Technical Note III: The Risk of G-LOC and the Time to G-LOC Meter

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Summary

After obtaining the expression of the risk of G-LOC, I define a possible way to measure the time to G-LOC during a flyup with a variable *Gflyup*, assuming a certain risk of G-LOC. I finish with a discussion of some implementation issues of the time to G-LOC meter.

Introduction

All years USAF and other Air Forces lost many aircraft and pilots in fatal accidents consequence of G-LOC during a flyup. To reduce this type of accidents USAF created a program of GCAS (Ground Collision Avoidance System) installation in more modern aircraft.

My time to G-LOC meter is another measure to reduce this type of accidents, since the pilot is warned when he is approaching his own G-Tolerance limit and is said he must reduce Gflyup or terminate the flyup.

During the Second World War happened some cases of G-LOC at high altitude which were reported by allied and nazi pilots, but there were only in 1956 that appeared the first paper where time to G-LOC and G-Tolerance were studied exhaustively with a human centrifuge [2].

But it was only in 1993 that appeared the first serious work where was proposed a mathematical model of G-Tolerance and the time to G-LOC [1].

Based on this model and from the results of the analysis of the physics of flyup I deduce the expression of the risk of G-LOC.

Finally from the expression of the risk of G-LOC and from the expression of the time to G-LOC I define the time to G-LOC meter.

Flyup Time and the Paradox of Flyup

Obtaining the exact flyup time, *Tflyup*, is a difficult task because both speed and resultant centripetal acceleration, *Gflyup*- g cos α, decrease continuously during the flyup. Since we are interested in a pessimistic estimate, we will consider *Vflyup=V(0)*,

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t=0 when the pilot pulls the stick, and $Gflyup\_resultant=Gflyup - g$, that is we will approximate the flyup by an arc of circumference of radius $Vflyup^2/(Gflyup\text{-}g)$. We have

$$\text{Gflyup-g}=\omega\ \text{Vflyup} \qquad (1)$$

Then, considering that the angle of trajectory during the flyup varies $\Delta\alpha$ radians, after some algebraic manipulations, we have

$$\text{Tflyup}=\Delta\alpha\ /\ (\text{Gflyup-g})\ \text{Vflyup} \qquad (2)$$

(2) Can be interpreted as *the time of flyup is proportional to the speed of flyup* that is the paradox of flyup. This paradox is solved considering that the arc of circumference is given by $Vflyup^2/(Gflyup\text{-}g)\ \Delta\alpha$, that is the length of the path we have to travel during the flyup is proportional to $Vflyup^2$.

The Time to G-LOC and the Risk of G-LOC

From [1], and after some simplifications, the time to G-LOC can be approximated by

$$\Delta\text{t\_G-LOC}=\frac{\text{Kpilot}}{\text{Gflyup}^2} \qquad (3)$$

Where *Kpilot* measures the pilot G-Tolerance which can be determined measuring the time to G-LOC in the centrifuge at a certain high level of *Gflyup.* The risk of G-LOC will be the quotient between the flyup time given by (2) and the time to G-LOC given by (3). We have

$$RiskG\text{-}LOC=\text{Tflyup}\ /\ \Delta\text{t\_G-LOC} \sim \Delta\alpha\ \text{Vflyup Gflyup / Kpilot} \qquad (4)$$

When the risk of G-LOC associated to a given flyup approximates the value 1, we must reduce *Gflyup* and/or *Vflyup* and/or the length of the flyup $\Delta\alpha$ and/or increase the pilot G-Tolerance *Kpilot* through physical intensive training.

The Time to G-LOC Meter for a Given Risk of G-LOC

If we only want to take a certain level of risk of G-LOC, *RiskG-LOC*, then we will have a lower time to G-LOC given by

$$\Delta\text{t\_G-LOC}=RiskG-LOC\frac{\text{Kpilot}}{\text{Gflyup}^2} \qquad (5)$$

Let's consider the general case where *Gflyup* is not constant through the flyup. At t=0 when the pilot pulls the stick, $Gflyup=Gflyup_0$, and considering he do not want to take a risk greater than *RiskG-LOC*, the time to G-LOC meter will display Δt_0 given by

$$\Delta t_0 = RiskG - LOC \frac{\text{Kpilot}}{\text{Gflyup}_0^2} \tag{6}$$

Now consider that after a time Δt during which the pilot pulled $Gflyup_0$ he changed *Gflyup* to a new value $Gflyup_1$. What will be the new time to G-LOC, Δt_1, that must be displayed in the time to G-LOC meter? Since the time to G-LOC is inversely proportional to the square of *Gflyup* and after a time Δt would remain Δt_1-Δt to G-LOC if *Gflyup* would maintains at $Gflyup_0$, Δt_1 will be

$$\Delta t_1 = (\Delta t_0 - \Delta t) \frac{\text{Gflyup}_1^2}{\text{Gflyup}_0^2} \tag{7}$$

Generalizing, after *i* time intervals we will have

$$\Delta t_i = (\Delta t_{i-1} - \Delta t) \frac{\text{Gflyup}_i^2}{\text{Gflyup}_{i-1}^2} \tag{8}$$

Equations (6) and (8) define our time to G-LOC meter that may be seen as a count down counter that after Δt is *set* to a new *initial value*. Since (6) and (8) are very simple this gadget could be implemented with a very simple digital circuit. The main difficulty would be the implementation of the communication with the flight computer to get *Gflyup* or the interface with the G-meter.

Conclusions and Future Work

I showed that the time to G-LOC meter is a simple and beautiful idea as is its implementation with state of the art digital hardware.

I'm planning to propose the development of a prototype of this gadget to my students of digital design and to students of Portuguese Air Force Academy.

Reference

1 Moore, T. W., Jaron, D., Hrebien, L. and Bender, D. (1993): "A Mathematical Model of G Time-Tolerance", *Aviat. Space Environ. Med.*, 64:947-951.

2 Stoll, A. M. (1956): "Human Tolerance to Positive G as Determined by the Physiological End Points", *Aviat. Med.*, 27:356-367.