pilot came out of afterburners and initiated pitchup recovery. At 24,000 feet with airspeed 230 knots and increasing, stick full forward and no negative "G" sensed, the aircraft again reacted violently. After the aircraft descended through 20,000 feet out of control, the crew ejected safely. The primary cause was determined to be materiel failure, system and/or source unknown.

• During a functional flight test, the pilot attempted to engage the autopilot without success. While straight and level, he turned on the MCSL switch and the light went out. A moment later the aircraft nosed over abruptly and it continued with an ever increasing nose down pitching movement with the control stick frozen in the full forward position. The pilot depressed the paddle switch, throttled to idle, opened speed brakes and tried to pull the AFCS circuit breaker. The aircraft then stalled from a negative "G" condition and entered severe gyrations. The pilot observed less than 200 knots and deployed the drag chute. The aircraft stabilized for a short period and airspeed was increasing above 280 knots when a violent nose down pitching moment again occurred. After descending through 20,000 feet, both crewmembers ejected successfully. The primary cause was determined to be malfunction of the pitch control features of the flight control system.

• On arrival at destination fix, the pilot was cleared to descend from 31,000 to 9,000 feet. Shortly after beginning his descent the pilot observed his airspeed decreasing at a moderate rate. He increased his descent attitude and increased power to near military to compensate for speed loss. The airspeed continued to decrease and the pilot thought he was in pitchup and applied more forward stick which resulted in negative "G" forces. The RIO struck his helmet against the top of the canopy. While in this negative "G" condition, the canopy left the aircraft. A wingman later stated that his airspeed was 465 knots and altitude 21,000 feet at this point. Shortly after the canopy left, the pilot ejected because he could not read his instruments. The RIO ejected when the canopy departed because he thought the pilot had ejected. The primary cause was considered aircrew error in that the pilot should have recognized airspeed indicator malfunction since there was no abnormal aircraft attitude and the aircraft was still flying in a 15° dive. The sequence of events tended to substantiate inadvertent canopy jettison by the RIO as he was subjected to startling negative "G."

1966—One aircraft lost due to pitchup.

- The mission was a front snap-up against a target above 60,000 feet. After lockon, small azimuth corrections were made manually and then the coupler was engaged. The steering dot was high and the coupler brought the dot to within 1/16 inch from the top of the steering circle at a range of 7 miles. The armament door rotated at this point and the steering dot moved rapidly up and to the right. The coupler chased the dot and the pilot noted 220 knots. He disconnected the coupler and began rolling to the right in the recovery maneuver. At this point the pusher engaged and the aircraft snap-rolled to the left. The pilot terminated afterburning, deployed the drag chute, and applied full forward stick. The aircraft entered a left spiral and did not respond to recovery procedures. The crew ejected at 17,000 feet. The primary cause was considered pilot factor in that he allowed the aircraft to get into a nose high, low speed situation from which he could not recover.

1967—No aircraft lost due to pitchup.

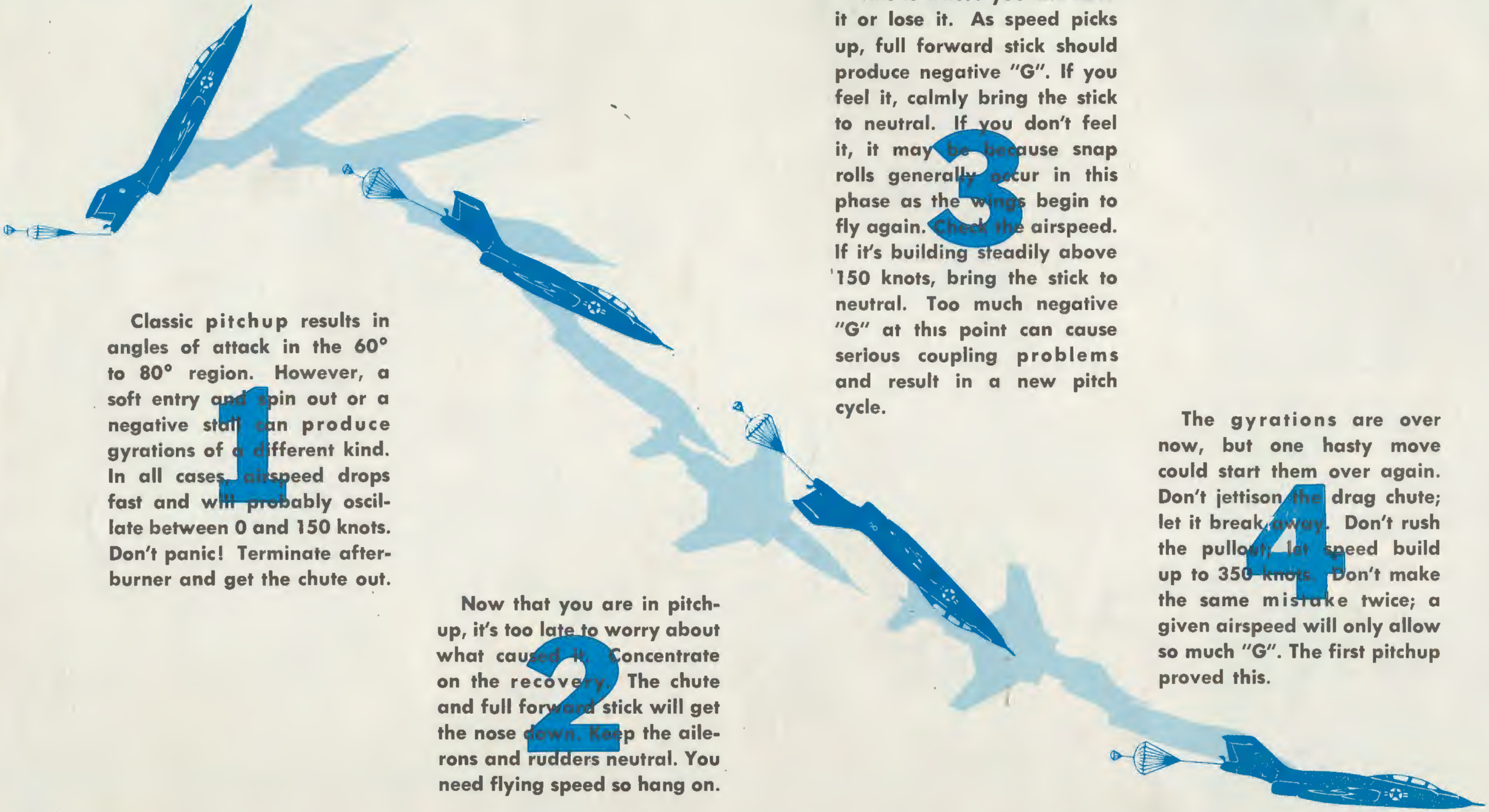
1968—Two aircraft lost due to pitchup.

- The pilot was making a supersonic attack against a target at 49,000 feet. It was a gentle fly-up resulting in 3-5 degrees of pitch attitude and very little airspeed bleed-off. No abnormalities were experienced until after fire time. As the pilot rolled smoothly through a 20° bank angle to the right for the escape maneuver, the control stick drove forward subjecting the aircraft to considerable negative "G" forces and apparently caused a snap roll to the right to an inverted attitude. The pilot was unable to regain aircraft control since he was pressed against the canopy by negative "G" forces. When the negative forces subsided, he observed the airspeed rapidly decreasing through 250 knots. He terminated afterburning and applied full forward stick. As the airspeed decreased through 200 knots, he deployed the drag chute. Negative "G" forces were not felt again. No warning lights were observed nor was the PCS warning horn heard. The nose fell through the horizon and the aircraft rolled rapidly several times. A flat spin was entered at about 38,000 feet. No recovery was evident at 15,000 feet, so the crew ejected safely. The primary cause was considered to be an undetermined malfunction of the pitch control system at a highly critical point in the flight.
- After completing a low level intercept mission, a flight of two aircraft joined in formation and cancelled their IFR clearance. After approximately ten minutes of formation, the wingman went into trail position for confidence maneuvers. The lead aircraft began a barrel roll to the left. An aggressive pull-up to about a 45° pitch attitude resulted in a rapid airspeed bleed-off. The pilot decided to discontinue the maneuver and effect a recovery. He began a rapid roll while still in heavy buffet and the aircraft pitched up. Because of a suspected malfunction, the pusher, CSL, and MCSL had been turned off. Since the aircraft was below 15,000 feet, both crewmembers ejected safely. The primary cause was considered operator factor in that the pilot exceeded the critical angle of attack of the aircraft, resulting in pitchup at an altitude too low to permit successful recovery. ★

THE END

the Cold Hard Facts..

Pitchup fever has caused premature recovery action in many accidents. Fly it till you run out of the last available knot.



1

Classic pitchup results in angles of attack in the 60° to 80° region. However, a soft entry and spin out or a negative stall can produce gyrations of a different kind. In all cases, airspeed drops fast and will probably oscillate between 0 and 150 knots. Don't panic! Terminate afterburner and get the chute out.

2

Now that you are in pitchup, it's too late to worry about what caused it. Concentrate on the recovery. The chute and full forward stick will get the nose down. Keep the ailerons and rudders neutral. You need flying speed so hang on.

3

This is where you can save it or lose it. As speed picks up, full forward stick should produce negative "G". If you feel it, calmly bring the stick to neutral. If you don't feel it, it may be because snap rolls generally occur in this phase as the wings begin to fly again. Check the airspeed. If it's building steadily above 150 knots, bring the stick to neutral. Too much negative "G" at this point can cause serious coupling problems and result in a new pitch cycle.

4

The gyrations are over now, but one hasty move could start them over again. Don't jettison the drag chute; let it break away. Don't rush the pullout; let speed build up to 350 knots. Don't make the same mistake twice; a given airspeed will only allow so much "G". The first pitchup proved this.

RECOVER WITS: THEN RELATIVE WIND: THEN CONTROL