Toy Model of an Aero Vehicle "RR"

The purpose of this "toy" simulation is to estimate and evaluate the performance of a air vehicle I am calling "RR" based on what little information I am able to gather on the web about a similar real world product and time available. The overall planform dimensions were generated by importing a picture into 2D cad software (ref: https://librecad.org/) and scaling the image based on the estimated height of the person in the picture.

Table of Contents

```
%clear; %clear the workspace
```

English units

This simulation uses English units.

unit	desc
ft	length
lbf	weight
slug	mass
s	time
degrees	angle

Globals

```
G=32.174; %ft/s^2
```

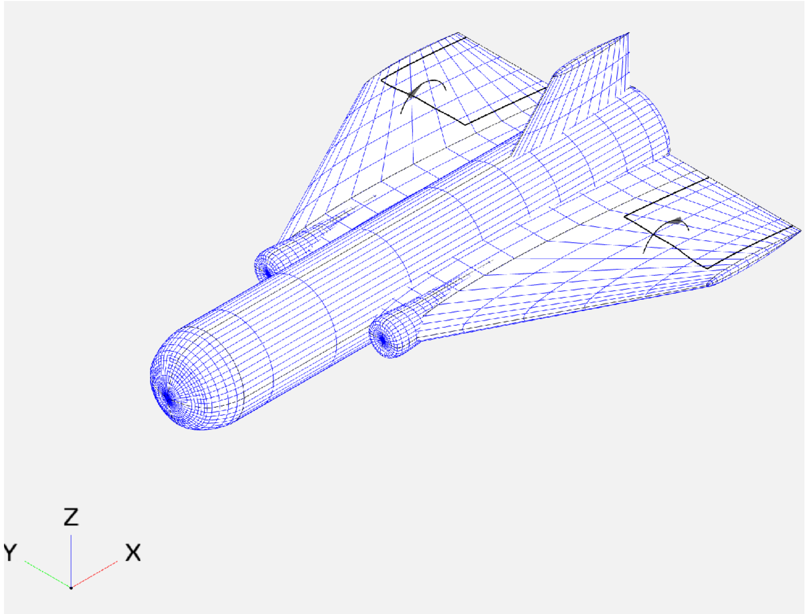
Simulation Limits

The simulation is limited to altitudes less than 30,000 ft and speeds less than mach 0.9.

parameter	value
mach	0.0 to 0.9

altitude	0.0 to 30,000

Vehicle



The planform measurements were transferred into OpenVSP and a 3D model was created as seen in the image above.

ref: https://openvsp.org/

```
RR_Len=5; %ft (from OpenVSP)
RR_Span=3.6; %ft (from OpenVSP)
RR_AERO_S=8.85; %ft^2 (from OpenVSP)
RR_AERO_CORD=2.575; %ft (from OpenVSP)
```

For the vehicle airframe, I assume a light composite structure with very little metal, and estimate it at some factor heavier than high density foam.

ref: https://www.owenscorning.com/en-us/insulation/products/foamular-250

```
High_Density_Foam_Density=150/1000/1*12 ; %lbf/1000ft^2 1 in thick, 12in/ft -> lbf/ft^3
RR_Airframe_Mass_Density=1.5*High_Density_Foam_Density/G %slugs/ft^3
```

```
RR_Airframe_Mass_Density = 0.0839
```

Propulsion

For propulsion I am using two Jet Cat turbojet engines and carrying two gallons of fuel.

ref: https://www.jetcat.de/jetcat/anleitungen/DataSheet-P220-PRO-Versions-01-2023.pdf

```
% Thrust range: 9-220N
RR_Motors_Thrust=convforce(2*[9,220],'N','lbf') %lbf
```

```
RR_Motors_Thrust = 1×2
    4.0466   98.9159
```

```
RR_Fuel_Weight=2*6.8 %lbf 2 gallon kerosene
```

```
RR_Fuel_Weight = 13.6000
```

```
RR_Fuel_Mass=RR_Fuel_Weight/G %slugs
```

```
RR_Fuel_Mass = 0.4227
```

```
% gal ft^3/7.48052gal
RR_Fuel_Volume=2.0/7.48052 %ft^3
```

```
RR_Fuel_Volume = 0.2674
```

```
% Fuel consumption: 130-725 ml/min l/1000ml min/60s ft^3/28.317l
RR_Fuel_Consumption=[130,725]/1000/60/28.317 %ft^3/s
```

```
RR_Fuel_Consumption = 1×2
10^-3 ×
    0.0765    0.4267
```

```
% Fuel mass rate (dm/dt), ft^3/s 7.48052gal/ft^3 6.8lbf/gal 1/G
RR_Fuel_Mass_Rate=RR_Fuel_Consumption*7.48052*6.8/G % slugs/s
```

```
RR_Fuel_Mass_Rate = 1×2
10^-3 ×
    0.1210    0.6746
```

```
RR_Fuel_Time=RR_Fuel_Volume/RR_Fuel_Consumption(2) % s
```

```
RR_Fuel_Time = 626.5543
```

```
RR_Mass_Fuel_Time=RR_Fuel_Mass/RR_Fuel_Mass_Rate(2) % s, validate
```

```
RR_Mass_Fuel_Time = 626.5543
```

The minimum mission time is ~10 minutes at full throttle before two gallons of fuel are exhausted.

```
% Weight: 1850g
RR_Motors_Mass=convmass(2*1850/1000,'kg','slug') %slugs
```

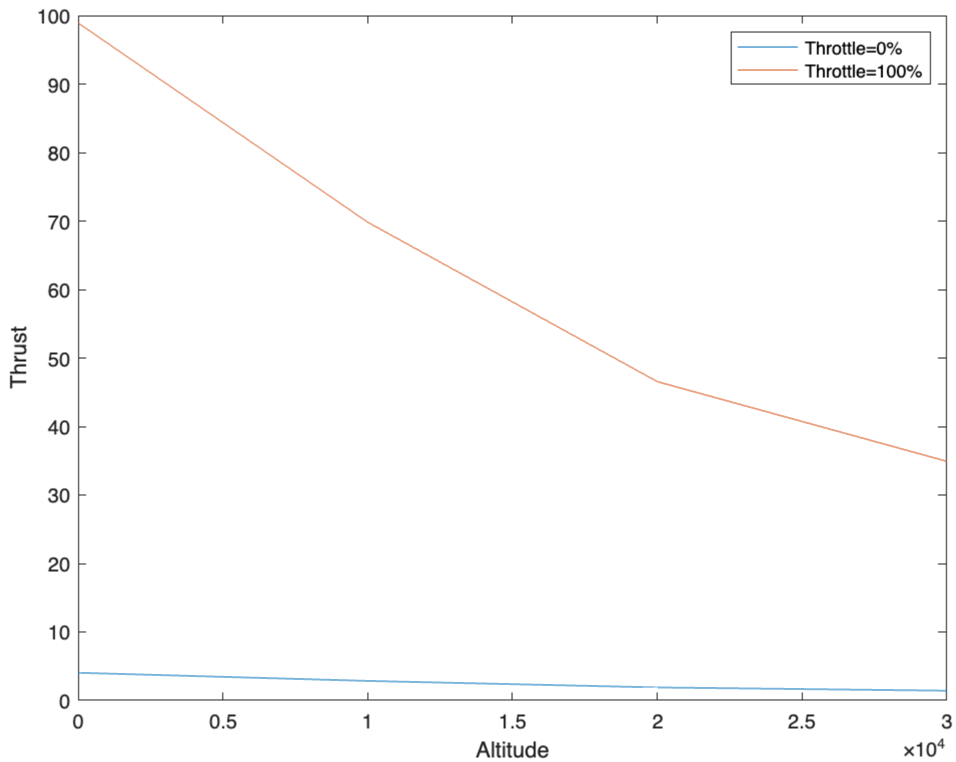
```
RR_Motors_Mass = 0.2535
```

```
RR_Motors_Weight=RR_Motors_Mass*G %lbf
```

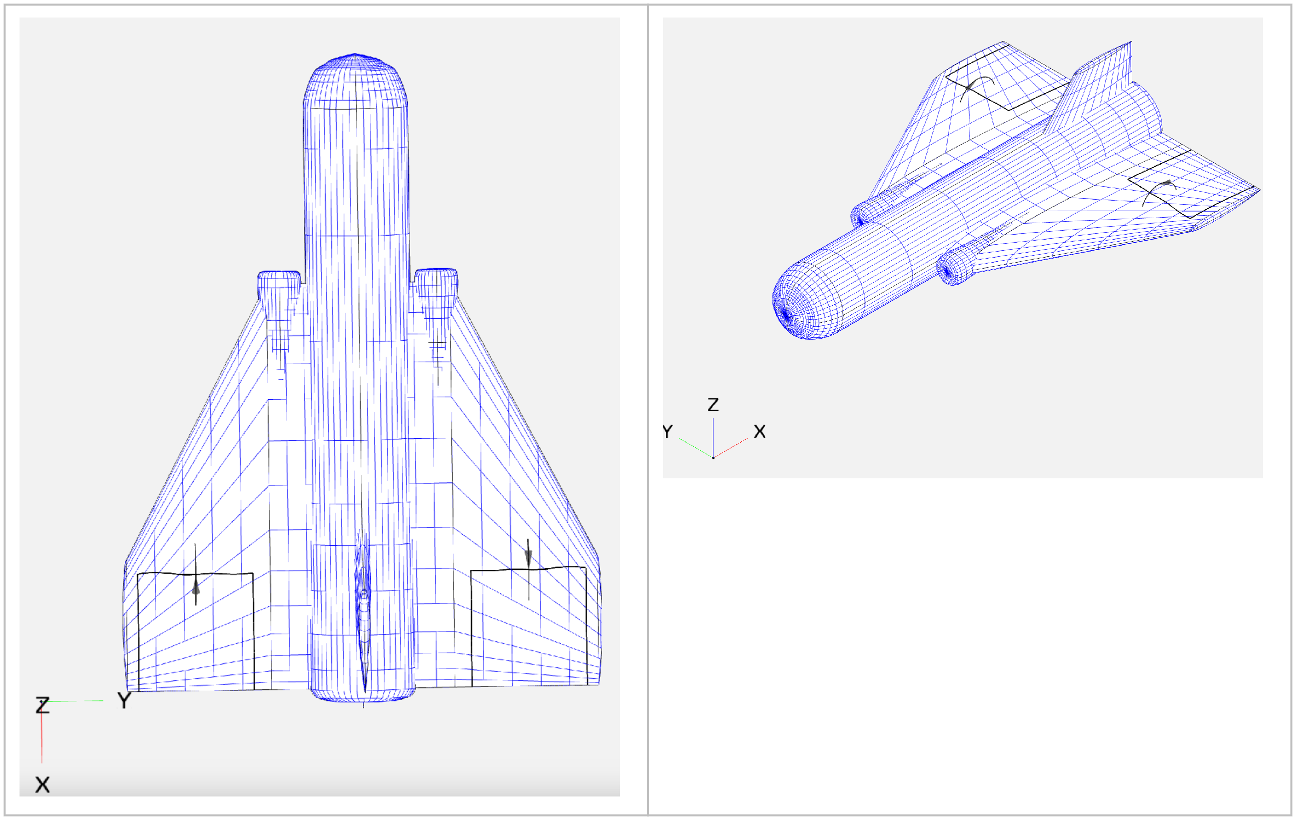
```
RR_Motors_Weight = 8.1571
```

The motors thrust is estimated to decrease with altitude using a curve I found on the web. This would have to be followed up on with the vendor.

```
%Thrust vs Alt LUT (estimate)
RR_Motors_Thrust_Alt_Lut= [0.0 10000.0 20000.0 30000.0];
RR_Motors_Thrust_Pct_Lut= [17.0 12.0 8.0 6.0]/17.0;
%set(0,'DefaultAxesFontSize', 15);
plot(RR_Motors_Thrust_Alt_Lut,RR_Motors_Thrust_Pct_Lut*RR_Motors_Thrust(1), ...
    RR_Motors_Thrust_Alt_Lut,RR_Motors_Thrust_Pct_Lut*RR_Motors_Thrust(2));
xlabel('Altitude');
ylabel('Thrust');
legend('Throttle=0%','Throttle=100%')
```



Aero Model



To determine the aerodynamic performance of the airframe, the OpenVSP 3D model was created as seen in the image above along with its coordinate axis. The origin of the simulation coordinate system is located at the center leading edge of the main wing.

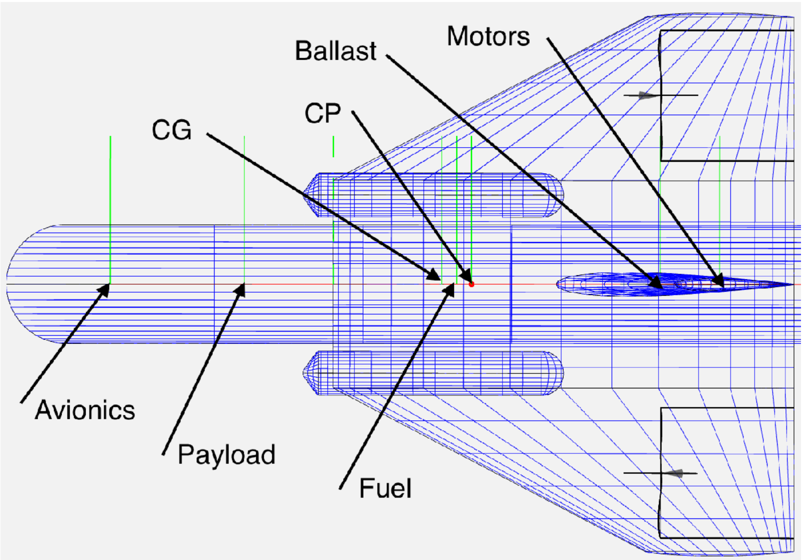
Aerodynamic Center

Using OpenVSP/VSPAERO a pitch stability simulation was run with the CG set to the origin to find the aerodynamic center.

parameter	value
mach	0.15
AoA	1
Xcg	0

```
RR_Aerodynamic_Center=0.9278426; %ft from leading edge of wing (from OpenVSP)
```

Center of Gravity and Mass Rollup



Knowing the aerodynamic center, OpenVSP mass properties analysis was run to calculate the overall mass of the vehicle and I set the center of gravity slightly ahead of aerodynamic center for stability. Ballast was required in this case to move the center of gravity to the desired location.

```
%Remaining inputs for the mass model
RR_Avionics_Weight=10; %lbf (guess)
RR_Avionics_Mass=RR_Avionics_Weight/G %slugs
```

```
RR_Avionics_Mass = 0.3108
```

```
RR_Payload_Weight=10; %lbf (guess)
RR_Payload_Mass=RR_Payload_Weight/G %slugs
```

```
RR_Payload_Mass = 0.3108
```

```
RR_Ballast_Mass=0.35; %slugs to move CG
RR_Ballast_Weight=RR_Ballast_Mass*G %lbf
```

```
RR_Ballast_Weight = 11.2609
```

```
RR_Airframe_Mass=0.1319+0.1836+2*0.00312+2*0.00197 % slugs (from OpenVSP)
```

```
RR_Airframe_Mass = 0.3257
```

```
RR_Total_Mass=1.974; % slugs (from OpenVSP)
RR_CG=0.732; %ft from leading edge of wing (from OpenVSP)
RR_Iyy= 4.432; %slug-ft^2 (from OpenVSP)
RR_Total_Weight= RR_Total_Mass*G %lbf
```

```
RR_Total_Weight = 63.5115
```

```
RR_Total_Dry_Weight= RR_Total_Weight-RR_Fuel_Weight %lbf
```

```
RR_Total_Dry_Weight = 49.9115
```

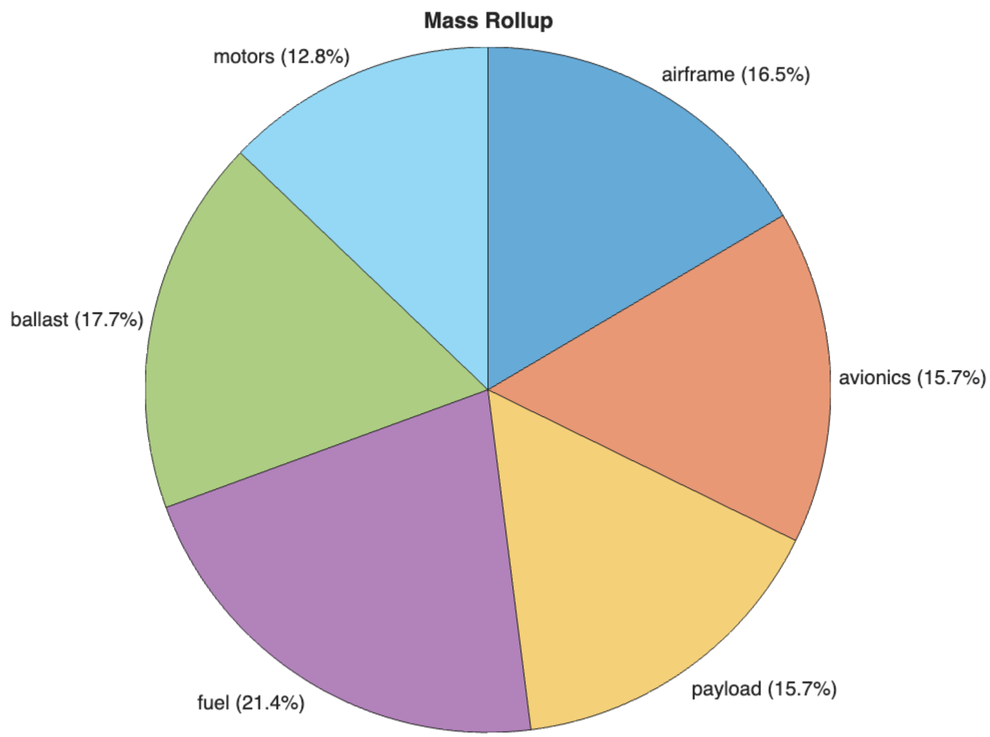
```
RR_Total_Dry_Mass=RR_Total_Dry_Weight/G %slugs
```

```
RR_Total_Dry_Mass = 1.5513
```

```
RR_Thrust_To_Weight=RR_Motors_Thrust(2)/RR_Total_Dry_Weight
```

```
RR_Thrust_To_Weight = 1.9818
```

```
h=piechart([RR_Airframe_Mass RR_Avionics_Mass RR_Payload_Mass ...
    RR_Fuel_Mass RR_Ballast_Mass RR_Motors_Mass], ...
    ["airframe" "avionics" "payload" "fuel" "ballast" "motors"]);
h.Title='Mass Rollup';
```



Stability

After setting the center of gravity, OpenVSP/VSPAERO was run with stability on to find the stability margin.

parameter	value
mach	0.15
AoA	0
Xcg	0.732

```
RR_X_CG=0.7324250; % ft from leading edge of wing (from OpenVSP)
RR_SM=0.0716877; % 7% stablity margin (OpenVSP, 5-40% typical range)
RR_X_NP=0.9170209; % ft from leading edge of wing (from OpenVSP)
```

```
RR_CMYQ=-1.210696; % pitch moment dampening (from OpenVSP)
```

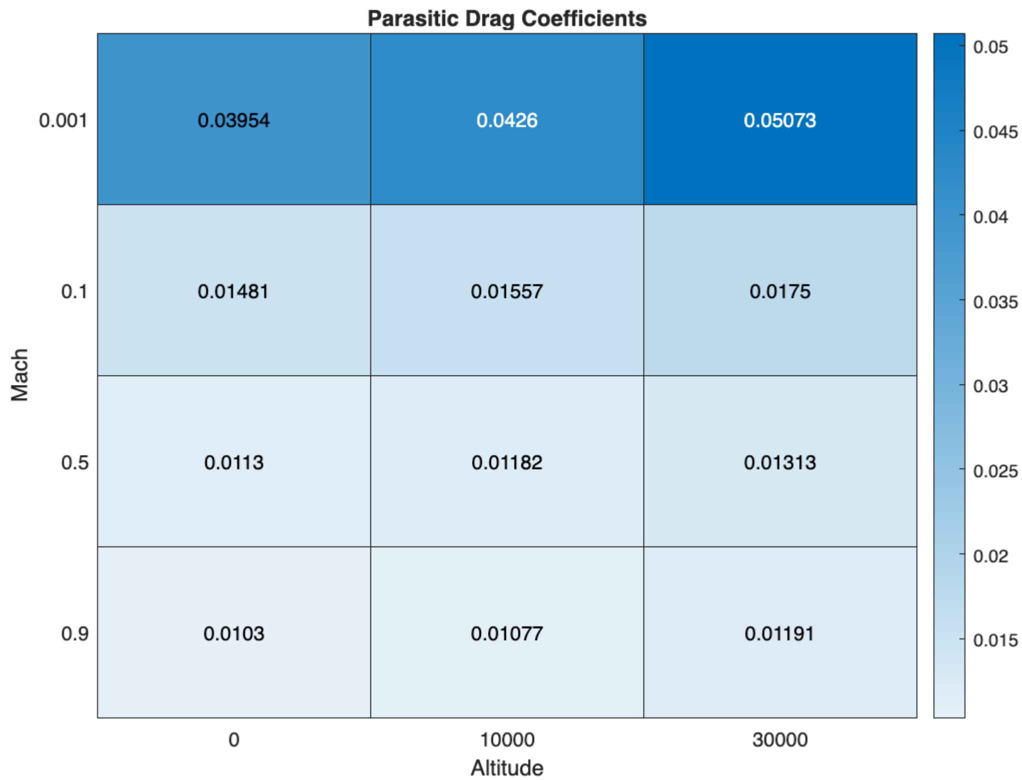
With the current center of gravity, the result is seven percent positive stability margin which is adequate but will still allow for aggressive maneuvering.

Parasitic Drag

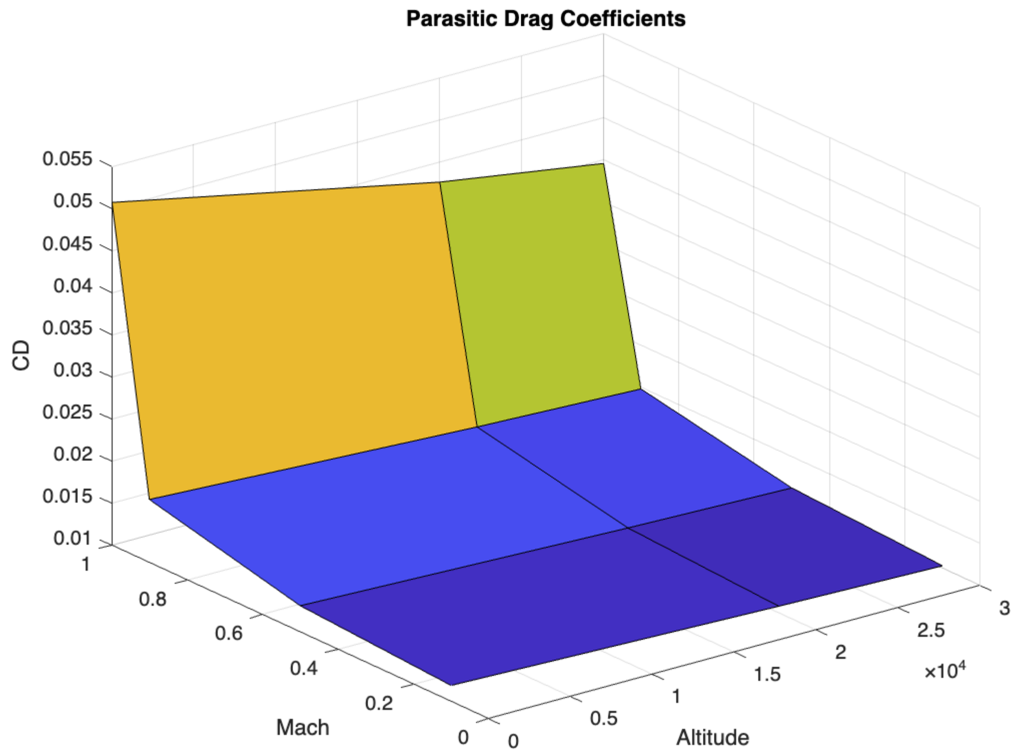
Zero angle of attack drag was simulated using the parasitic drag tool in OpenVSP and look up tables were generated.

parameter	value
mach	0.001 to 0.9
altitude	0 to 30,000

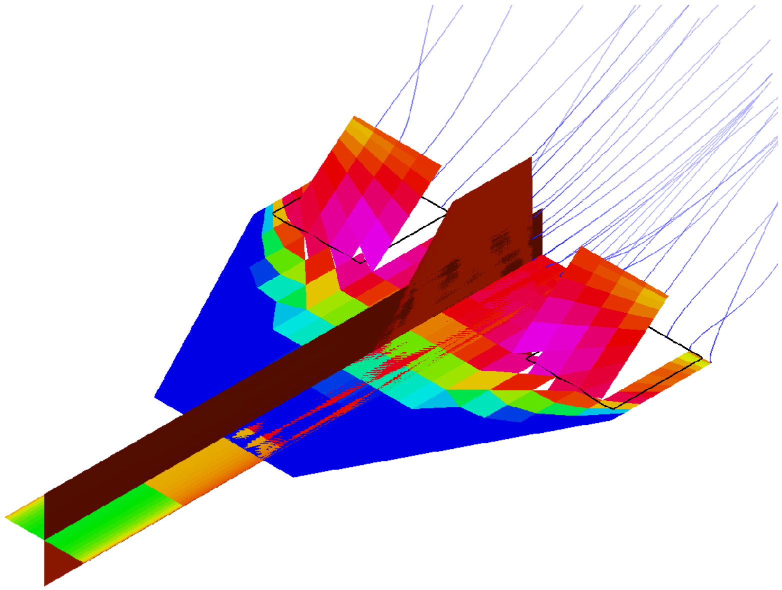
```
% 2D Parasitic Drag lookup table (from OpenVSP)
RR_PD_ALT=[0.0 10000.0 30000.0];
RR_PD_MACH=[0.001 0.1 0.5 0.9];
RR_PD_CD=[ 0.03954 0.04260 0.05073;
    0.01481 0.01557 0.01750;
    0.01130 0.01182 0.01313;
    0.01030 0.01077 0.01191; ];

h=heatmap(RR_PD_ALT,RR_PD_MACH,RR_PD_CD);
h.Title = 'Parasitic Drag Coefficients';
h.XLabel = 'Altitude';
h.YLabel = 'Mach';
```




```
h=surf(RR_PD_ALT,RR_PD_MACH,RR_PD_CD);
title('Parasitic Drag Coefficients');
xlabel('Altitude');
ylabel('Mach');
zlabel('CD');
rotate(h,[0 0 1],180);
```



Aerodynamic Forces



To collect data for the X,Y,Pitch simulation in Simulink, the angle of attack and elevon angle was varied in OpenVSP/VSPAERO and look up tables were generated. The fin and wing use symmetrical airfoils which is why there is symmetry in the results.

parameter	value
mach	0.01 to 0.9
AoA	-40 to 40
elevons	-40 to 40

```
run("aero.m");

RR_Aero_Aoa
```

```
RR_Aero_Aoa = 1×9
   -40   -20   -10    -5     0     5    10    20    40
```

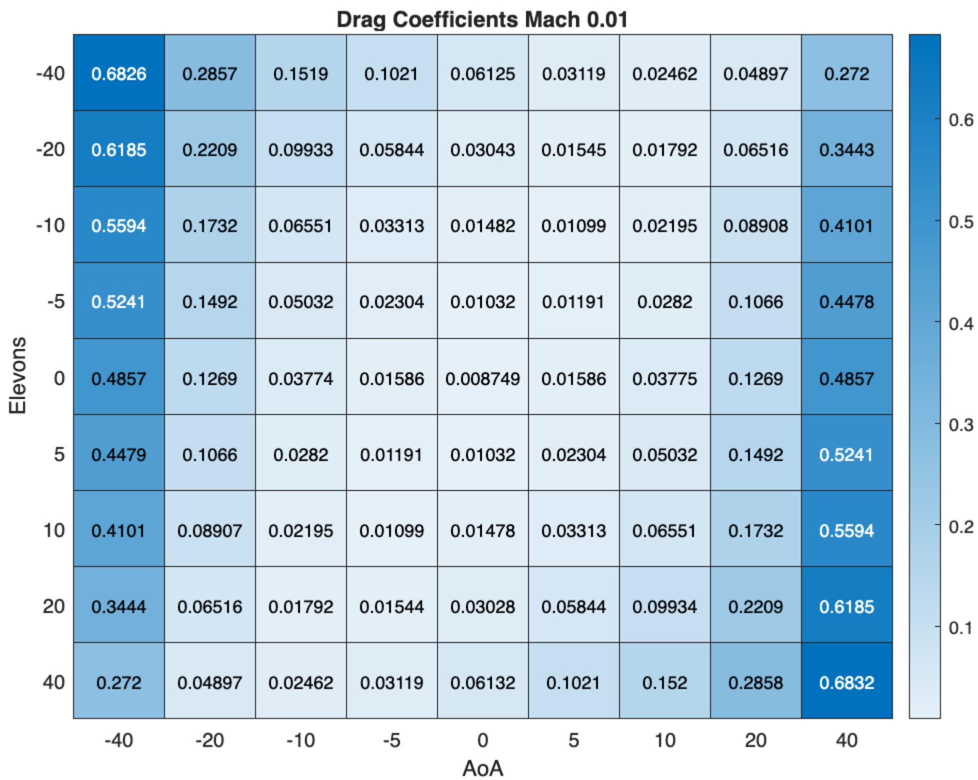
```
RR_Aero_Elevons
```

```
RR_Aero_Elevons = 1×9
   -40   -20   -10    -5     0     5    10    20    40
```

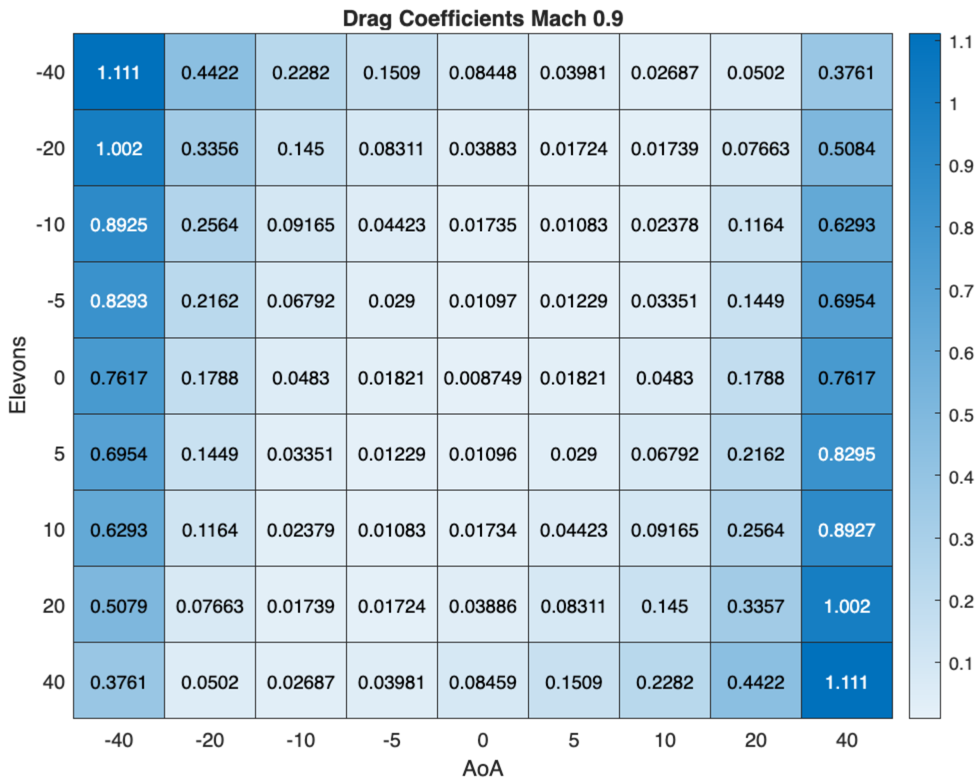
```
RR_Aero_Mach
```

```
RR_Aero_Mach = 1×5
    0.0100    0.1000    0.2000    0.5000    0.9000
```

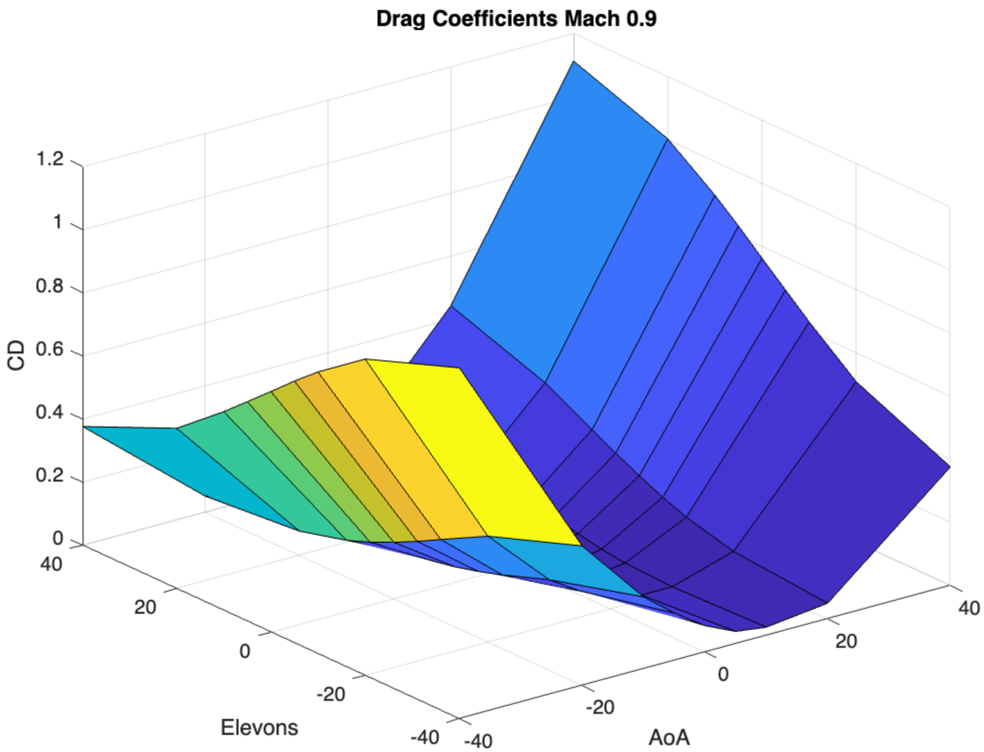
```
h=heatmap(RR_Aero_Aoa, RR_Aero_Elevons, RR_Aero_CD(:,:,1));
h.Title='Drag Coefficients Mach 0.01';
h.XLabel='AoA';
h.YLabel='Elevons';
```



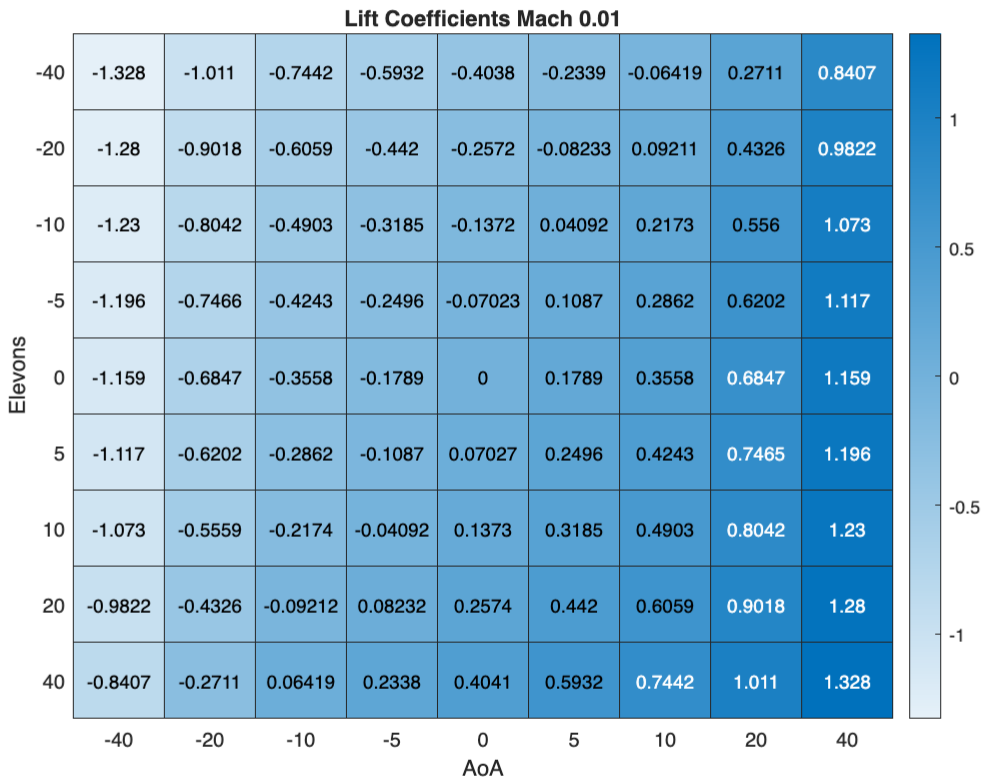

```
h=heatmap(RR_Aero_Aoa, RR_Aero_Elevons, RR_Aero_CD(:,:,5));
h.Title='Drag Coefficients Mach 0.9';
h.XLabel='AoA';
h.YLabel='Elevons';
```



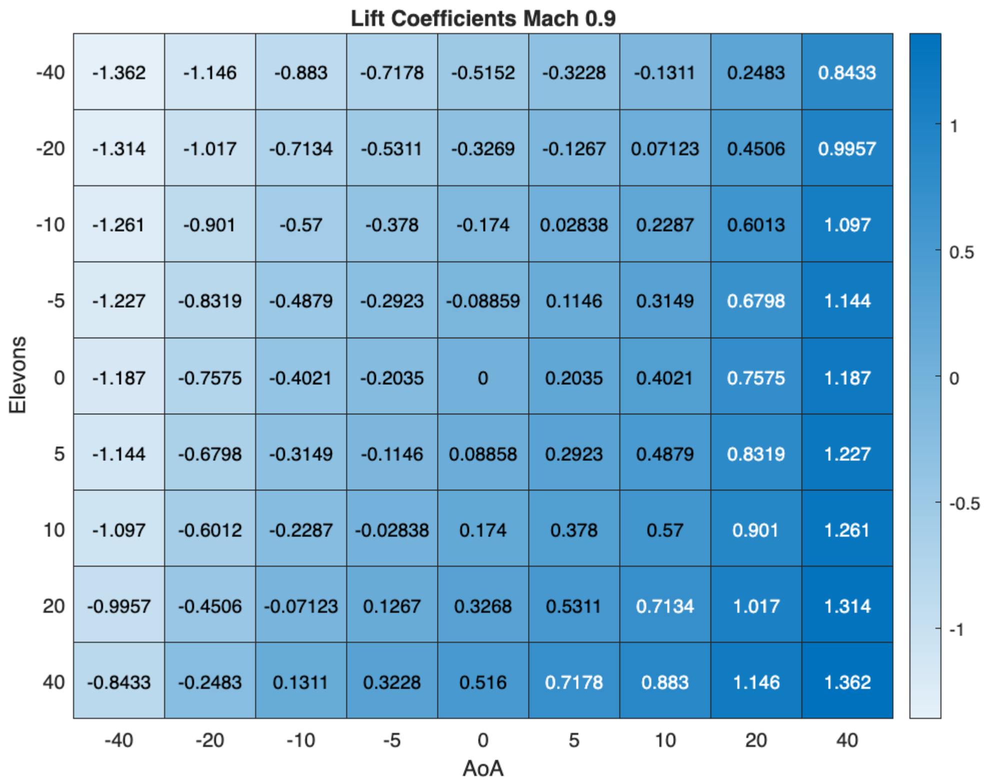

```
surf(RR_Aero_Aoa, RR_Aero_Elevons, RR_Aero_CD(:,:,5));
title('Drag Coefficients Mach 0.9');
xlabel('AoA');
ylabel('Elevons');
zlabel('CD');
```



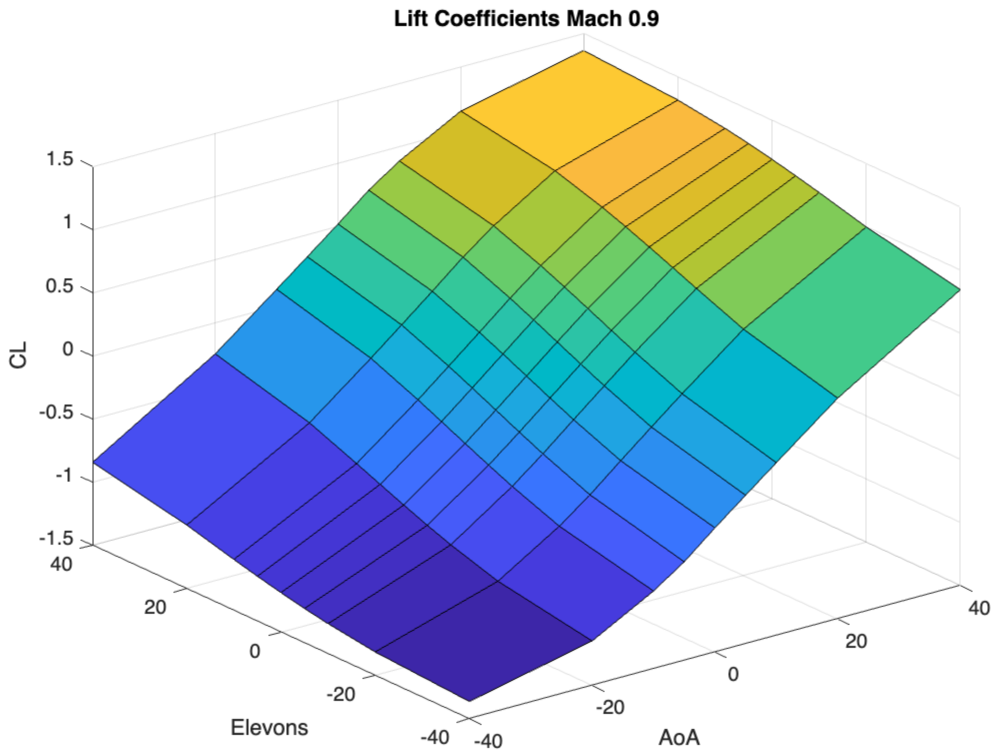

```
h=heatmap(RR_Aero_Aoa, RR_Aero_Elevons, RR_Aero_CL(:,:,1));
h.Title='Lift Coefficients Mach 0.01';
h.XLabel='AoA';
h.YLabel='Elevons';
```



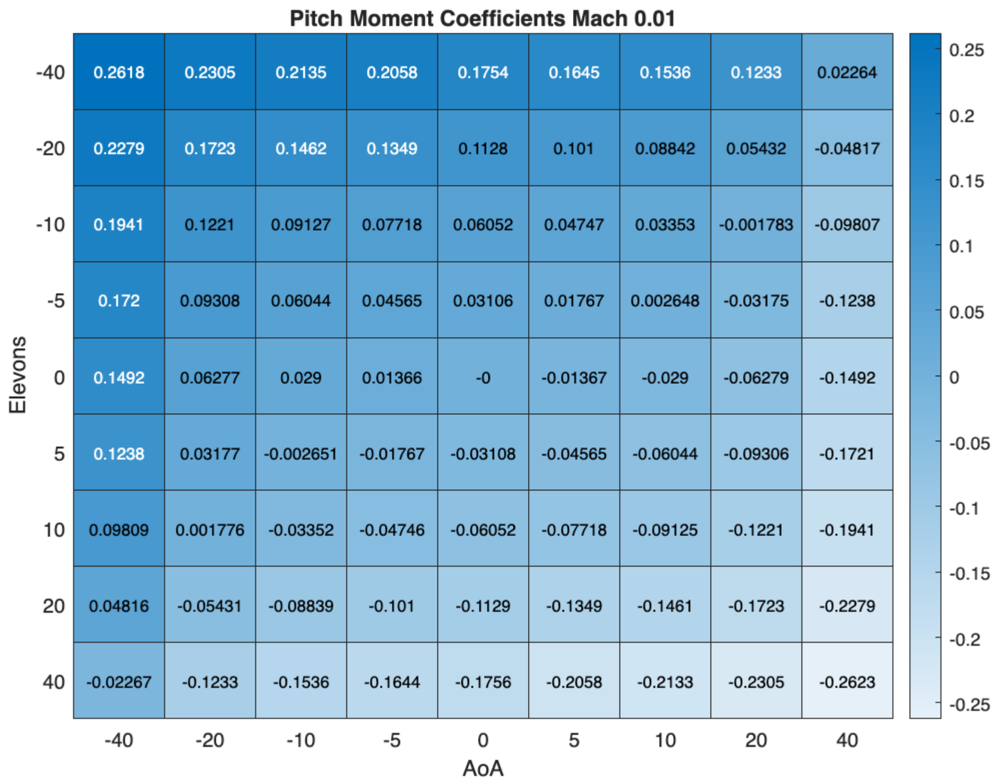

```
h=heatmap(RR_Aero_Aoa, RR_Aero_Elevons, RR_Aero_CL(:,:,5));
h.Title='Lift Coefficients Mach 0.9';
h.XLabel='AoA';
h.YLabel='Elevons';
```



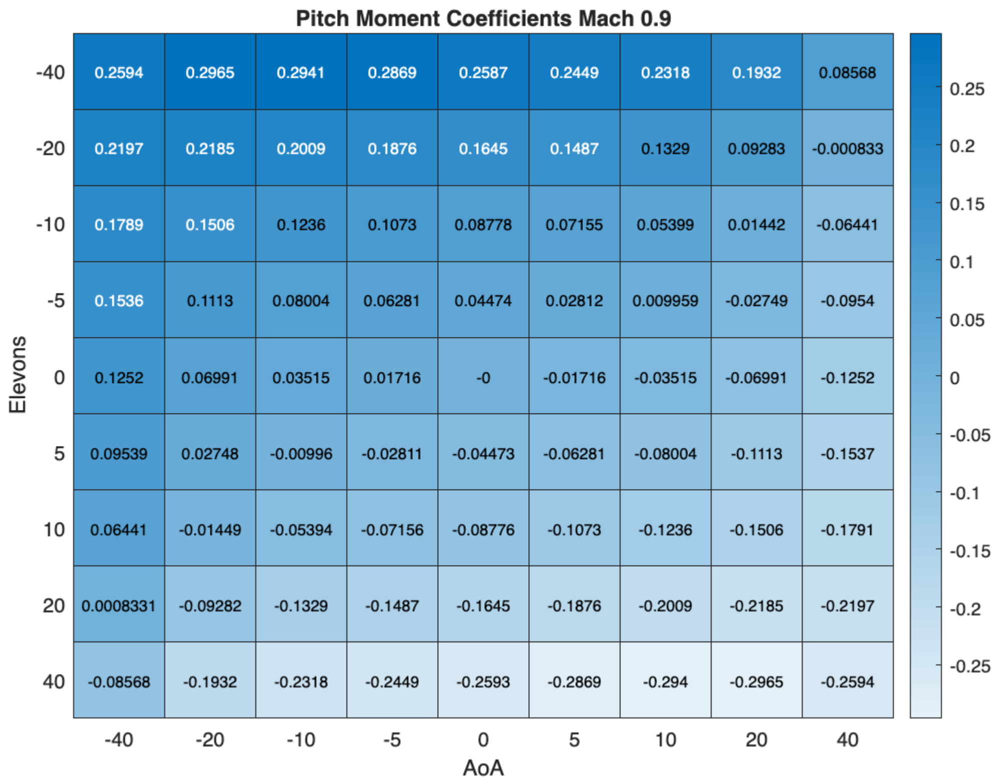

```
surf(RR_Aero_Aoa, RR_Aero_Elevons, RR_Aero_CL(:,:,5));
title('Lift Coefficients Mach 0.9');
xlabel('AoA');
ylabel('Elevons');
zlabel('CL');
```



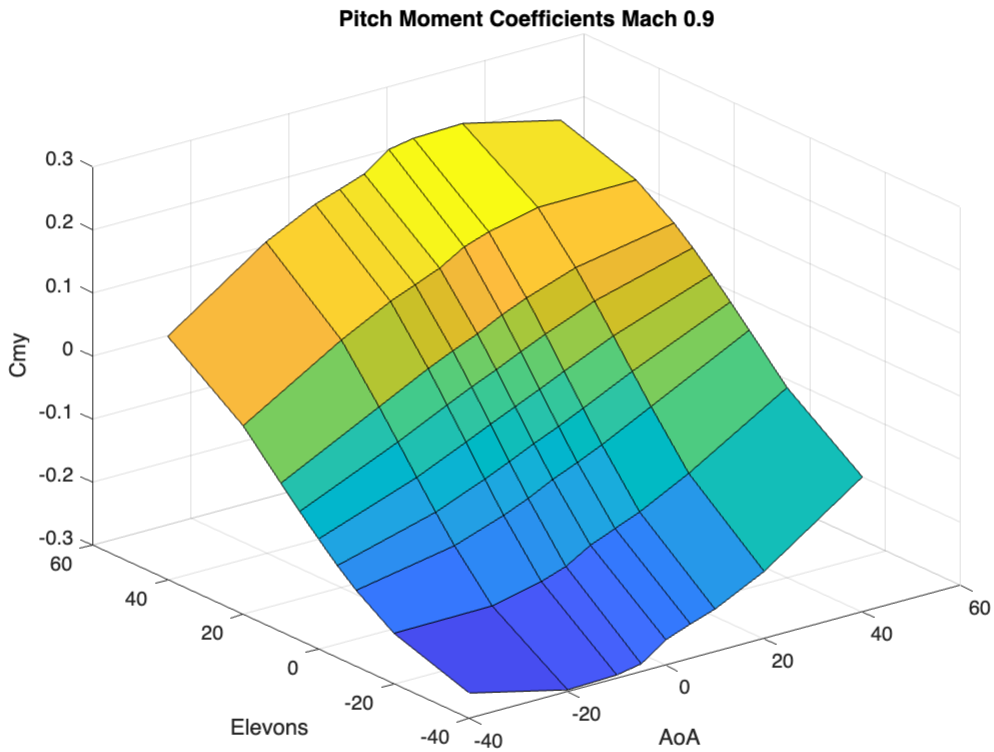

```
h=heatmap(RR_Aero_Aoa, RR_Aero_Elevons, RR_Aero_CMy(:,:,1));
h.Title='Pitch Moment Coefficients Mach 0.01';
h.XLabel='AoA';
h.YLabel='Elevons';
```




```
h=heatmap(RR_Aero_Aoa, RR_Aero_Elevons, RR_Aero_CMy(:,:,5));
h.Title='Pitch Moment Coefficients Mach 0.9';
h.XLabel='AoA';
h.YLabel='Elevons';
```




```
h=surf(RR_Aero_Aoa, RR_Aero_Elevons, RR_Aero_CMy(:,:,5));
title('Pitch Moment Coefficients Mach 0.9');
xlabel('AoA');
ylabel('Elevons');
zlabel('Cmy');
rotate(h,[0 0 1],180);
```



Save Workspace

With all this data about the RR vehicle I'm ready to save the data from the workspace for Simulink simulations.

```
save('RR.mat');
```