**Correction of the Handling Qualities tutorial 2**

**1° Engine failure**

1. When the speed decreases, the rudder efficiency decreases (1/2 SV² Cnn ) . (In addition, the thrust asymmetry increases because the sane engine thrust increases when the airspeed decreases.  
   Thus, to counteract the yawing moment caused by the thrust asymmetry, it will be necessary, at low speed, to push the rudder on its stop (except if the stall occurs earlier).  
   To be balanced at speeds even lower, it will be necessary to bank on the sane engine side : the balance in lateral force induced that the lateral component of the weight allows to fly with some sideslip coming from the sane engine side. This sideslip then causes a « weathercock effect » towards the sane engine which helps to counteract the thrust asymmetry : we can fly steadily at lower speeds .  
   Do again the scheme of the course (balance in Cy and Cn).
2. At low speed, with a failed engine, when the rudder is already on its stop, it is more difficult to bank on the sane engine side: in fact, during the roll initiation, the rudder, which is already on its stop, cannot be more deflected : it cannot coordinate the turn: a sideslip will be generated on the side where we bank (sane engine side here), and the resulting dihedral effect Cl, will be opposite to the roll initiation).
3. Drag minimisation.

The right engine fails. The pilot must counteract the yawing moment (to the right) caused by this failure : he deflects the rudder to the left.

The deflection of this control surface to the left generates a right roll (because we don’t neglect here the adverse roll Cln).

To minimise drag raisons, we don’t want to use ailerons and spoilers to counteract this adverse roll (we assumed that ClF was null). So we use sideslip coming from right in order that its dihedral effect Cl counteracts this adverse roll :

Thanks to the rolling equation, in straight flight, we may write : Cl=0 because (p=r=0)  
 and therefore Cl+ Cln. n=0 . Whence = - Cln / Cln.

This sideslip allows balancing the aircraft in roll without using the spoilers. However, in yaw, the sideslip has a detrimental effect, because as it comes from right, it generates a weathercock effect Cn to the right which will be added to the engine thrust asymmetry. The rudder deflection is therefore greater (than if the sideslip was null or coming from left). This balance is then possible only if the aircraft speed is not too small.

The balance in lateral force will be performed in order that the lateral weight component will balance the lateral force caused by the rudder Cyn (towards the right) and the lateral force caused by the sideslip Cy (towards the left).

To find the necessary rudder deflection n, we need to write the yawing moment equation Cn+ CnF=0 (because p=r=0).

Cn+ Cnn. n=- CnF=- F\* b/ ( 1/2 S V² l )

and we use the expression of the sideslip found previously : = - Cln / Cln.

Whence : n (Cnn - CnCln / Cl=- CnF

and so

**n=- F\* b/ ( 1/2 S V² l ) ClClCnn - CnCln )**

Numerical results :  
 CnF= 200 000 \* 5/ (0.5 \* 1\*200**\***60² \*6)=0.463

n = - 0.463 \* (-1.4)/( (-1.4)(-1.5)-1.1\*0.1) \*57.3 = 18.6° (>0 to the left… Normal)

= - 0.1/(-1.4) \*18.6 =1.3° (>0 to the right)

**2°) Turn to the right**

a) Angular rotation speed  :

The turn being coordinated, the load factor is placed in the symmetry plane (Gxz).

We may then write that (see course):

(nz mg)² = (mgcos)² + (mV)²

whence **= g/V(nz²-1)1/2** with >0 because turn to the right

Numerical results :  
= 9.8/100\*(1.414²-1) 1/2 \*57.3 = 5.6°/s (or 0.098 rd/s)

=arcos(1/nz)=45° (( is small)

b) Ailerons deflection(l) and rudder (n) :

We use the yawing and rolling moment equations, with p=r=cste et p=0.

Thus Cl=0 and Cn=0

Besides, the sideslip  is null because in a coordinated turn, ny=0 , which corresponds to Cy=0 , i.e. =0 when we neglect Cyn.

Whence :

Cll. l + Clr rl/V=0 *(neglecting Cln)*

Cnn. n + Cnr rl/V=0 *(neglecting Cnl)*

Thus :

Ailerons l= - Clr/Cll . rl/V

Rudder n= - Cnr /Cnn . rl/V

where r= cos =4.0°/s (>0 to the right)

Ailerons l= - 15/(-2,5) \* 2,8\*6/100=1,4° *(>0 to the left)*

Rudder n= - (-10) /(-1.5) \* 2,8\*6/100=-1,6° *(<0 to the right)*

c)

We see that the roll stick input is deflected to the left to counteract the rolling moment induced by the yaw rate r (roll to the right for a turn to the right : the outer wing (wrt the centre of the turn) flies quicker and so lifts more and induces then a right rolling moment)

The rudder pedal is deflected towards the right to counteract the yaw damping Cnr (yaw towards the left caused by the yaw rate : in particular, the outer wing (left one her) flies quicker and therefore drags more :left yawing damping moment).