

# MECH5675M Vehicle Systems Engineering

**Full Mark: 100%**

*(This is 30% of the final mark of the module.)*

Include all source codes including Simulink block diagrams.

Fail to include source codes would cause significant reduction in the marks.

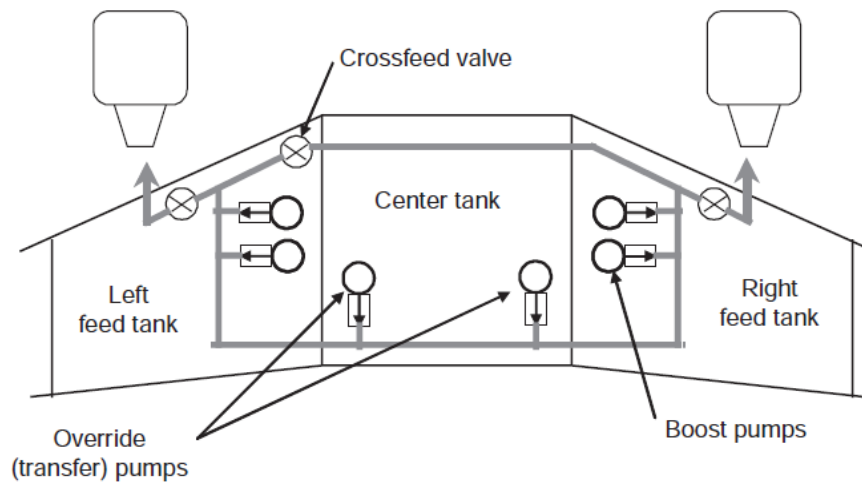
Submit your final report in pdf format through Minerva.

The submission link will be activated in April.

You are not allowed to discuss or share any codes, program, diagrams, etc, directly related to the term project assignment. Similarities in the programming & diagram are to be checked and copies of any part of source code/diagrams from others are considered as plagiarism.

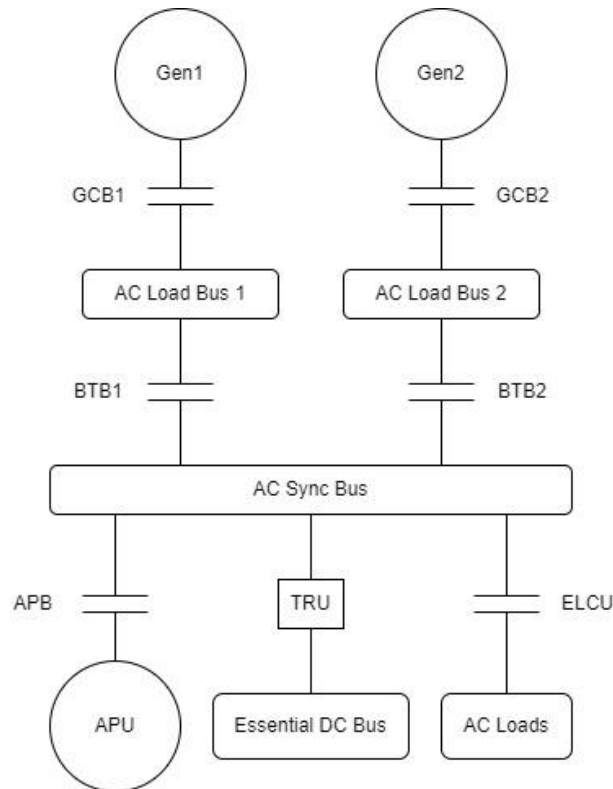
## Part 1

Use the correct SysML (Systems Modelling Language) elements to draw the diagrams in the following questions. For this task, you can use the Modelio software to draw SysML diagrams. Modelio (<https://www.modelio.org/>) is a freeware and can be installed on your computer. You can also use any other SysML drawing software that you may have access to.



**Figure Q1.1:** Twin Engine Fuel System Diagram.

1. Draw a **bdd** (block definition diagram) for the hardware of the fuel system presented in Figure Q1.1. **[15 marks]**



**Figure Q1.2:** Electric Power diagram.

2. Draw an **ibd** (internal block diagram) for the electric power **distribution** system presented in Figure Q2.2, including all signals from/to various components and subsystems. **[15 Marks]**

3. Draw the activity diagram (**act**) for the operation of a fuel jettison system for an aircraft. **[15 Marks]**

The jettison system requirements are given as:

- The flight crew shall be able to jettison excess fuel in an emergency situation in order that the aircraft may land under the maximum landing weight.
- The flight crew shall be able to jettison down to a preselected fuel quantity.
- The flight crew shall be given indications that fuel jettison is underway.
- The flight crew shall be given indications that fuel jettison is completed.

4. Draw an **ibd** (internal block diagram) for a FW UAV (Fixed-Wing Unmanned Aerial Vehicle with wing-tail configuration) roll attitude control algorithm including all signals from/to various components and subsystems including hardware and software subsystems, and components. **[10 Marks]**

## Part2

Given the simplified aircraft roll dynamic equation below.

$$I_{xx}\dot{p} = QS_w b C_l + QS_w b C_{lp} \left(\frac{b}{2U}\right)p$$

With  $C_l = C_{l\delta_a} \delta_a$  and  $Q = \frac{1}{2}\rho U^2$ .

$$C_{l\delta_a} = 0.5 /rad$$

$$C_{lp} = -0.25$$

$$U = 50 \text{ m/s}$$

$$S_w = 1.5 \text{ m}^2$$

$$b = 3 \text{ m}$$

$$-22^\circ \leq \delta_a \leq 20^\circ$$

$$\rho = 1.115 \text{ kg/m}^3$$

$$I_{xx} = 2.8 \text{ kg.m}^2$$

$p$  is the roll rate in radians per second (rad/s)

$C_{lp}$  is the roll damping coefficient; it is the change in roll moment coefficient with respect to change in roll rate

$\rho$  is the air density

$b$  is the wingspan of the aircraft

$U$  is the airspeed that the aircraft is flying at

$C_{l\delta_a}$  is the rolling control derivative; it is the change in roll moment coefficient with respect to change in aileron deflection angle

$\delta_a$  is the aileron deflection angle

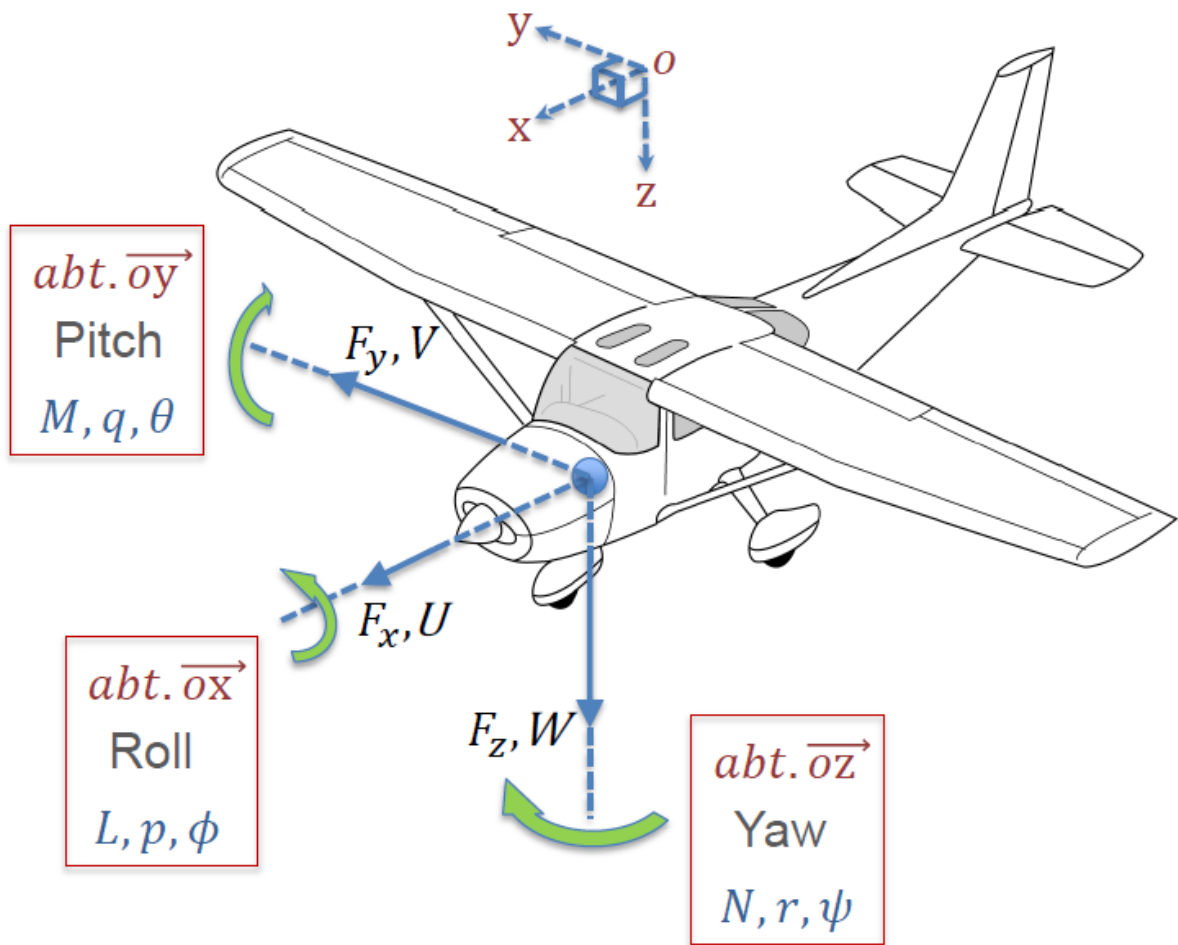
$I_{xx}$  is the moment of inertia about the roll axis

$S_w$  is the wing area

$Q$  is the dynamic pressure

1. Model the aircraft pitch dynamics in Simulink. Using the dynamic equation and the values provided, create a Simulink model that allows you to simulate the roll response for the following inputs. **[15 Marks]**
  - a. Implement the given equation(s) in Simulink and show a screenshot of your model.
  - b. Run the simulation for 2 seconds with the aileron deflection angle  $\delta_a$  at  $5^\circ, 10^\circ, 15^\circ$  and  $20^\circ$ .  
Plot the change in the resulting roll acceleration against time for the four deflection angles on the same plot. Do the same for the roll rate and roll angle against time.
  - c. What do you observe and what can you conclude.

2. Add a feedback controller to your model in order to allow the pilot to have control over the roll angle of the aircraft and allow the controller to maintain level flight. **[20 Marks]**
- Add a feedback controller (e.g. PID controller) in order to control the aircraft's roll angle based on a reference roll angle command. Show a screenshot of your model.
  - Adjust your controller gains so that the response to a  $30^\circ$  roll angle input with  $0^\circ$  initial condition has a settling time of less than 1.5 second with an error of  $\pm 0.2^\circ$  and no overshoot. Show the plot of the roll angle response and aileron deflections. Adjust the simulation time as appropriate.
  - Plot the variation of roll angle, roll rate and aileron deflection in response to pilot roll angle demands. Explain the response to the aileron deflections.  
 $\varphi_{pilot} = [-10, -5, 5, 7, 9, 0]$  with a 3 second separation between each command input. Adjust the simulation time as appropriate.
3. Your aim is to maintain level flight i.e. roll demand of  $0^\circ$ , simulate the response of the model to an initial condition of a roll angle  $\varphi = 30^\circ$ .  
Plot the variation of roll angle, roll rate and aileron deflections. Adjust the simulation time as appropriate. **[10 Marks]**



$F_x$  Axial 'Drag' Force  
 $F_y$  Side Force  
 $F_z$  Normal 'Lift' Force

$L$  Rolling Moment  
 $M$  Pitching Moment  
 $N$  Yawing Moment

$p$  Roll Rate  
 $q$  Pitch Rate  
 $r$  Yaw Rate

$U$  Axial Velocity  
 $V$  Lateral Velocity  
 $W$  Normal Velocity

Sum of the components of aerodynamic, thrust and weight forces (sometimes written X, Y, Z)

Sum of the components of aerodynamic, thrust and weight moments

Components of angular velocity

Total linear velocity components of the CG.