Project work part 1, due at 12:00 on February 4

The programming in Matlab is individual work, all students must do their own programming. However, you are encouraged to discuss how to solve the problems in your project group and also in the workshop sessions.

There is one project report required for this course. The report is developed in steps starting with an introduction of the aircraft in general, followed by technical sections that are developed as the course progresses. For the first version of the report, which is due as stated above, there should be an introduction with a brief description of the SAAB J35 Draken aircraft and at least a performance model analysis resulting in a SEP graph as described below. Students aiming for a higher grade than D should make a serious effort also on solving the minimum time to climb problem as described below.

The model

The aircraft model is provided as a set of Matlab scripts that define the different functions needed to evaluate the performance. The data is only valid for a flying airplane with landing gear up.
The functions are:

File	Use	Description
fpl35.m	fpl35	Example use of the model
initfpl35.m	initfpl35;	Initialize the J35 model
initrm6.m	initrm6;	Initialize the engine model
cd0cal.m	cd0=cd0cal(mach)	Zero lift drag with area
ca0cal.m	ca0=ca0cal(mach)	Zero lift offset angle (deg)
clacal.m	cla=clacal(mach)	Lift slope (1/deg)
etacal.m	[eta,dxeta]=etacal(mach)	Induced drag coefficient
rm6cal.m	[thrust,fuelb]=rm6cal(mach,altkm,iebk)	Newton and kg/s
stdatm.m	[rho,aspeed,temp,press] = stdatm(altkm)	Standard atmosphere
xtpcal.m	xtp=xtpcal(fuelmass)	c.g. vs fuelmass

Study the script fpl35.m carefully to see how the model is used and how all quantities are defined. The Matlab files are stored in a unix archive file fpl35.tar (extract using **tar xvf fpl35.tar**) which you can download from bilda.kth.se, or if you are in on a different computational platform, the files are also given one by one. You will need to use a number of Matlab functions in this project. It is useful to carefully study the following functions: ode45, interp1, contour and fsolve.

1. Static performance

Perform the following set of analyses:

a) Compute excess thrust for altitudes 0:1:16 km and Mach number in the range 0 to 2. Assume loadfactor n_z=1, full thrust using afterburner in ISA 0 conditions, 30% fuel, and level flight ($\gamma = 0$).

   Write a Matlab function that gives excess thrust (N) as function of altitude (km), Mach number, mass (kg) and flight path angle (radians):

```
function [Tex]=texcess35(hkm,mach,mass,gamma)
```

Present your results in one graph with excess thrust on the y-axis and Mach number on the x-axis. There should be one curve for each altitude and all curves should be shown in one graph.

In the same graph, also give the envelope limits governed by $\alpha_{max} = 15$ degrees and a maximum dynamic pressure corresponding to 1350 km/h true airspeed at sea-level in ISA 0 conditions. The limits define the end points of each curve corresponding to one altitude.

b) Produce a so-called SEP-graph showing level curves of the specific excess power in a graph with Mach number on the x-axis and altitude on the y-axis. Make sure that one level curve corresponds to zero specific excess power. Add curves to the graph defining the envelope through α_{max} and dynamic pressure limits. Assume again n_z=1, 30% fuel and level flight.

c) What is the maximum altitude where this aircraft can fly level ($\gamma = 0$) in equilibrium?

d) Find the maximum Mach number that this aircraft can reach and sustain in this configuration (any altitude, n_z=1, 30% fuel).

2. Minimum time to climb

Define a performance analysis model of the aircraft using the model defined by the differential equations:

$$\begin{aligned} m\dot{V} &= T\cos(\alpha + \epsilon_T) - D - mg\sin\gamma \\ mV\dot{\gamma} &= T\sin(\alpha + \epsilon_T) + L - mg\cos\gamma \\ \dot{h} &= V\sin\gamma \\ \dot{x}_{\mathrm{E}} &= V\cos\gamma \\ \dot{m} &= -b \end{aligned}$$

Approximate the differential equations by assuming that accelerations perpendicular to the flight path are negligble giving,

$$\begin{aligned} m\dot{V} &= T\cos(\alpha + \epsilon_T) - D - mg\sin\gamma \\ \dot{h} &= V\sin\gamma \\ \dot{x}_{\mathrm{E}} &= V\cos\gamma \\ \dot{m} &= -b \end{aligned}$$

The angle-of-attack is obtained in each instance by solving the nonlinear algebraic equation

$$T\sin(\alpha + \epsilon_T) + L - mg\cos\gamma = 0$$

using for example Newton's method. The recommended procedure is to use a fixed number (5-10) iterations all the time or use a very strict termination condition ensuring that the algebraic equation is accurately solved.

Use one of matlab's ODE solvers, for example ODE45, to integrate the equations of motion for a given control. The flight path angle γ is used as control variable and should be given as a function of time. Use for example linear interpolation (Matlab interp1) based on a matrix of time nodes and gamma values. For example:

```
gamvec=[  0     0
        100    0
        200    0.2
        250    0.2
        300    0
     100000    0     ]
```

Defines a piecewise linear control as a function of time. The flight path angle γ can now be determined at any time t in the interval (0,100000) using a call to the matlab function:

```
gamma=interp1(gamvec(:,1),gamvec(:,2),t);
```

Try integrating the ODE using different control functions. Make sure to check that the flight path satisfies limits on C_L, dynamic pressure, fuelburn, and load factor.

Using your Matlab script, try solving the following problems:

a) Find $\gamma(t)$ giving the shortest time from altitude h=0.1 km and V=100 m/s to $h \geq 11$ km and $M \geq 1.5$.

b) Find the trajectory that reaches the maximum Mach number (as derived in part 1d) in minimum time from initial conditions h =0.1 km and V=100 m/s.

c) Find the trajectory that reaches the maximum altitude (as derived in part 1c) in minimum time from initial conditions h =0.1 km and V=100 m/s.

Your flight path must of course satisfy limits on α, dynamic pressure, load factor etc. The final fuel reserve should be at least 30% in both cases. Present your solution in graphs showing the state and control variables as functions of time. Plot the flight path in the SEP graph you produced in part 1 of the exercise.