# Technical Note: An Automatic Pilot to Make *Perfect Loops* Varying only *Gflyup* through the Loop

J. Barahona da Fonseca[1]

## Summary

In this paper I define an automatic pilot to make a perfect loop, that is a circumference, making the centripetal acceleration, *Gflyup*, to vary through the loop and maintaining a constant motor impulse, although it varies a little bit with altitude. I prove that this automatic pilot could be implemented easily in the flight computer of an F16, F15, F18, or in any other aircraft with a *GonSetRate* > 0.62 g/s. In the near future I will study alternative approaches varying only the engine impulse and varying simultaneously *Gflyup* and the engine impulse.

## Introduction

In a preliminary study with loops with constant centripetal acceleration, *Gflyup*, through the loop [1], with a simplified model of the F16 [2], I obtained the following result, apparently paradoxal: making >> v_through_a_flyup(3, [300 400 450 500], 1000, 0, 360,5000, 0) in matlab environment I got

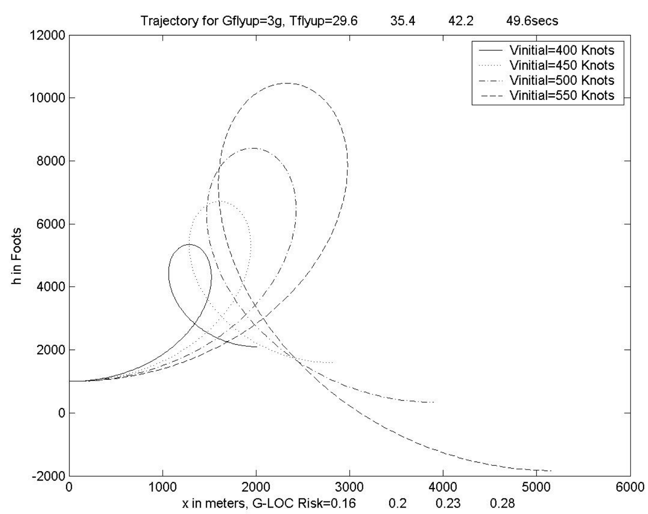


Figure 1- *Penetrating Loops* from [1] that result from a constant *Gflyup*.

[1] Department of Electrical Engineering and Computer Science, Faculty of Sciences and Technology, New University of Lisbon, Monte da Caparica, Portugal

We see that for Vinitial=500Knots we have an almost perfect loop (h(0º)~h(360º)) and for Vinitial=550Knots we have a clearly *penetrating loop* (h(0º)>>h(360º)), all these for *Gflyup*=3g. In practice, and we will see in theory, *Gflyup* is not constant through the loop, and the Penetrating *Loops* (h(0º)>h(360º)) only happen with constant *Gflyup*. Moral of the history: constant *Gflyup* besides generate deformed loops, may provoke crashes!

### Auto Pilot for Perfect Loops Varying only *Gflyup*

Next I will define the automatic pilot to make a perfect loop, that is a circumference, making the centripetal acceleration, *Gflyup*, to vary through the loop and maintaining a constant motor impulse, although it varies a little bit with altitude. Taking in account the geometry of the problem, the radius of the loop will be

$$R = \text{Vinitial}^2 / (\text{Gflyup\_initial} - g) \quad (1)$$

Then, after some algebraic manipulations, we have

$$\text{Gflyup}(\alpha) = V(\alpha)^2 / (g\,R) + \cos\alpha \quad [\text{g's}] \quad (2)$$

(2) Can be interpreted as the definition of an automatic pilot that would command *Gflyup* through the loop, resulting in a circumference of radius R given by (1). Here there are the results of some simulations implemented with the F16 simplified model in Matlab®: making >> v_through_a_p_loop(5, [500 600 650 700], 1000, 5000) we have

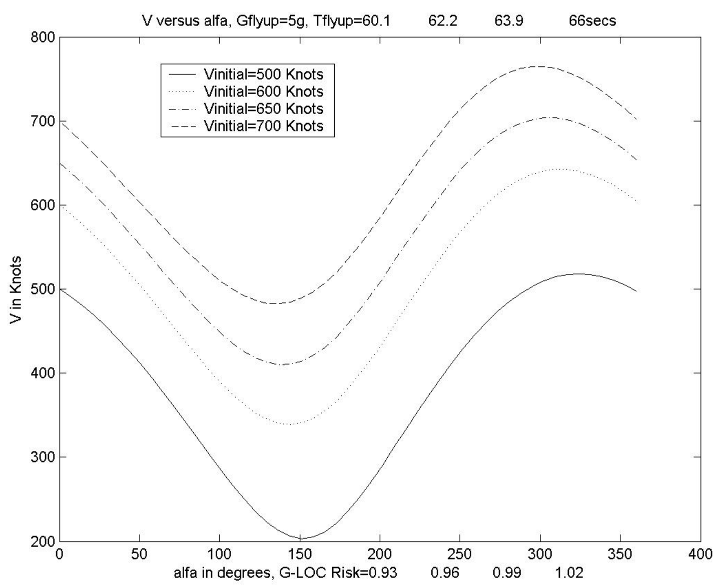


Figure 2- Variation of speed through the perfect loop for various initial speeds.

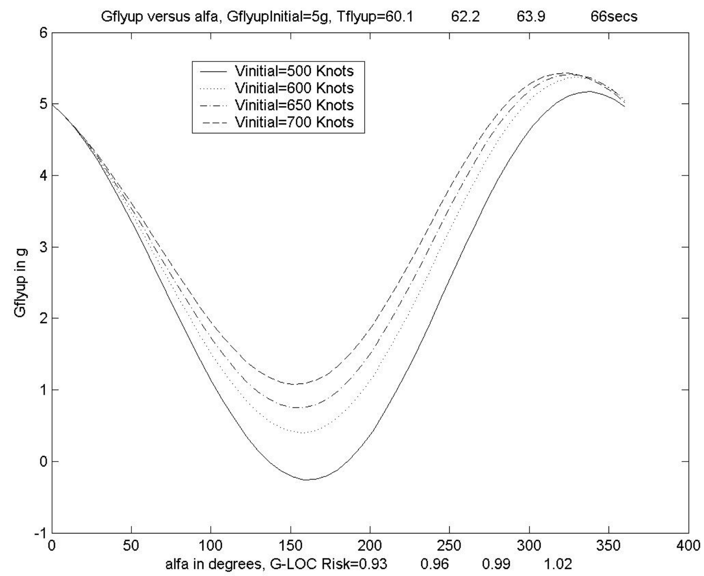


Figure 3- Variation of *Gflyup* through the perfect loop for various initial speeds.

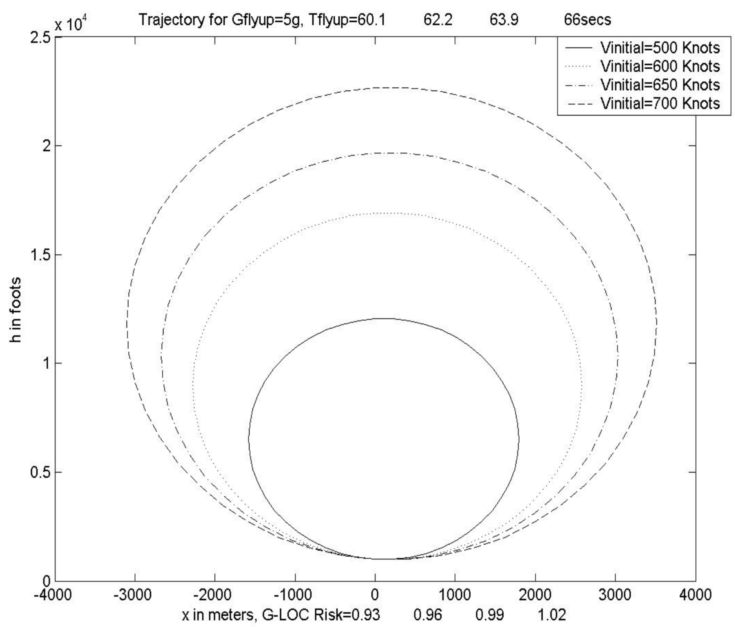


Figure 4- Resultant trajectories, circumferences, for various initial speeds.

**Analysis of the Viability of the Auto Pilot to Make Perfect Loops**

Since the F16 passes from *Gflyup*=0g to *Gflyup*=9g in about 1s, that is it has a *GonSetRate*=9g/s, it seems that will be possible to implement this automatic pilot in the F16 or in any other aircraft with a similar *GonSetRate*; since the speed of *loosing g's,* GoffSetRate, is much greater (~ -20g/s), the critical parts of the loop will be those where *Gflyup* increases, that is between 180º and 360º. In mathematical terms the viability of our automatic pilot for perfect loops will be

$$\left(\frac{dGflyup}{dt}\right)_{\max} < GonSetRate \tag{3}$$

We will see that d*Gflyup*/dt, that is the *instantaneous GonSetRate,* is maximum for α~263º. Next I will verify if (3) is true for the F16, simulating the more unfavourable situation, that is minimum initial speed that would imply a minimum loop time (why?) and maximum initial *Gflyup*, say (450Knots, 9g), that would imply a minimum *Tloop* and a maximum *ΔGflyup*, maximizing the first term of (3).

(3) being true translates in, during the descendent part of the loop (180º-360º), the next condition be always true

$$Gflyup(i)-Gflyup(i-1) < GonSetRate\ \Delta t(i-1) \tag{4}$$

Making >>v_through_a_p_loop_gti(9, 450, 1000, 5000), we have

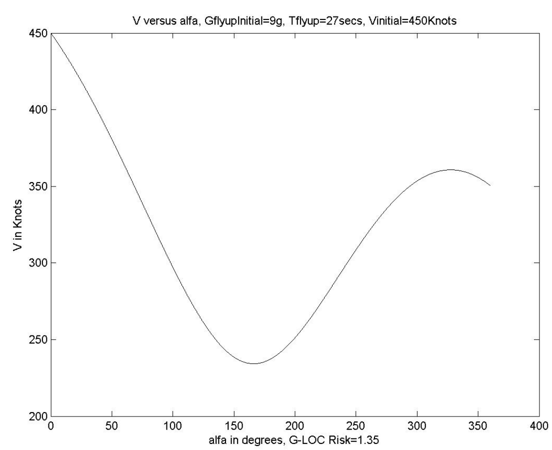


Figure 5- Variation of speed through the perfect loop with the most unfavourable initial *Gflyup*=9g and *Vinitial*=450 knots.

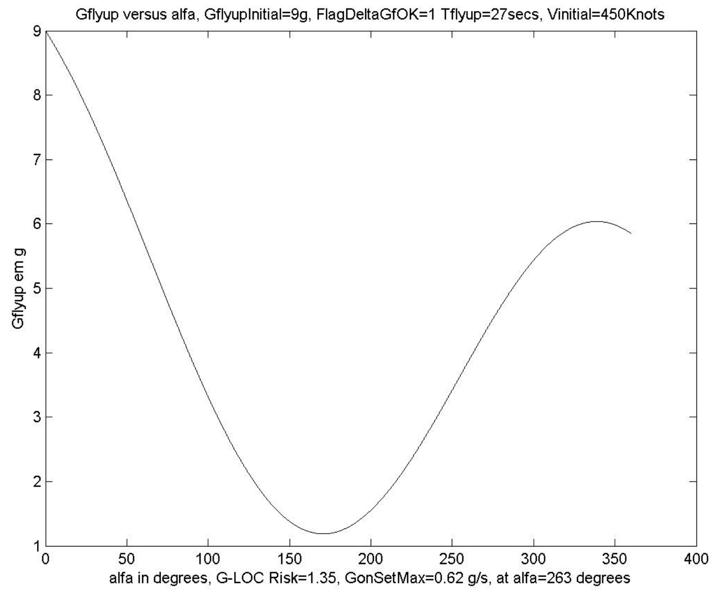


Figure 6- Variation of *Gflyup* through the perfect loop with the most unfavourable initial *Gflyup* and *Vinitial*.

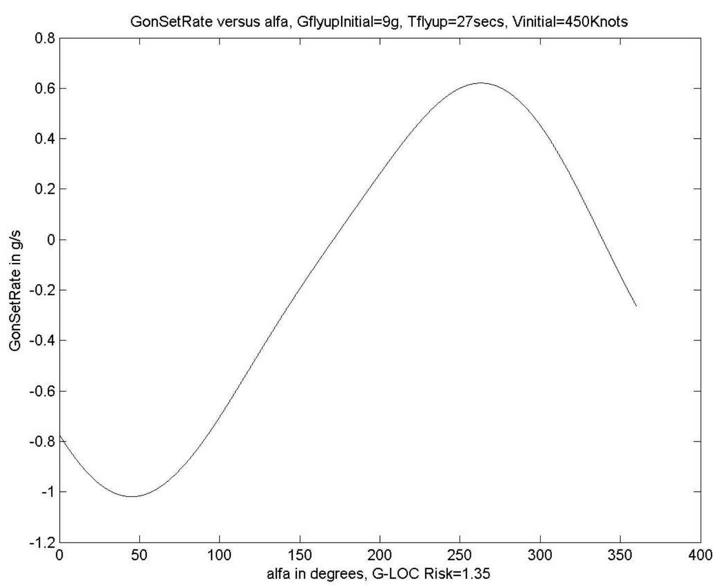


Figure 7- Variation of instantaneous *GonSetRate* through the perfect loop with the most unfavourable initial *Gflyup* and *Vinitial*.

*FlagDeltaGfOK*=1 means that (4) was always true during 180º-360º, which implies that (3) is true for the F16. Since *GonSetRateMax*=0.62g/s, our automatic pilot can be implemented in any aircraft with a *GonSetRate*>0.62g/s, which include many aerobatic low power aircrafts with a propeller engine.

## Conclusions and Future Work

I showed that makes sense to try to make a circumference like loop, since loops with constant *Gflyup* could result in *Penetrating Loops* that may provoke crashes.

The implementation of the perfect loops automatic pilot results in a very simple mathematical formula which could be easily implemented in the flight computer, without any computation time problems, that is, to compute the new *Gflyup*(t+Δt) in a time less than Δt.

I'm planning to study other versions of the automatic pilot where I will maintain a constant radius trying to maintain constant the speed through the loop varying the engine impulse. This seems to be possible with the F16, F15, F18 and other fighters that can maintain a constant speed at –90 degrees flight. Finally I will study another version where I will combine the variation of *Gflyup* and engine impulse trying to reduce *Fmax* and the minimum *GonSetRate* necessary to implement the perfect loops automatic pilot.

## Acknowledgements

To Our General António Bispo (Antonio.Bispo@ineti.pt), a former F86 fighter pilot of Portuguese Air Force (www.emfa.pt), that works at INETI (www.ineti.pt) in the development of a very realistic training system for fighter pilots, that told me that the *Penetrating Loops* may result from the consideration of a constant *Gflyup* through the loop.

## Reference

1 Barahona da Fonseca, J. (2003): *Incursões dum Engenheiro Electrotécnico na Aero Mil II: do Modelo Estático para o Modelo Dinâmico*, work submitted to Fernandes Costa 2003 Award (written in Portuguese), www.inst-informatica.pt/v20/produtos/premio_fern_costa/default.htm.

2 Stevens, B. L. and Lewis, F. L. (2003): *Aircraft Control and Simulation*, John Wiley & Sons, 2nd Edition.