



University  
of Glasgow

ENG4014 Aerospace Design Project 4M  
Interim Report  
Group 8

School of Engineering  
College of Science and Engineering  
University of Glasgow

Anton Soderqvist, Fraser Morrison, Mark Sullivan, Matthew Murphy,  
Rafał Trzeciak, Saad Saeed and Tomas Coelho

January 19, 2022

# Contents

<b>1</b>	<b>Introduction</b>	<b>2</b>
<b>2</b>	<b>Market Analysis and Concept Selection</b>	<b>3</b>
<b>3</b>	<b>Concept Summary and Aircraft Layout</b>	<b>4</b>
<b>4</b>	<b>Design Analysis and Feasibility</b>	<b>5</b>
4.1	Safety . . . . .	5
4.2	Center of gravity (Fraser and Rafał) . . . . .	5
4.2.1	Method of Analysis . . . . .	5
4.2.2	Matlab code . . . . .	6
4.2.3	Consequence of result of code on design decisions . . . . .	6
4.3	Delivery release system and Tank Pressurisation (Anton and Fraser) .	6
4.4	Structural Support (Matthew) . . . . .	7
4.4.1	Floor structure . . . . .	7
4.4.2	Beam calculations . . . . .	7
4.4.3	Stress distribution . . . . .	8
<b>5</b>	<b>Draft Plans for the Preliminary Design Stage</b>	<b>12</b>
<b>6</b>	<b>Conclusions</b>	<b>13</b>
<b>7</b>	<b>Project Plan</b>	<b>14</b>
<b>A</b>	<b>Center of gravity MATLAB code</b>	<b>16</b>
<b>B</b>	<b>Structural MATLAB code</b>	<b>18</b>

# Chapter 1

## Introduction

Introduction here

## Chapter 2

# Market Analysis and Concept Selection

Market Analysis and Concept Selection here

# Chapter 3

## Concept Summary and Aircraft Layout

Concept Summary and Aircraft Layout here

# Chapter 4

## Design Analysis and Feasibility

### 4.1 Safety

Safety here

### 4.2 Center of gravity (Fraser and Rafał)

Seeing as the RJ100 is originally a commercial aircraft, converting it to a firefighter aircraft would result in a lot of unnecessary weight, for example passenger seats, kitchen and cabin bins ect. This allows the plane to carry more retardant, meaning better performance for this specific application. However, by removing the excess weight, the center of gravity is shifted and thus will need to be recalculated. The RJ100 has an acceptable safe range for the center of gravity as a percentage of the chord length is 28% to 44%. The plane cannot fly safely if the value of the center of gravity along the x-axis of the plane is outwith this range. The center of gravity also has to remain within this range before, during and after the ejection of retardant.

#### 4.2.1 Method of Analysis

The process of calculating center of gravity is relatively trivial but can be time consuming if done if done by hand, especially in this case where there are lots of components being removed, greatly altering the mass. Using MATLAB instead of hand calculations greatly simplifies the process of changing individual values such as the mass, or the position of objects in the plane, to help achieve the safe center of gravity position.

According to [Baker & Haynes \(2020\)](#) the formula for the x,y and z value of the center of gravity are shown in the equation 4.2:

$$\bar{x} = \frac{\sum \bar{x}_i m_i}{\sum m_i} \quad \bar{y} = \frac{\sum \bar{y}_i m_i}{\sum m_i} \quad \bar{z} = \frac{\sum \bar{z}_i m_i}{\sum m_i} \quad (4.1)$$

The aircraft mass and center of gravity, before excess weight removal, can effectively be represented in equation 4.2 as a particle with known mass and position. By representing the aircraft in this way, the center of gravity after the removal of unnecessary weight can be calculated. The mass of the components to be removed are taken as negative, removing them from the original total mass.

### 4.2.2 Matlab code

Applying the method above, code was written in MATLAB to calculate the new cg position through implementing equation 4.2, see appendix A.

The data for the components to be removed were formatted into an excel file named “aircraftitems.xlsx” and then imported to be represented in the variable “Data”. This data included each component’s mass and it’s center of gravity position. These position’s were taken relative to the standard aircraft axis with the origin at the nose of the aircraft.

### 4.2.3 Consequence of result of code on design decisions

The position of the tank along the aircraft was tweaked in order to find a result from the MATLAB code that allowed the position of the center of gravity in the x axis was within the safe limits of 28% to 44% of the mean aerodynamic chord. The value of the x position of the center of gravity of the tank was found to be 16m away from the nose of the aircraft. This position of the tank results in a center of gravity position of the airplane of 44% of the aerodynamic chord with the tank full of retardant and 28% when the tank is full.

## 4.3 Delivery release system and Tank Pressurisation (Anton and Fraser)

Delivery system ect... here

## 4.4 Structural Support (Matthew)

### 4.4.1 Floor structure

To support the retardant tank in the aircraft selected, we initially tested the option of removing the floor of the aircraft cabin. This would release additional weight for retardant and would allow for free placement of the tank anywhere in the cabin. Through further research, however, it was discovered that the floor section of the cabin provides extra support for the frame which when removed could increase the likelihood of failure in our aircraft. Also, the floor structure is lightweight due to the use of a honeycomb structure cast from a high-density composite material as shown in Figure (Honeycomb structure in aircraft flooring). Thus, the removal will not reduce the weight significantly enough to remove it and suffer from the reduced structural strength.

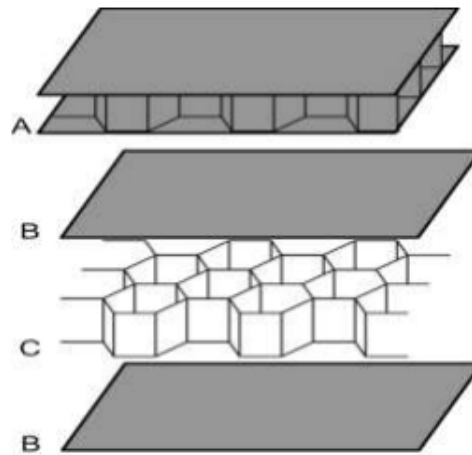


Figure 4.1: Honeycomb structure in aircraft flooring

As the floor panel is to be kept, further structural support for the placement of the tank was considered. A consideration could be to change the material of the floor beams from aluminum to CFRP (Carbon Fibre Reinforced Plastics), these have a lower weight whilst having higher strength and durability compared to an Aluminum floor.

### 4.4.2 Beam calculations

The final length of the tank was estimated using a standard radius of 1.03m which would suitably fit in the aircraft cabin and using a length of 6.55m which resulted in a  $15.14m^3$  volume tank. To support the tank four webs were designed to calculate the resulting stresses and loads, these webs were equally spaced with one at each end



as shown in Figure 4.3

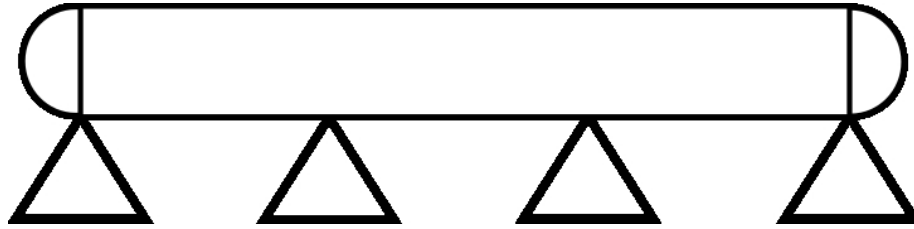


Figure 4.2: Tank supported by four equally spaced webs

For the initial calculations the web shape is simplified as shown in figure 3 which will be further refined using FE analysis to gather an accurate final value for the stress distribution. The structure is split into 3 sections as shown and the data representing the sections is displayed in Table (Web structure geometry dimensions).

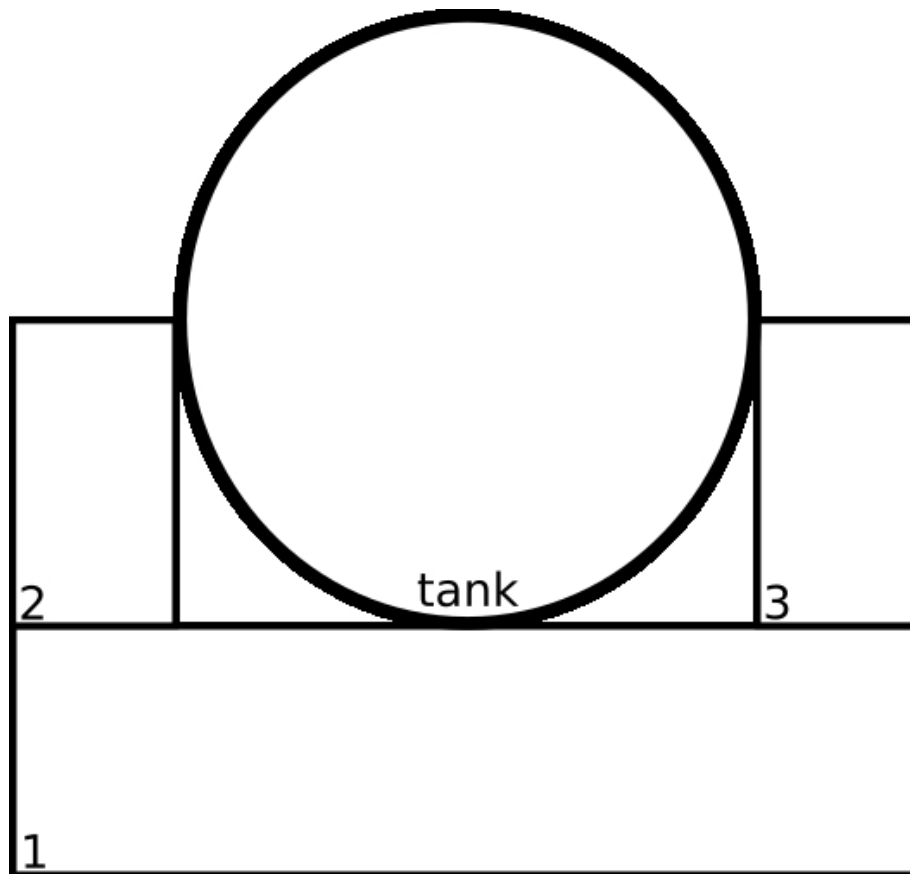


Figure 4.3: Simplified web structure

#### 4.4.3 Stress distribution

The formulae used in these calculations are all standard structural equations as shown to allow for initial estimates:

Sections	Length(m)	Height (m)
1	2.06	0.27
2	0.2	1.17
3	9.2	1.17

Table 4.1: Web Structure geometry dimensions

$$I_{yy} = \frac{1}{12}db^3 + A(\bar{x} - x_i)^2$$

$$Z_e = \frac{I_{yy}}{(y_{top} - \bar{y})}$$

$$Z_{e_{bottom}} = \frac{I_{yy}}{(y_0 - \bar{y})}$$

$$R_y = \frac{FL}{4} \tag{4.2}$$

$$M_{C/D} = LR_y - \frac{4}{18}FL^2$$

$$Stress = \sigma = \frac{M}{Z_e}$$

$$Load = \sigma \times Length \times Thickness$$

The tank is treated as a uniformly distributed load along the length of the supports and calculations were made at the supports located centrally as these will have the maximum value of stress. The calculations can be seen in appendix B.

From these simple calculations a stress distribution plot was produced (Figure 4.4) allowing us to analyse the initial feasibility of a four-support system and estimate the total load.

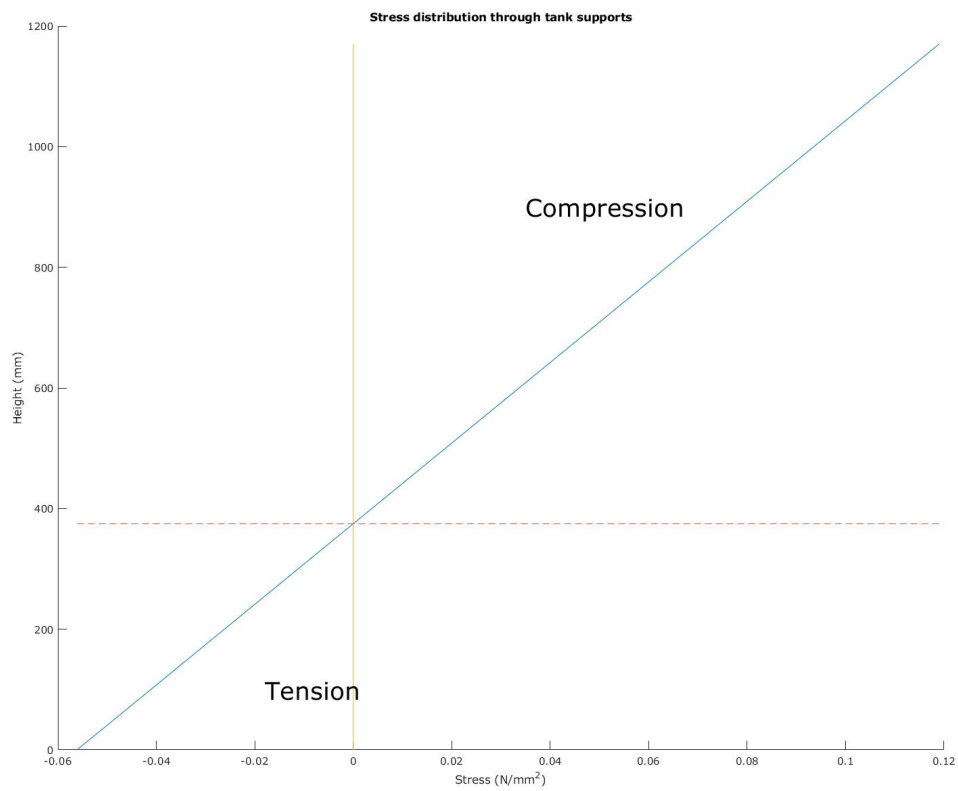


Figure 4.4: Stress distribution on central supports

We will need to consider the maximum stress at the bottom of the support to ensure the floor panels in the aircraft have the structural strength to withstand this load. To allow for enough space between the supports the thickness was estimated as  $0.1m$  which will add  $277.6kg$  to the overall weight of the aircraft reducing the maximum payload achievable slightly. This value of weight is if the material chosen is aluminum with a density of  $2710kg/m^3$ , chosen as it is regularly used in structural support of aircraft due to its high material strength properties. Using the stress displayed in figure 4.4 the total load at the bottom of each support is  $18.52kN$  which will need to be considered when the supports are fixed to the floor. The maximum stress value is equivalent to  $0.12MPa$  at the top of the structure so the chance of failure is miniscule as shown in the stress-strain curve of aluminium in figure 4.5. This value of stress is a considerable distance from failure and even yield so the number of supports could be reduced to save weight in further analysis.

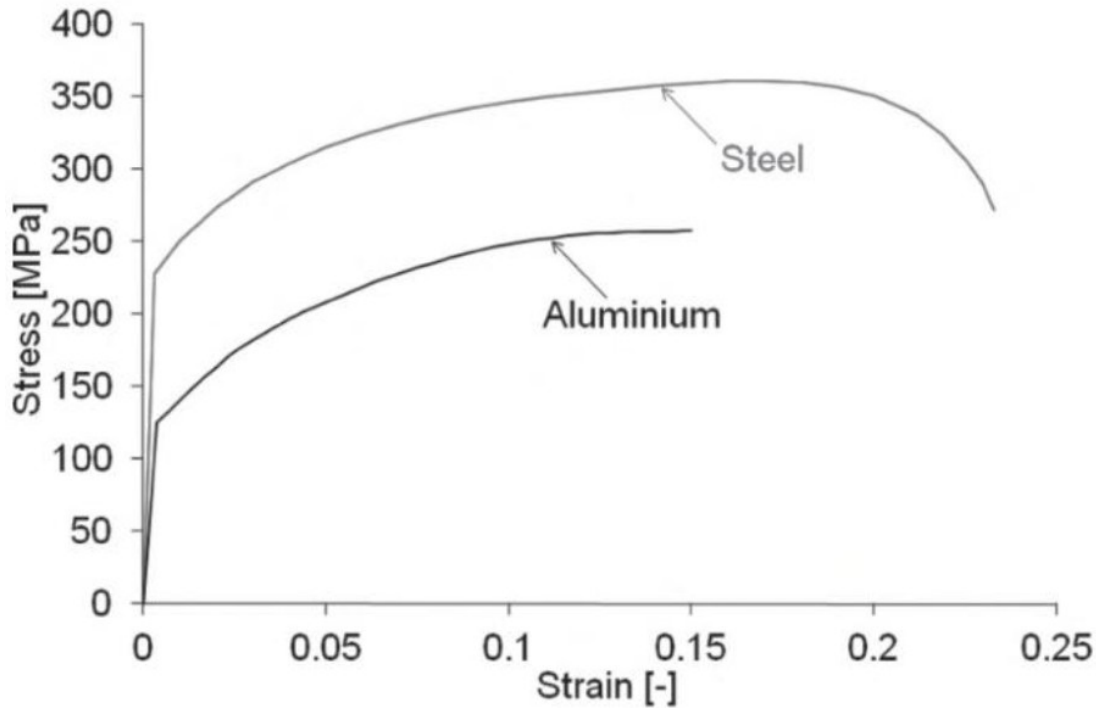


Figure 4.5: Stress-strain curve for steel and aluminum [Liu et al. \(2013\)](#)

# Chapter 5

## Draft Plans for the Preliminary Design Stage

Draft Plans for the Preliminary Design Stage here

# Chapter 6

## Conclusions

Conlusions here

# Chapter 7

## Project Plan

project plan here

# References

Baker, D. W., & Haynes, W. (2020). Engineering statics: Open and interactive.

Liu, B., Villavicencio, R., & Soares, C. G. (2013). Failure characteristics of strength-equivalent aluminium and steel plates in impact conditions. *Analysis and Design of Marine Structures*, vol., no, 167.



# Appendix A

## Center of gravity MATLAB code

```
1 clc
2 clear
3 close all
4 format long g
5
6 Data = readtable("aircraft_items.xlsx"); %import data from excel file
7
8 starting_mass=37875; %starting mass in kg (operational empty weight 25600)(Operational zero fuel mass
   37875)
9 absolute_cog_to_nose=14 + 1.719; %%distance from nose to the wing start + x_mgc
10
11 cg.x=-1*(absolute_cog_to_nose+1.239056); % starting cg x position
12 cg.y=0; %starting cg y position
13 cg.z=0; %starting cg z position
14
15 %starting moment of inertia tensor values
16 I_convert=1.3558179619; %slug*ft^2 to kg/m
17
18 I.xx=533965*I_convert;
19 I.xy=0*I_convert;
20 I.xz=59261*I_convert;
21 I.yx=I.xy;
22 I.yy=607525*I_convert;
23 I.yz=0*I_convert;
24 I.zx=I.xz;
25 I.zy=I.yz;
26 I.zz=1019696*I_convert;
27
28 %calculating new cg
29 cg_sum.x=starting_mass*cg.x;
30 cg_sum.y=starting_mass*cg.y;
31 cg_sum.z=starting_mass*cg.z;
32
33 end_mass=starting_mass;
34
35 for i=1:height(Data)
36
37     %extract mass,x,y and z values from file for object
38     mass=Data{i,2};
39     x=Data{i,3};
40     y=Data{i,4};
41     z=Data{i,5};
42
43     %take away object mass
44     end_mass=end_mass - Data{i,2};
45
46     cg_sum.x=cg_sum.x - (mass*x);
47     cg_sum.y=cg_sum.y - (mass*y);
48     cg_sum.z=cg_sum.z - (mass*z);
49
50 end
51
52 %calculate new cg position
53 cg_new.x=cg_sum.x/end_mass;
54 cg_new.y=cg_sum.y/end_mass;
55 cg_new.z=cg_sum.z/end_mass;
56
57 %print new cg position
58 cg_new
59 %print new mass
60 end_mass
61
62 %calculate and print value of cg position in x axis as a fraction of the
63 %MAC
```

```
64 | cg_from_mac = cg_new.x + absolute_cog_to_nose;  
65 | fraction_of_mac = cg_from_mac / - 3.404
```

# Appendix B

## Structural MATLAB code

```
1 %Beam tank calculation
2 clc
3 clf
4 %element data
5 length1=2060;
6 height1=270;
7 length2=200;
8 height2=1170;
9 length3=200;
10 height3=1170;
11 thickness=200;
12 %area of each element
13 area1=length1*height1;
14 area2=length2*height2;
15 area3=length3*height3;
16 atotal=area1+area2+area3;
17
18 %individual cg values
19 ycg1=height1/2;
20 ycg2=height1+(height2/3);
21 ycg3=height1+(height3/3);
22 xcg1=(length1/2)+200;
23 xcg2=length2/2;
24 xcg3=(length3/2)+200+2000;
25 %total cg
26 ycg=((area1*ycg1)+(area2*ycg2)+(area3*ycg3))/atotal;
27 xcg=1200;
28 %2nd moments of inertia
29 inertia1=((1/12)*length1^3*height1)+(area1*(xcg1-xcg));
30 inertia2=((1/12)*length2^3*height2)+(area2*(xcg2-xcg));
31 inertia3=((1/12)*length3^3*height3)+(area3*(xcg3-xcg));
32
33 totalInertia=inertia1+inertia2+inertia3;
34
35 %tank data
36 length=6550;
37 F=(16623*9.81)/length;
38 supports=4;
39 sections=supports-1;
40 momentLength=0;
41 loadLength=0;
42
43
44 %Resultants
45 Ry=(F*length)/supports;
46
47 %Moment
48 Mmax=(Ry*length)-((F*length^2)*(4/18));
49
50 %stress positive downwards (compression)
51 ZETop=totalInertia/(height2-ycg);
52 ZEBottom=totalInertia/(0-ycg);
53
54 stressTop=Mmax/ZETop;
55 stressBottom=Mmax/ZEBottom;
56
57 totalweight=0.1*2710*(atotal*10^-6);
58 %total load with 0.1m thick aluminium
59 totalLoad=(stressBottom*(length1+length2+length3)*(thickness))/1000;
60 %plotting stress at top/bottom
61 %stress in compression at top
62 %stress in tension at bottom
63 x=[stressTop, stressBottom];
64 y=[height2, 0];
```

```
65 xconstant=[0,0];
66 yconstant=[ycg,ycg];
67 hold on
68 %plot stress distribution
69 plot(x,y);
70 plot(x,yconstant,'—');
71 plot(xconstant,y);
72 hold off
73 ylabel('Height (mm)');
74 xlabel('Stress (N/mm^2)');
75 title('Stress distribution through tank supports')
76 txt = 'Compression';
77 t=text(0.035,900,txt);
78 t.FontSize=24;
79
80 txt2 = 'Tension';
81 m=text(-.018,100,txt2);
82 m.FontSize=24;
```