Detailed specification of the Longitudinal Flight System

1 Goals

The LF (Longitudinal Flight) system must allow the pilot to:

- direct the aircraft according to the altitude (climb/descent)
- land and take off

The pilot's orders are taken into account by the computers that control the control surface deflections as needed in order to obtain the desired trajectory, but, independently of the pilot's orders, the computers avoid excessive maneuvers in order to not leave the planned flight envelope.

The LF system does not handle curves because it only controls the elevators. It is used only for longitudinal flight. It must also provide flight safety information to the pilot in the form of alarm indicator lights.

2 Architecture of the system

The LF system will be comprised of a computer and its software. In terms of software, 4 functions must be clearly identified:

- Calculation of the flight parameters
- Alarms
- Flight controls
- Automatic pilot

The execution cycle of the software will be 10 ms (this time parameter is integrated into the splitter of the library).

3 Interfaces of the system

<u>Inputs</u>

Data coming from sensors:

Req_1.
Static pressure P_0, pressure taken on the back of the aircraft (in Pa)
Req_2.
Stop pressure P_a, pressure taken in front of the aircraft (in Pa)

Data coming from other computers:

Req_3.
Incidence (in degrees)

Data coming from pilot controls:

Req_4.
Landing gear extended (true/false)
Req_5.
Position of the stick (in degrees)
Req_6.
Automatic pilot (true/false)

It is preferable to respect the order of these inputs, in order to be able to use the scenario provided for the simulation.

<u>Outputs</u>

Servos:
Req_7. Elevators (in m)

3 Alarm indicator lights:
Req_8 Stall
Req_9 crash
Req_10 Descent

General Calculations:
Req_11 Speed (m/s)
Req_12 Slope (degrees)
Req_13 Altitude (m)

4 Functions of the subsystems

<u>Alarms and indicators</u>

Req_14.
Risk of stalling: incidence > 12°

Req_15.
Risk of crashing: aircraft too close to the ground (altitude < 300 m) and gear not extended.

Req_16.
Too fast descent: vertical speed > 100 m/s

Req_17.
Any activation of alarms can be done only after a confirmation time of 100 ms.

<u>Calculation of the flight parameters</u>

Req_18.
Calculation of the altitude in m and in ft (1 ft = 0.3048 m)

Req_19.
Calculation of the speed/upwind of the aircraft in m/s

Req_20.
Calculation of the slope in degrees

Flight controls

Req_21.
The positioning of the elevators is linear with respect to the set point of the stick (stick [-15°, 15°] = elevator [-40 mm, 40 mm])

Req_22.
The displacement speed of the elevators must be limited to 10 mm/second.

Req_23.
The position of the elevators must be limited between -40mm and 40mm (see Req_21)

Req_24.
If the aircraft is stalled for more than 100ms, impose a stick set point of -12°.

Automatic Pilot

Req_25.
The automatic pilot can be triggered by the pilot by pressing the "Automatic pilot" button. It manages the set point of the stick automatically in order to maintain the aircraft.
If the "Automatic pilot" button is not pressed, then the set point of the stick is equal to the position of the stick.

Req_26.
3 operating modes according to the altitude h can be distinguished, when the "Automatic pilot" button is pressed:

- Climb Mode ($h < 8{,}000$m) → StickSetPoint = 5°

- Cruising Mode ($8{,}000\text{m} \leq h \leq 12{,}000$m) → StickSetPoint = 0°

- Descent Mode ($h > 12{,}000$m) → StickSetPoint = -5°

Req_27.
The management of the automatic pilot will be specified in part in the form of a finite state automaton.

Calculation of the flight parameters cont.

Req_28.

Roll: roll has to be limited to 1°/s. Roll must not exceed 15° to the left or to the right. Roll is an input of the System_PA. If this is exceeded (variation or limit) an alarm is activated for 5 cycles, a confirmation of the exceeding is required for 2 cycles. Connect the roll to the display provided.

Req_29.

Yaw: yaw has to be limited to 7°/s. Yaw must not exceed 6° to the left or to the right. Yaw is an input of the System_PA. If this is exceeded (variation or limit) an alarm is activated, a confirmation of the exceeding is required for 4 cycles.

Req_30.

Yaw must not exceed 5° starting at 130m/s. If this is exceeded an alarm is activated for 15 cycles, a confirmation of the exceeding is required for 3 cycles.

For Req_28, Req_29, Req_30 use the TestScenarioRollYaw.in scenario. The Roll/Yaw inputs must be added to the System_PA node (in this order).

Req_31.

The display on the display is sometimes difficult to read because blinking effects appear. Modify the design in order to prevent this blinking while still retaining pertinent information on the display for the pilot.

Req_32 Outside temp. calculation

At zero level, the temperature is set by convention to 15°C. It decreases linearly with the altitude by 6.5°C per 1000 m (or about 2°C per 1000ft) until an altitude of 11,000 m (about 36,100 ft) or the temperature remains constant at equal to -56.5°C until the altitude of 20,000m (about 65,600 ft). Propose an operator to display the outside temp. in C°.

Req_33: When the temperature exceeds -55C° then an alarm is triggered for 10 cycles.

Req_34: When the temperature falls below -30C°, the heating system of the leading edges must then be triggered (50% of the capacity) automatically then returns to the OFF position is the outside temperature rises above the threshold of -30°. Below -40°, heating is at 100% of its capacity. The left/right heating are independent and can be placed in the OFF state at any time as ordered by the pilot.

Req_35: Probe fault

Outside probes have a fault during flight. Analyze the faults and propose a solution. Plot the curves of the pressure probes with Excel for example. Use the FaultSensor scenario. Associate an alarm in case of breakdown. Your analysis must be delivered in the final report.

Req_36: Vertical acceleration

The pilot has to know the vertical acceleration. Propose an operator.

Req_37: Vertical acceleration alarm

An alarm is triggered if the vertical acceleration exceeds a threshold (positive/negative).

This alarm is stopped with the clearance from the pilot.

Req_38: Longitudinal acceleration

The pilot has to know the instantaneous longitudinal acceleration. Propose an operator.

Req_39: Longitudinal acceleration alarm

An alarm is triggered for 10 cycles if the longitudinal acceleration exceeds a threshold (positive/negative).

Req_40: Calculation of the pitch

Express the pitch in degrees. (pitch = slope + incidence).

Req_41: Calculation of the Mach number (see appendix)

Propose an operator that calculate the Mach number. This operator will also have to determine if the flight is subsonic, sonic, supersonic. Ma <1, Ma = 1, Ma >1

Req_42: Alarm / Mach
An alarm (over 10 cycles) must report the flight approaching a supersonic phase. Crossing to the supersonic phase is pre-evaluated at t+250 cycles.

Req_43: Load factor alarm

If the aircraft undergoes an excessive vertical and longitudinal acceleration for more than 5 cycles, an alarm has to be activated for 15 cycles. The acceleration thresholds can be adjusted.

Flight controls - cont.

Req_44.
The displacement speed of the elevators must be limited to 10 mm/second but inversely proportional to the speed of the aircraft, with a min of 2 mm/second. This does not apply to stalling. The max speed of the craft will be established at 800km/h.

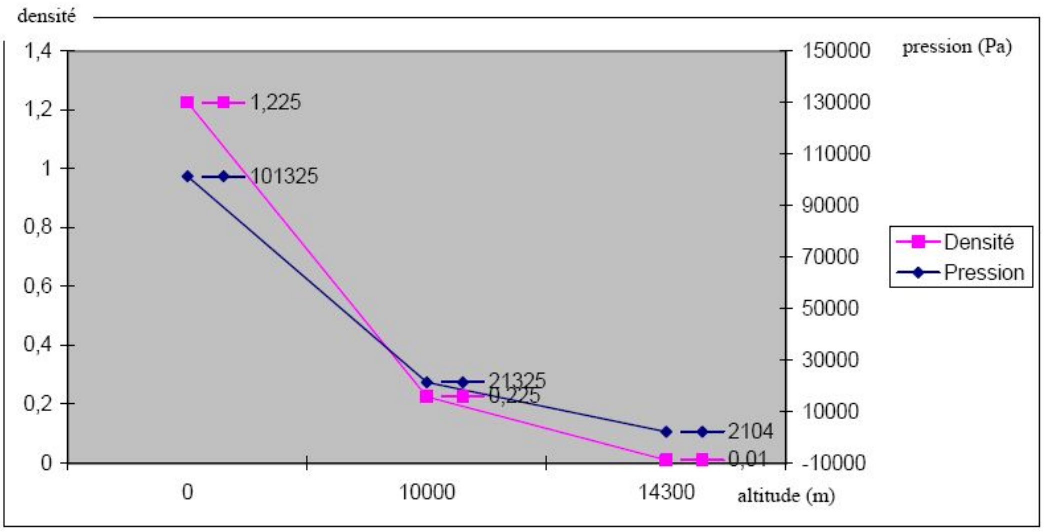
Req_45.
Climb and descent are carried out at a low slope. Given an approximation of $\sin\gamma$ and $tg\gamma$. Express γ in radians.

5 Behavior at launch

At launch, all of the computer memory is empty. The initialization values are therefore FALSE for the booleans, 0 for the integers and 0.0 for the reals.

APPENDIX 1 - Equations and formulas

<u>Relationships between the static pressure P0, the altitude and the density of the air ϱ.</u>



Giving the following formulas:

• if P0 < 21325

h = [(1 / 4.47) * (21325 - P0)] + 10000

• if P0 ≥ 21325

h = (1 / 8) * (101325 - P0)

• if h < 10000

ϱ = 1.225 - (h / 10000)

• if h ≥ 10000

ϱ = 0.745 - (h * 5.2.10-5)

<u>Calculation of the speed using Bernoulli's relationship</u>

$$\tfrac{1}{2}\rho V^2 + P_0 = P_a$$

<u>Calculation of the slope γ (the arcsin operator returns degrees)</u>

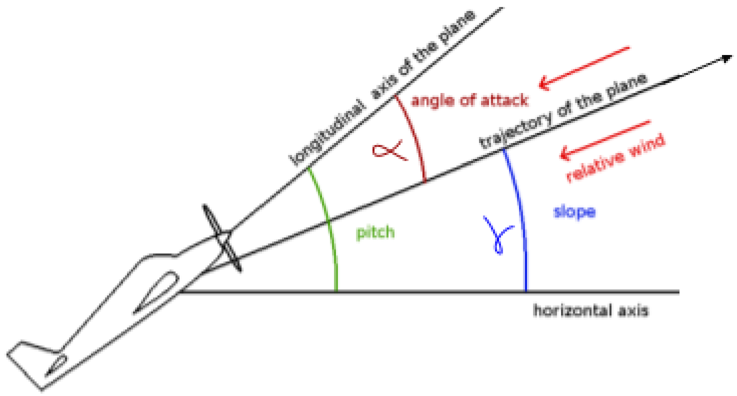
$$\sin(\gamma) = \frac{\frac{\Delta h}{\Delta t}}{V}$$

Speed of sound

Ma = U /a*

Ma: Mach number without unit
U: speed of the aircraft in m/s
a: sound velocity

Altitude (m) deg C	t m/s	a
-1000	21.5	344.111
0	15	340.294
1000	8.5	336.434
2000	2	332.529
3000	-4.5	328.578
4000	-11	324.579
5000	-17.5	320.529
6000	-24	316.428
7000	-30.5	312.274
8000	-37	308.063
9000	-43.5	303.793
10000	-50	299.463
11000	-56.5	295.069
20000	-56.5	295.069
25000	-51.5	298.455
30000	-46.5	301.803
35000	-36.1	308.649
40000	-22.1	317.633
45000	-8.1	326.369
50000	-2.5	329.799
51000	-2.5	329.799
52600	-6.98	327.058
55000	-13.7	322.903
60000	-27.7	314.070
65000	-41.7	304.982
70000	-55.7	295.614
75000	-66.5	288.179
80000	-76.5	281.120



Pitch (θ) = SLOPE(γ) + INCIDENCE(α)