MANEUVERABILITY

A useful function is to determine how many "G's" an aircraft might require to make a given turn without altitude loss. From Newton's laws, F cos ϕ = W , where F = force applied to an aircraft, W = weight, and ϕ = bank angle. By definition "G's" is the ratio of the force on an object to it's weight, i.e., G = F/W = 1/cos ϕ

Simple calculations will show the results presented in table 1, to the right.

Table 1. G vs Angle of Bank (No altitude loss)

G	ϕ
1.0	0
1.4	45
2.0	60
3.9	75
7.2	82
11.5	85

Given that the average structural limit of an aircraft is about 7 G's, the maximum bank angle that can be achieved <u>in level (non-descending) flight</u> is 81.8°.

Figure 1 can be used to determine the turn radius and rate-of-turn for any aircraft, given speed and angle of bank (assuming the aircraft maintains level flight). It may also be used in the reverse context. It should be noted that not all aircraft can fly at the speeds depicted - they may stall beforehand or may be incapable of attaining such speeds due to power/structural limitations.

In the example shown on Figure 1, we assume an aircraft is traveling at 300 kts, and decides to make a 30° angle of bank turn. We wonder what his turn radius is so we can approximate his flight path over the ground, and what his rate of turn will be. We enter the chart at the side at 300 kts and follow the line horizontally until we intercept the 30° "bank angle for rate of turn" line. We then go down vertically to determine the 2.10°/sec rate of turn. To get radius, we continue horizontally to the 30° "bank angle for turn radius" line . We can then go down vertically to determine the radius of 13,800 ft.

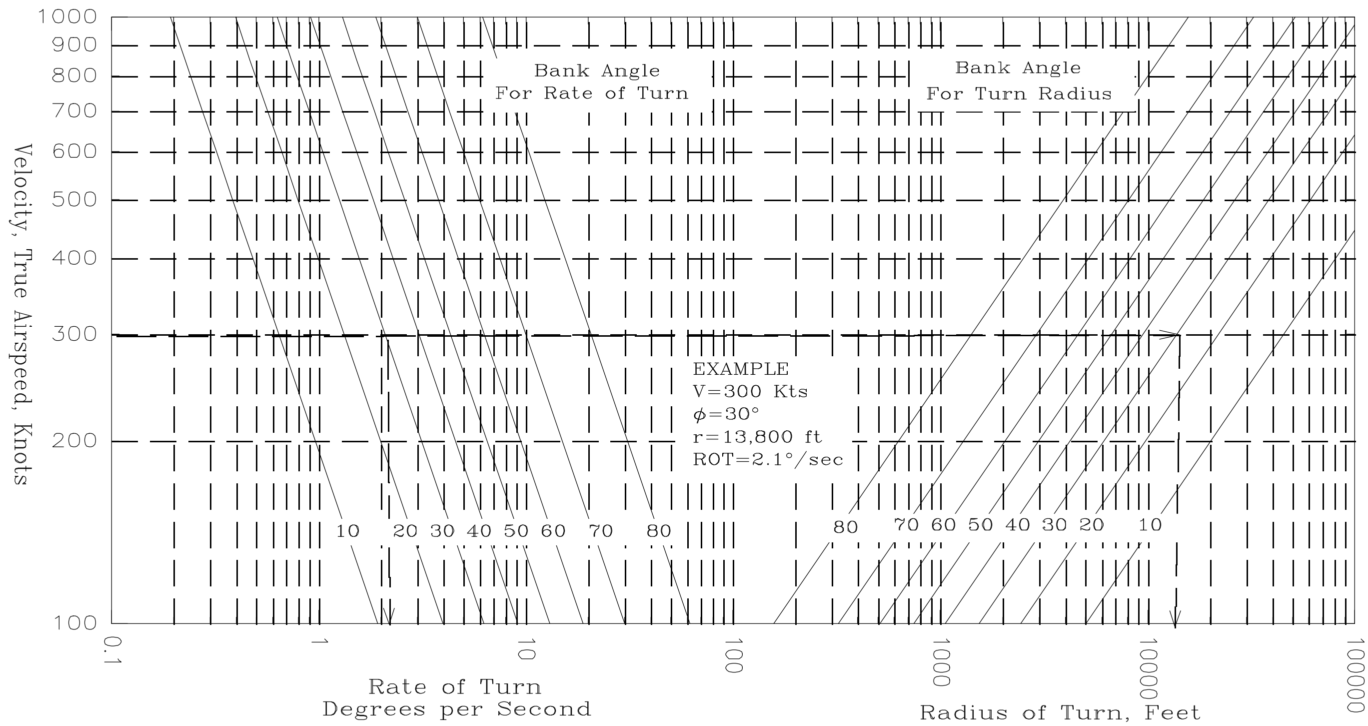

Figure 1. Aircraft Turn Rate / Radius vs Speed

The exact formulas to use are:

$$Rate\ of\ Turn = \frac{1091\ \tan(\phi)}{V} \qquad Radius\ of\ Turn = \frac{V^2}{11.26\ \tan(\phi)} \qquad Where:\ \begin{array}{r} V = Velocity\ (Kts) \\ and\ \phi = Angle\ of\ Bank \end{array}$$

Another interesting piece of information might be to determine the distance a typical aircraft might travel during a maneuver to avoid a missile.

Figure 2 shows a birds-eye view of such a typical aircraft in a level (constant altitude) turn.

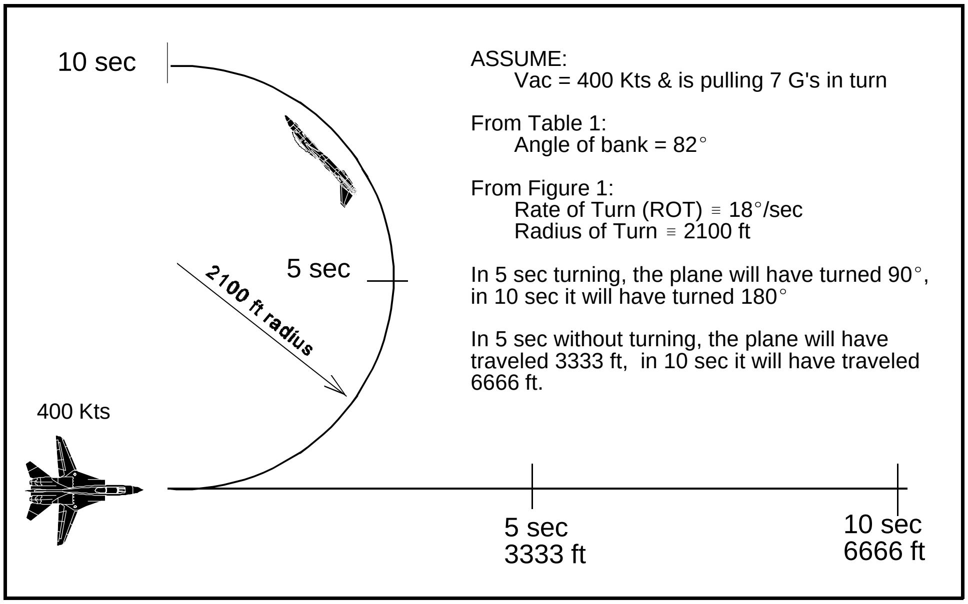

Figure 2. Maneuvering Aircraft

To counter many air-to-air missiles the pilot might make a level turn, however in countering a SAM, altitude is usually lost for two reasons: (1) the direction of maneuvering against the missile may be downward, and (2) many aircraft are unable to maintain altitude without also losing speed. These aircraft may have insufficient thrust for their given weight or may be at too high an altitude. The lighter an aircraft is (after dropping bombs/burning fuel), the better the performance. Likewise, the higher the altitude, the poorer the thrust-to-weight ratio. Maximum afterburner is frequently required to maintain altitude at maximum "G" level.

REFERENCE AXES (Roll, Pitch, Yaw):

The rotational or oscillating movement of an aircraft, missile, or other object about a longitudinal axis is called roll, about a lateral axis is called pitch, and about a vertical axis is called yaw as shown in Figure 3.

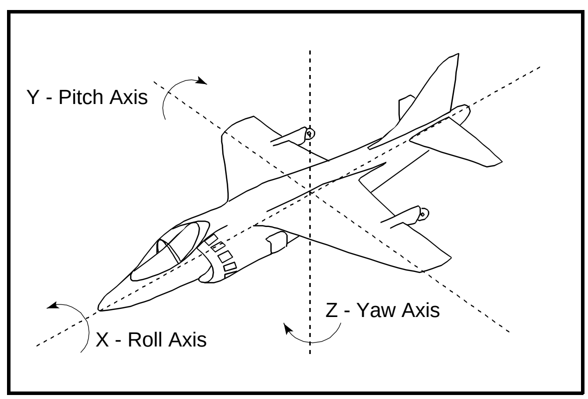

Figure 3. Reference Axes

SAMPLE CALCULATIONS:

If we want to determine the rate of turn or turn radius more precisely than can be interpolated from the chart in Figure 1, we use the formulas. For our initial sample problem with an aircraft traveling 300 kts, in a 30° angle of bank turn, we have:

$$Rate\ of\ Turn = \frac{1091\ \tan(\phi)}{V} = \frac{1091\ \tan(30)}{300} = 2.1°/\text{sec}$$

$$Radius\ of\ Turn = \frac{V^2}{11.26\ \tan(\phi)} = \frac{300^2}{11.26\ \tan(30)} = 13{,}844\ ft$$

These are the same results as we determined using Figure 1.