**Correction of the Handling Qualities tutorial**

**1°) Manoeuvrability**

1. In turn, the angle of attack increases, at iso-speed, because it allows to increase the lift which has to balance the increase of the apparent weight nmg , because in stabilised turn, the load factor n has increased (1/cos)  
   We may write the simplified lift equation nz mg =1/2 SV² Cz : an increase of nz needs an increase of Cz and so an  increase.
2. The main aerodynamic coefficient allowing to determine the incidence variation is Cz the lift gradient in incidence and .  
     
   We might determine the required incidence writing :
   * 1. Wings level : mg=1/2 SV² Cz- )
     2. In turn : n mg=1/2 SV² Cz- )

*(neglecting Czm*

*We have of course n=1/cos  (in stabilized turn with small )*

* =* - 

1. Comparing to the flight wings level at the same speed, the elevator deflection in stabilised turn will be modified because this control surface has to counteract the changes in pitching moments induced by angle of attack variation and by pitch damping (caused by the pitch rate q).  
   Direction of the variation of elevator deflection :  
    - the angle of attack increase due to the turn will cause a pitch-down moment (Cm) because we have assumed that the aircraft is stable   
    - in addition, the pitch damping is in nose-down direction because the pitch rate q is in the nose-up direction in turn.  
   The elevator has to counteract both nose-down moments (to maintain a stabilised turn , with  and q constant): the elevator has to be deflected in the **nose-up** direction.
2. The main aerodynamic coefficients allowing to compute it are:

- Cm, the pitching moment due to angle of attack (stability)

- Cmq, the pitch damping

- Cmm, the elevator efficiency (wrt pitching moment)

- Cz and  the incidence change in turn

- The pitch rate q is linked to load factor n and therefore to  (see course)

We may determine the necessary elevator deflection m , writing Cm=0 (because q=cst)for the 2 phases :

* + 1. Wings level : Cm=0 =Cm0 +Cm  -) + CmmT mT (m=0 because the aircraft is trimmed)
    2. In turn : Cm=0 =Cm0 + Cm  -) + Cmm m + CmmT mT + Cmq ql/V (unchanged trim)

*We have q =g/V(n-1/n) (see course) and n=1/cos  (in stabilised turn with small )*

*We may thus deduce* m

1. Margin wrt the stall:

We write the simplified lift equation for the 2 following cases:  
 - Stall wings level at n=1g and Vs1g : mg=1/2 S (Vs1g)² Czmax (1)  
 - Stall in turn at n and Vsn (at the same Czmax) : n mg=1/2 S (Vsn)² Czmax (2)

The turn is performed at VREF=1.23Vs1g at n=1/cos .

The speed margin in turn is VREF/VSn = 1.23 Vs1g/Vsn= 1.23 (1/n)1/2 , having done the ratio of the equations (1) /(2) .

Whence VREF/VSn= 1.23(cos  ) ½

VREF/VSn= 1.23(cos ½=1.145 : *we have no longer 23% but 14.5% wrt stall speed.*

2° a) Increase of angle of attack to balance the increase of apparent weight nmg.

b)

* + 1. Wings level : mg=1/2 SV² Cz- )
    2. In turn : n mg=1/2 SV² Cz- )

*(neglecting Czm*

*We have of course n=1/cos  (in stabilized turn with small )*

NA : = 7.9°

d)

We may determine the necessary elevator deflection m , writing Cm=0 (because q=cst)for the 2 phases :

* + 1. Wings level : Cm=0 =Cm0 +Cm  -) + CmmT mT (m=0 because the aircraft is trimmed)
    2. In turn : Cm=0 =Cm0 + Cm  -) + Cmm m + CmmT mT + Cmq ql/V (unchanged trim)

*We have q =g/V(n-1/n) (see course) and n=1/cos  (in stabilised turn with small )*

*We may thus deduce* m