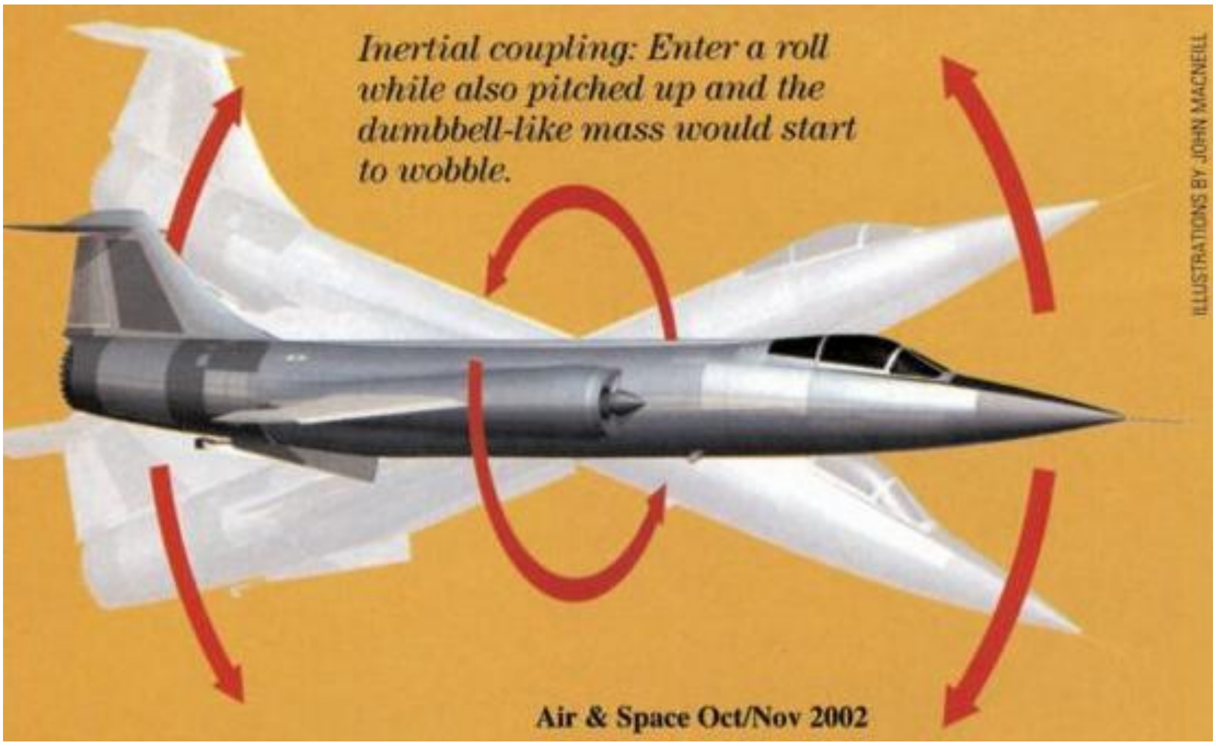
F-104 technical: Inertial Coupling

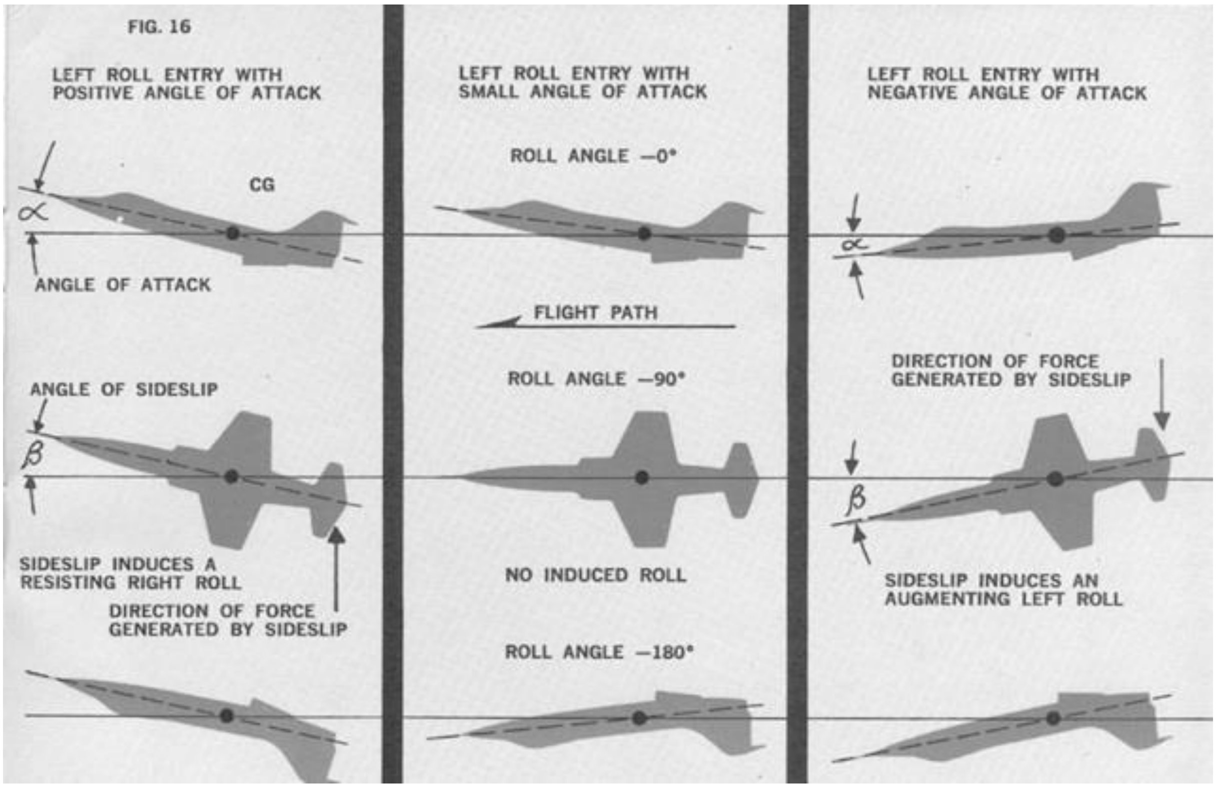
from: Test Pilot's Notebook (by Glenn L. Reaves, Lockheed Production Flight Test Pilot)

Inertial Coupling

Surprisingly enough, inertial coupling has existed for some time in fighter type aircraft that have high rates of roll. However, the fighters did not have the speed potential to carry them in to the flight area where inertial coupling could develop. We'd like to explain inertial coupling and how we've attempted to prevent it in the Starfighter.



Roll instability is experienced as a result of the design requirements for a supersonic fighter. The mass weight has been concentrated in the fuselage resulting in high inertial moments in yaw and pitch with very low inertia in roll. At high rolling velocities, the forces and moments generated due to rolling are transmitted into pitch and yaw through inertial coupling, resulting in centrifugal forces which tend to displace the aircraft fuselage normal to the flight path. Noting this, let's look at our illustrations (Fig. 16 below) of a Starfighter going through a left roll with different angles of attack and see how inertial coupling can develop. The first series shows a high angle of attack entry. It can be seen that the aircraft will initially develop a left sideslip in a left roll and a right sideslip in a right roll. Our illustrations show all left rolls so in the first series there is left sideslip. Due to the sideslip, the high tail effects which we discussed previously in the Negative Dihedral section, now comes into effect. The component of force high up on the tail resists the sideslip but also induces a right roll which will resist the initial left roll. This is beneficial to the aircraft with respect to retarding divergent characteristics in that the roll rate is reduced. As the aircraft continues its roll, in the first series, the angle of attack has decreased by the time the Starfighter is inverted but it is still positive.



In the second series, the aircraft is being rolled with the angle of attack almost nil. Here we see that no sideslip or additional rolling moments are generated. This is the type of roll we all strive for.

In the third series, the aircraft is entering a roll from a negative angle of attack. From this condition of entry, sideslip buildup will be to the right. Again, a rolling moment is induced by the high tail configuration, but in this case, the component of force high up on the tail induces a left roll which augments the original roll. If we now consider two facts about these rolling maneuvers, it will become clear how inertial coupling builds up:

1.The sideslip build-up is controlled by the induced rolling moment.

2.As sideslip builds up, the centrifugal or rolling forces increase and this tends to displace the aircraft fuselage perpendicular to the flight path.

So now it is apparent that entering a roll with a positive angle of attack is beneficial to the Starfighter. The induced rolling moment dampens the sideslip build-up. In a negative angle of attack entry, however, the induced roll increases the sideslip. The sideslip buildup then couples with the centrifugal or rolling forces and the fuselage axis begins to diverge from the flight path. Need we say that this maneuver can have a rather abrupt ending? Therefore, we issue this note of warning:

1.Use caution when entering a supersonic roll with a negative or "Zero G" pushover.

2.Attempt only one 360° supersonic roll in one direction.

There are two things we have done to prevent inertial coupling in the STARFIGHTER. One is the restriction of roll rate. Since you do not need the maximum roll capability that the Starfighter has with full aileron deflection, the ailerons have been limited so that ample but not extreme rates of roll are available. The second preventive was the ventral fin with its increase in directional stability, especially at the higher Mach.

This combination will make it very difficult to encounter inertial coupling in the Starfighter.

But let's get back to our Starfighter which is high up in the blue and find out a bit more about its flight characteristics.

A lot of you, I am sure, have had your fighters up at a goodly altitude and have been satisfied with its performance up to that point. But as you approached the region around 45,000 feet the aircraft had to be handled with kid gloves or you'd stall in a tight turn and lose precious altitude and airspeed.

Well, the Starfighter has increased its maneuvering capability by the existence of its wide speed range.

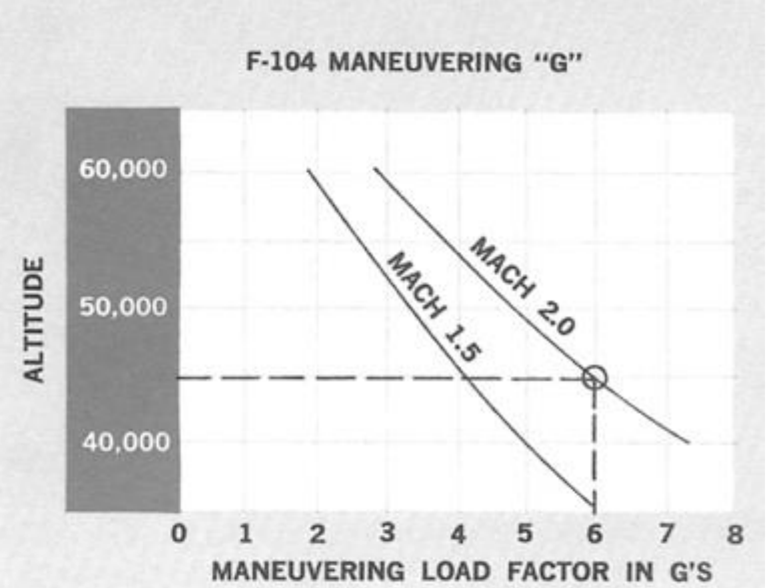


FIG. 17

An illustration we have drawn up (Fig. 17) has curves for two Mach numbers and maneuvering load factor. Actually a family of curves would be needed to portray the entire picture. But these curves show that if you are flying at 45,000 feet and Mach 2.0 you can easily pull 6 g's in maneuvering. The fiercest of you tigers will agree that this is a healthy hunk of maneuvering "g" to be able to play with. Use it skillfully and employ it wisely. Upon completion of your high altitude work, you can pop the boards and come screaming down if you desire. Actuation of the speed boards can take place at any time you prefer. Up to Mach 1.8, a mild nose up occurs upon extension of the boards and from Mach 1.8 to 2.0, a mild nose down occurs. Although the pitch changes are very mild, we recommend that above Mach 1.8 the boards be deployed in increments for positive control. After slowing down to subsonic flight, if you decide to make a clean let-down, be careful you don't accidentally slip back through Mach 1.0 and "Boom" the populace.

In the traffic pattern, you'll probably carry a little more power than you're used to and you'll fly the pattern a little wider and faster, too. But if you're on the stick and make a smooth pattern, the landing will be a dream. You can actually land the Starfighter and not know you've touched down until suddenly you are aware of rolling along the runway. Wait until the nose gear is definitely on the runway before pulling the drag chute. If the nose is still high when you pull the drag chute it forces the nose gear down onto the runway pretty hard. Drag chute deployment and reaction is better if actuated right after letting the nose down. Nose wheel steering is effective and should be used as needed. Braking action is firm and effective and the brakes alone are completely adequate to stop the Starfighter after a normal landing.

After shutting down and climbing out of the pit, we believe that you will be proud to have become a member of The Royal Order of Starfighters.

These notes of "Snake" Reaves are reproduced by André Richir from documents belonging to Wolfgang Czaia (F-104 Experimental Test Pilot)

http://dogfighthistory.be/Dogfighthistory/F104_Notes.html

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compiled by: Hubert Peitzmeier