```
clear
clc
seats_per_row=6;
fig_num=1;

seat_width=.5;
seat_height=1;
seat_pitch=0.8128;
% aisle_width=0.381;
aisle_width=0.40;
headroom=1.68;
total_seats=250;
total_luggage_weight=18.14*250+8*13.61;
luggage_density=161;
luggage_volume=total_luggage_weight/luggage_density;
type2_width=0.508;
typea_width=1.0668;
number_of_rows=ceil(total_seats/seats_per_row);
total_seat_length=number_of_rows*seat_pitch+type2_width;
area_req=luggage_volume/total_seat_length;
toilet_size=1;
galley_per_passenger=0.04;
galley_volume=galley_per_passenger*250;
afterbody_fineness=1.75;
nose_fineness=5;

p_8000=75262.4;
ptot_42000=17035.1;
Mmax=0.82;
gamma=1.4;
uts_cfrp=4300000000;

pstat_42000=ptot_42000/((1+(gamma-1)/2*Mmax^2)^(gamma/(gamma-1)));

r=((seat_height/2)^2+(seats_per_row/2*seat_width+aisle_width/2)^2)^.5;
D=2*r;
h=((r)^2-(aisle_width/2)^2)^.5)-(headroom-seat_height/2);
w=((r)^2-(headroom-seat_height/2)^2)^.5)-(aisle_width/2);

t=abs(p_8000-pstat_42000)*r/uts_cfrp;

syms x

A1=vpa(2*int((r^2-x^2)^.5-(headroom-
seat_height/2),aisle_width/2,aisle_width/2+w),4);
A2=vpa(2*int((r^2-x^2)^.5-
seat_height/2,0,aisle_width/2+seats_per_row/2*seat_width),4);
galley_area=pi*r^2-A2;

cabin_length=total_seat_length+2*typea_width;
galley_length=galley_volume/galley_area;
cabin_frontal_area=r^2*pi;
cabin_surface_area= cabin_length*D*pi;
tail_length=afterbody_fineness*D;
```

```
nose_length=nose_fineness/2*D;
full_length=tail_length+cabin_length+nose_length;

disp(['Number of seats per row of ',num2str(seats_per_row)])
disp(' ')
disp(['Diameter = ',num2str(D),'m'])
disp(['Skin Thickness = ',num2str(t*1000),'mm'])
disp(['Galley Length = ',char(ceil(galley_length)),'m'])
disp(['Nose Length = ',num2str(nose_length),'m'])
disp(['Cabin Length = ',char(vpa(cabin_length,6)),'m'])
disp(['Tail Length = ',num2str(tail_length),'m'])
disp(['Plane Length = ',char(vpa(full_length,6)),'m'])
disp(['Cabin Frontal Area = ',num2str(cabin_frontal_area),'m^2'])
disp(['Cabin Surface Area = ',char(vpa(cabin_surface_area,7)),'m^2'])
disp(['Required luggage space = ',num2str(area_req),'m^2'])
disp(['Overhead luggage space = ',char(A1),'m^2
(',char(vpa(A1/area_req*100,3)),'% of required)'])
disp(['Underfloor luggage space = ',char(A2),'m^2
(',char(vpa(A2/area_req*100,3)),'% of
required/',char(vpa(A2/cabin_frontal_area*100,3)),'% of frontal)'])
disp(' ')
disp('------------------------------------------------------------------')
disp(' ')

theta=0:pi/1000:2*pi;
inside_radius(1,:)=r*sin(theta);
inside_radius(2,:)=r*cos(theta);
outside_radius(1,:)=(r+.1)*sin(theta);
outside_radius(2,:)=(r+.1)*cos(theta);



figure(fig_num)
hold on
grid on
grid minor
plot(inside_radius(1,:),inside_radius(2,:),'k')
for i=-1:2:1
    plot(i*[0,aisle_width/2+seats_per_row/2*seat_width],[-seat_height/2,-
seat_height/2],'b')
    plot(i*[aisle_width/2,aisle_width/2],[headroom-seat_height/2,headroom-
seat_height/2+h],'r')
        plot(i*[0,1.2],-.5-.2+[0,0],'m')
    plot(i*[aisle_width/2,aisle_width/2+w],[headroom-seat_height/2,headroom-
seat_height/2],'r')

plot(i*[aisle_width/2,aisle_width/2+seats_per_row/2*seat_width],[seat_height/
2,seat_height/2],'b')
    for j=0:seats_per_row/2
        plot(i*[aisle_width/2+j*seat_width,aisle_width/2+j*seat_width],[-
seat_height/2,seat_height/2],'b')
    end
    plot(i*[0,aisle_width/2],[0,0]-.5,'k')
    plot(i*[0,r*.92],[0,0]-.5-(r+.1)*.05*2,'k')

%     plot(i*1.2,-.5-.2,'m*')
%     plot(i*1.2,-.5-.2-.6,'m*')
```

```
%     plot(i*.75,-1.6,'m*')

    plot(i*[1.2,1.2],[-.5-.2-.6,-.5-.2],'m')
    plot(i*[1.2,.75],[-.5-.2-.6,-1.6],'m')
    plot(i*[0,.75],-1.6+[0,0],'m')
end
plot(outside_radius(1,:),outside_radius(2,:),'k')
plot([-r,r],[0,0],'k--')
plot([0,0],[-r,r],'k--')
xlabel('Horizontal Position from Fuselage Centerline (m)')
ylabel('Vertical Position from Fuselage Centerline (m)')
legend('Fuselage Walls/Floor','Seats','Overhead Storage','ULD')
axis(2*[-1,1,-1,1])
pbaspect([1,1,1])
hold off

%% INITIAL SIZING

d=3.544; %inner fuse diameter
wall_thick=0.1; %fuselage thickness
seat_width=.5;
seat_pitch=0.8128;
type2_width=0.508;
type2_height=1.1176;
typea_width=1.0668;
typea_height=1.8288;
nose_length=8.2;
cabin_length=42*seat_pitch+2*typea_width+type2_width;
tail_length=5.74;
total_length=cabin_length+nose_length+tail_length;
engine_length=4.689;
engine_width=2;
nacelle_thickness=(2.353425-engine_width)/2;
nacelle_extra_length=5.791-4.689;

Wing_Loading=4019.75;


% W0=143136.74;
W0=138680.7;


% final_fuel_fraction=0.372459863;
final_fuel_fraction=0.372459863;
passengers=79.38*250;
luggage=18.14*250;
cargo=luggage+passengers;
fuel_density=804;

x_H=49; %Horizontal aero center from nose
x_W=27; %wing ''
L=x_H-x_W;
Vert_Pos=2.85; %forward positioning of Vert from hori

conv=2;
```

```
while conv>=.05
    %%
    %------------------WING SIZING-------------------


    taper_W=.2;
    AR_W=9.5;
    area_W=143136.74/Wing_Loading*9.81;
    sweep_W=33;

    syms c

    mean_chord_W=(.5*(c+taper_W*c));
    span_W=area_W/mean_chord_W;
    F_AR=(span_W^2)/area_W-AR_W;

    root_c_W=double(max(vpa(solve(F_AR,c))));
    mean_chord_W=vpa(subs(mean_chord_W,c,root_c_W));
    half_span_W=vpa(subs(span_W,c,root_c_W)/2);

    clear c

    syms y

    c_front=y*tand(sweep_W);
    c=root_c_W-(root_c_W-root_c_W*taper_W)*y/half_span_W;
    c_4=c_front+c/4;

    aero_position_W=double(2/area_W*int(c_4*c,0,half_span_W));
    c_bar_W=double(2/area_W*int(c^2,0,half_span_W));
    c_bar_bpos_W=(c_bar_W-root_c_W)/(root_c_W*taper_W-root_c_W); %as ratio
along span in y
    c_bar_xpos_W=c_bar_bpos_W*half_span_W*tand(sweep_W)+x_W-aero_position_W;

    clear y

    %------------------HORIZONTAL SIZING--------------------

    taper_H=.4;
    AR_H=4.75;
    area_H=0.8*c_bar_W*area_W/L;
    sweep_H=sweep_W+5;

    syms c

    mean_chord_V=(.5*(c+taper_H*c));
    span_H=area_H/mean_chord_V;
    F_AR=(span_H^2)/area_H-AR_H;

    root_c_H=double(max(vpa(solve(F_AR,c))));
    half_span_H=vpa(subs(span_H,c,root_c_H)/2);

    clear c
```

```
    syms y

    c_front=y*tand(sweep_H);
    c=root_c_H-(root_c_H-root_c_H*taper_H)*y/half_span_H;
    c_4=c_front+c/4;

    aero_position_H=double(2/area_H*int(c_4*c,0,half_span_H));
    c_bar_H=double(2/area_H*int(c^2,0,half_span_H));
    c_bar_bpos_H=(c_bar_H-root_c_H)/(root_c_H*taper_H-root_c_H);

    clear y

    r_c_H=root_c_H-(root_c_H-root_c_H*taper_H)*(d/2)/half_span_H; %horizontal
chord at fuselage diameter

    el_c_percent=0.36;
    el_span_length=0.8;
    el_span_start=0.15;

    %-------------------VERT SIZING----------------------

    AR_V=2;
    sweep_V=sweep_H;
    taper_V=0.5;

    x_V=x_H-Vert_Pos;
    area_V=0.07*half_span_W*2*area_W/(x_V-x_W);

    syms c

    mean_chord_V=(.5*(c+taper_V*c));
    span_V=area_V/mean_chord_V;
    F_AR=(span_V^2)/area_V-AR_V;

    root_c_V=double(max(vpa(solve(F_AR,c))));
    mean_chord_V=vpa(subs(mean_chord_V,c,root_c_V));
    span_V=vpa(subs(span_V,c,root_c_V));

    clear c

    syms y

    c_front=y*tand(sweep_V);
    c=root_c_V-(root_c_V-root_c_V*taper_V)*y/span_V;
    c_4=c_front+c/4;

    aero_position_V=double(1/area_V*int(c_4*c,0,span_V));
    c_bar_V=double(1/area_V*int(c^2,0,span_V));
    c_bar_bpos_V=(c_bar_V-root_c_V)/(root_c_V*taper_V-root_c_V);

    clear y
```

```
    rudder_size=0.46; % percent of Vert that is rudder

    b1=x_H-aero_position_H+(d/2)*tand(sweep_H);
    b2=x_V-aero_position_V+root_c_V;
    b3=b1+span_V*tand(30);
    b4=x_V-aero_position_V+span_V*tand(sweep_V)+root_c_V*taper_V;


    blanketed_area=double((b2-b1+b4-b3)/2*span_V);


    rudder_blanket_ratio=blanketed_area/(area_V*rudder_size) %must be <.66


    %%
    %-------------------------------------------------------
    %-----------------------CG------------------------------
    %-------------------------------------------------------

    %----------------------WING CG-----------------------

    dihedral_W=5;

    wing_height=-1.4; %from center of fus

    f_spar=0.15; %forward spar position along chord
    a_spar=0.7; %aft spar position along chord
    y_cg_W=0.35*half_span_W;
    x_cg_W=double(y_cg_W*tand(sweep_W)+(root_c_W-(root_c_W-
root_c_W*taper_W)*y_cg_W/half_span_W)*(f_spar+(a_spar-f_spar)*0.7))+x_W-
aero_position_W;
    z_cg_W=wing_height+0.35*half_span_W*sind(dihedral_W);

    %---------------------HORI CG-----------------------

    dihedral_H=dihedral_W;



    y_cg_H=0.38*half_span_H*cosd(dihedral_H);
    x_cg_H=y_cg_H*tand(sweep_H)+0.42*(root_c_H-(root_c_H-
root_c_H*taper_H)*y_cg_H/half_span_H)+x_H-aero_position_H;
    z_cg_H=0.38*half_span_H*sind(dihedral_H);


    %---------------------VERT CG-----------------------

    z_cg_V=0.38*span_V;
    x_cg_V=z_cg_V*tand(sweep_V)+0.42*(root_c_V-(root_c_V-
root_c_V*taper_V)*z_cg_V/span_V)+aero_position_H-Vert_Pos-
aero_position_V+x_H-aero_position_H;

    %---------------------FUS CG-----------------------
```

```
    x_cg_F=0.5*total_length;
    z_cg_F=0;

    %---------------------ENGINE CG-----------------------------
    engine_mounting_height=-.5; %top of engine nacelle to centre of wing
    engine_forwards_location=x_W-2.5;
    engine_ypos=10;
    engine_height=wing_height+engine_ypos*sind(dihedral_W)-engine_width/2-
nacelle_thickness+engine_mounting_height;

    x_cg_E=engine_forwards_location;
    y_cg_E=engine_ypos*cosd(dihedral_W);
    z_cg_E=engine_height;


    %---------------------MAIN LG CG----------------------------


Mlg_height=engine_width+2*nacelle_thickness+.0254*6+abs(engine_mounting_heigh
t);
    Mlg_length=2.294;
    Mlg_width=1.2;
    Mlg_span=((d+wall_thick*2)/2+6.5)/(half_span_W*cosd(dihedral_W));
%percent of span location of MLG
    Mlg_chord=a_spar; %percent along chord position

%     x_cg_MLG=x_W-
aero_position_W+Mlg_span*half_span_W*tand(sweep_W)+(root_c_W-(root_c_W-
root_c_W*taper_W)*Mlg_span)*Mlg_chord;
    x_cg_MLG=30.14;
%     y_cg_MLG=Mlg_span*half_span_W*cosd(dihedral_W);
    y_cg_MLG=(d+wall_thick*2)/2+6.5;
    z_cg_MLG=wing_height+Mlg_span*half_span_W*sind(dihedral_W)-Mlg_height/2;

    z_ground=z_cg_MLG-Mlg_height/2;
    %---------------------Nose LG CG----------------------------

    Nlg_length=2.26;
    Nlg_width=1.5;
    Nlg_mounting_height=-1; %from center of fus to top of NLG
    Nlg_mounting_length=2.958; %from nose to NLGCG
    Nlg_height=abs(-Nlg_mounting_height+z_cg_MLG-Mlg_height/2);

    x_cg_NLG=Nlg_mounting_length;
    y_cg_NLG=0;
    z_cg_NLG=Nlg_mounting_height-Nlg_height/2;



    %%
    %-------------------------------------------------------
    %-------------------WEIGHTS-----------------------------
    %-------------------------------------------------------
```

```
    Weng=4990*2; %cumlative engine weight

    kg2lb=2.20462;
    m2ft=3.28084;

    Wdg=W0*kg2lb;

    %---------------WING-WEIGHT------------------------
    Flap_Area=44.465*2; %1.8-17.86
    Slat_Area=15.425*2;
    Aileron_Area=8.7*.33*(4.489+2.048)/2;


    Nz=(2.1+24000/(Wdg/kg2lb+10000))*1.5; %Ultimate load factor
    Sw=area_W*m2ft^2; %sref
    Scsw=(Flap_Area+Slat_Area+Aileron_Area)*m2ft^2; %area of control surf
    LAMDA_W=sweep_W-3; %c_4 sweep
    thicc_W=1.2/root_c_W; %aerofoil thickness ratio

    Ww=((.78+(1-.78)/4)/kg2lb)*0.0051*(( ((Wdg*Nz)^.557) * (Sw^.649) *
(AR_W^.5) * ((1+0.2)^.1) * (Scsw^.1) )/( cosd(LAMDA_W) * (thicc_W^.4) ));

    %---------------------HORI-WEIGHT--------------------------------

    Kuht = 1 ; %if it was an all moving tail it'd be 1.43
    Sht = area_H*m2ft^2; %horizontal tailplane area
    Se = Sht*(el_span_length-el_span_start)*el_c_percent; %elevator area
    Lht = (x_H-x_W)*m2ft; %length from wing aero centre to tail aero centre
in feet %iterative
    Ky = 0.3*(Lht); %lever arm of horizontal tailplane in feet times some
constant
    Bh = half_span_H*2*m2ft; %horiz span
    Fw = 3.35*m2ft; %fuselage width at horizontal intersect
    LAMDA_H = sweep_H-3; %sweep of horizontal tail

    Wht = ((.75+(1-.75)/4)/kg2lb)* 0.0379 *( ( Kuht * (Wdg^0.639) * (Nz^0.1)
* (Sht^0.75) * (AR_H^0.166) * ((1+Se/Sht)^.1) * (Ky^.704) )/( ((1+Fw/Bh)^.25)
* Lht * cosd(LAMDA_H) ) );

    %---------------------VERT-WEIGHT--------------------------------

    Svt=area_V*m2ft^2; %ref area vert
    Lvt=(x_V-x_W)*m2ft; %dist between wing and vert
    Kz=Lvt; %gyration
    LAMDA_V=LAMDA_H;
    thicc_V=1/14;

    Wvt=((.75+(1-.75)/4)/kg2lb)*0.0026*(( (Wdg^.556) * (Nz^.536) * (Svt^.5) *
(Kz^.875) * (AR_V^.35) )/( (Lvt^.5) * cosd(LAMDA_V) * (thicc_V^.5) ));

    %---------------------FUSE-WEIGHT--------------------------------
```

```
    Kdoor=1.12; %1.0 for no cargo door/1.06 for 1 side ''/1.12  for 2 ''/1.12
for aft clamshell/1.25 for both
    Klg=1; %1.12 for fus mounted LG
    Sf=563.73*m2ft^2; %fus wet area
    Lfus=total_length*m2ft;
    Fineness=total_length/(d+2*wall_thick);

Kws=0.75*((1+2*taper_W)/(1+taper_W))*2*half_span_W*m2ft*tand(LAMDA_W/Lfus);

    Wfus=((.85+(1-
.85)/4)/kg2lb)*0.328*Kdoor*Klg*((Wdg*Nz)^.5)*(Lfus^.25)*(Sf^.302)*((1+Kws)^.0
4)*((Fineness)^.1);

    %---------------------MAIN LG-WEIGHT--------------------------

    Wl=(W0*.97)*kg2lb; %landing gross weight
    Kmp=1; %1.126 for kneeling
    Ngear=2.8; %2.7~3.0
    Nl=1.5*Ngear;
    Lm=Mlg_length*100/2.54; %inches
    Nmw=8; %wheels num
    Vs=194.098;
    Nmss=2; %number of main gear shock stuts


Wmlg=(1/kg2lb)*(0.0106*Kmp*((Wl)^0.888)*((Nl)^.25)*((Lm)^.4)*((Nmw)^.321)*((V
s)^.1))/((Nmss)^.5);

    %---------------------NOSE LG--WEIGHT----------------------------

    Knp=1.15; %1.0 for no kneeling
    Ln=Nlg_length*100/2.54; %inches
    Nnw=2; %wheel num

    Wnlg=(1/kg2lb)*0.032*Knp*((Wl)^0.646)*((Nl)^.2)*((Ln)^.5)*((Nnw)^.45);

    %-----------------------NACELLE  WEIGHT-----------------------------

    Kng=1.017; %for pylon mounted necelle
    Nlt=(engine_length+nacelle_extra_length)*m2ft; %nacelle length
    Nw=(engine_width+2*nacelle_thickness)*m2ft; %nacelle width
    Kp=1; %no prop
    Ktr=1.18; %1.18 for thrust reversers
    Wenc=2.331*Kp*Ktr*((Weng*kg2lb)^.901);
    Nen=2;
    Sn=pi*Nw*Nlt;


Winl=(1/kg2lb)*0.6724*Kng*((Nlt)^.1)*((Nw)^.294)*((Nz)^.119)*((Wenc)^.611)*((
Nen)^.984)*((Sn)^.224);


    %-----------------------ENGINE CONTROLS  WEIGHT-------------------------
----
```

```
    Lec=2*(c_bar_bpos_W*half_span_W+x_W)*m2ft; %routing distance engine to
cockpit

    Wec=(1/kg2lb)*(5*Nen+0.8*Lec);


x_cg_WEC=(Wec*x_W/(c_bar_bpos_W*half_span_W+x_W)*x_W/2+Wec*c_bar_bpos_W*half_
span_W/(c_bar_bpos_W*half_span_W+x_W)*x_W)/(Wec);

    %----------------------ENGINE STARTER  WEIGHT--------------------------
---

    Wes=(1/kg2lb)*49.19*((Nen*Weng*kg2lb/1000)^.541);

    %----------------------FUEL SYSTEM WEIGHT-----------------------------

    m32gal=219.969;

    Vt=W0*final_fuel_fraction/fuel_density*m32gal; %fuel tank volume
    Nt=2; %number of tanks
    Vp=0; %self sealing tank vol
    Vi=Vt; %integral tank volume

    Wfs=(1/kg2lb)*2.405*((Vt)^.606)*((Nt)^.5)*(1+Vp/Vt)/(1+Vi/Vt);

    %----------------------FLIGHT CONTROLS WEIGHT--------------------------
---

    Nf=6; %number of functions by controls
    Scs=Se+Scsw+Svt*rudder_size; %tot control surf area
    Iy=W0*kg2lb*Ky^2; %Iyy
    Nm=1; %number of mech funtions performed by controls

    Wfc=(1/kg2lb)*145.9*( ((Nf)^.554) * ((Scs)^.2) * ((Iy/1000000)^.07)
)/(1+Nm/Nf);

    x_cg_FC=c_bar_W+x_W-c_bar_W/4;

    %----------------------APU WEIGHT-------------------------------

    WAPU=2.2*525/kg2lb;

    x_cg_APU=total_length-1;

    %-------------------Instruments WEIGHT-------------------------

    Kr=1; %non recip engines
    Ktp=1; %non turboprop
    Nc=2; %crew num
    Lf=total_length*m2ft;
    Bw=2*half_span_W*m2ft;
```

```
    Winst=(1/kg2lb)*4.509*Kr*Ktp*((Nc)^.541)*Nen*((Lf+Bw)^.5);

    x_cg_inst=4;

    %-------------------HYDRAULICS WEIGHT-------------------------

    Whydr=(1/kg2lb)*0.2673*Nf*((Lf+Bw)^.937);

    %-------------------ELECTRONICS WEIGHT-------------------------

    Rkva=50; %sytem elect rating 40~60 for trans
    La=Lec+Lf; %routing distance
    Ngen=Nen+1; %eng + apu

    Wel=(1/kg2lb)*7.291*((Rkva)^.782)*((La)^.346)*((Ngen)^.1);

    %-------------------AVIONICS WEIGHT-------------------------

    Wuav=0.04*(W0-W0*final_fuel_fraction-cargo); %uninstalled avionics weight
800~1400

    Wav=(1/kg2lb)*1.73*((Wuav)^0.983);

    x_cg_AV=nose_length+cabin_length+2;

    %-------------------FURNISHING WEIGHT-------------------------

    Wc=40*250+30*8; %cargo weight
    Nseat=250;
    Wseat=32;
    Klav=1.11; %long range
    Kbuf=5; %1.02~5.86 short to long range
    Np=258;


Wfurn=(1/kg2lb)*(0.0577*((Nc)^.1)*((Wc)^.393)*((Sf)^.75)+Nseat*Wseat+Klav*((N
p)^1.33)+Kbuf*((Np)^1.12));

    x_cg_FURN=nose_length+cabin_length/2;

    %-----------------------AIR-CON WEIGHT-------------------------


nose_volume=2*pi*(((8.2*m2ft*d/2*m2ft)^1.6+(8.2*m2ft*d/2*m2ft)^1.6+(d/2*m2ft*
d/2*m2ft)^1.6)/3)^(1/1.6);
    Vpr=pi*(d/2*m2ft)^2*cabin_length*m2ft+nose_volume;

    Wac=(1/kg2lb)*62.36*((Np)^.25)*((Vpr/1000)^.604)*((Wuav)^.1);

    x_cg_AC=x_W-aero_position_W;
    z_cg_AC=-d/2+0.2;
```

```
    %-----------------------ANTI-ICING WEIGHT-------------------------

    Wai=(1/kg2lb)*0.002*Wdg;

    x_cg_AI=x_W-aero_position_W+c_bar_bpos_W*half_span_W*tand(sweep_W);
    z_cg_AI=wing_height+c_bar_bpos_W*half_span_W*sind(dihedral_W);

    %-----------------------HANDLING GEAR WEIGHT-------------------------

    Whg=(1/kg2lb)*0.0003*Wdg;

    %%
    %-------------------------------------------------------------
    %--------------------------FINAL CG---------------------------
    %-------------------------------------------------------------


Wempty=Ww+Wht+Wvt+Weng+Wfus+Wmlg+Wnlg+Winl+Wec+Wes+Wfs+Wfc+WAPU+Winst+Whydr+W
el+Wav+Wfurn+Wac+Wai+Whg;

    W0new=vpa((Wempty+cargo)/(1-final_fuel_fraction),7);

    x_cg_pas=nose_length+cabin_length/2;
    x_cg_lug=nose_length+cabin_length-14/2;
    z_cg_lug=-1;
    overhead=0.25;


x_cg_P0F0=(x_cg_W*(Ww+Wfs+Wes)+x_cg_H*Wht+x_cg_V*Wvt+x_cg_E*(Weng+Winl)+x_cg_
F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+Wec*x_cg_WEC+(Wfc+Whydr)*x_cg_FC
+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg_FURN*Wfurn+x_cg_AC*Wac+x_cg_A
I*Wai)/(Wempty);

z_cg_P0F0=(z_cg_W*(Ww+Wfs+Wes)+z_cg_H*Wht+z_cg_V*Wvt+z_cg_E*(Weng+Winl)+Wmlg*
z_cg_MLG+Wnlg*z_cg_NLG+z_cg_AC*Wac)/(Ww+Wvt+Weng+Wmlg+Wnlg+Winl+Wes+Wfs+Wac+W
ht);


x_cg_P0F1=(x_cg_W*(Ww+final_fuel_fraction*W0+Wfs+Wes)+x_cg_H*Wht+x_cg_V*Wvt+x
_cg_E*(Weng+Winl)+x_cg_F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+Wec*x_cg_
WEC+(Wfc+Whydr)*x_cg_FC+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg_FURN*W
furn+x_cg_AC*Wac+x_cg_AI*Wai)/(Wempty+final_fuel_fraction*W0);

z_cg_P0F1=(z_cg_W*(Ww+final_fuel_fraction*W0+Wfs+Wes)+z_cg_H*Wht+z_cg_V*Wvt+z
_cg_E*(Weng+Winl)+Wmlg*z_cg_MLG+Wnlg*z_cg_NLG+z_cg_AC*Wac)/(Ww+Wvt+Weng+Wmlg+
Wnlg+Winl+Wes+final_fuel_fraction*W0+Wfs+Wac+Wht);

    x_cg_P1F0=(x_cg_pas*(passengers+overhead*luggage)+x_cg_lug*(1-
overhead)*luggage+x_cg_W*(Ww+Wfs+Wes)+x_cg_H*Wht+x_cg_V*Wvt+x_cg_E*(Weng+Winl
)+x_cg_F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+Wec*x_cg_WEC+(Wfc+Whydr)*
x_cg_FC+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg_FURN*Wfurn+x_cg_AC*Wac
+x_cg_AI*Wai)/(Wempty+cargo);
    z_cg_P1F0=(z_cg_lug*(1-
overhead)*luggage+z_cg_W*(Ww+Wfs+Wes)+z_cg_H*Wht+z_cg_V*Wvt+z_cg_E*(Weng+Winl
```

```
)+Wmlg*z_cg_MLG+Wnlg*z_cg_NLG+z_cg_AC*Wac)/(Ww+Wvt+Weng+Wmlg+Wnlg+Winl+Wes+Wf
s+Wac+Wht+(1-overhead)*luggage);

    x_cg_P1F1=(x_cg_pas*(passengers+overhead*luggage)+x_cg_lug*(1-
overhead)*luggage+x_cg_W*(Ww+final_fuel_fraction*W0+Wfs+Wes)+x_cg_H*Wht+x_cg_
V*Wvt+x_cg_E*(Weng+Winl)+x_cg_F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+We
c*x_cg_WEC+(Wfc+Whydr)*x_cg_FC+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg
_FURN*Wfurn+x_cg_AC*Wac+x_cg_AI*Wai)/(Wempty+final_fuel_fraction*W0+cargo);
    z_cg_P1F1=(z_cg_lug*(1-
overhead)*luggage+z_cg_W*(Ww+final_fuel_fraction*W0+Wfs+Wes)+z_cg_H*Wht+z_cg_
V*Wvt+z_cg_E*(Weng+Winl)+Wmlg*z_cg_MLG+Wnlg*z_cg_NLG+z_cg_AC*Wac)/(Ww+Wvt+Wen
g+Wmlg+Wnlg+Winl+Wes+final_fuel_fraction*W0+Wfs+Wac+Wht+(1-
overhead)*luggage);

    conv=abs(W0-W0new);
    W0=W0new
end
%-----------------------------------------------------------------
%-----------------------------------------------------------------
%-----------------------------------------------------------------

%%
%--------------STABLILITY--------------------

cruise_start_w_fraction=0.94594;
cruise_start_f=final_fuel_fraction*W0-(1-cruise_start_w_fraction)*W0;
cruise_end_w_fraction=0.69524;
cruise_end_f=final_fuel_fraction*W0-(1-cruise_end_w_fraction)*W0;

LCS_W_cruise=5.5175*pi/180;
LCS_W_to=5.3538*pi/180;
LCS_W_lan=5.5807*pi/180;

LCS_H=0.1108;

KA=1/AR_W-1/(1+AR_W^1.7);
Klamda=(10-3*taper_W)/7;
Kh=(1-abs(wing_height/(2*half_span_W)))/((2*L/(2*half_span_W))^(1/3));
Kf=1.06;

CLAW_cruise=1.2409;
CLAW_to=1.2041;
CLAW_lan=1.2551;

deda_cruise=4.44*((KA*Klamda*Kh*((cosd(LAMDA_W))^(1/2)))^1.19)*CLAW_cruise;
deda_to=4.44*((KA*Klamda*Kh*((cosd(LAMDA_W))^(1/2)))^1.19)*CLAW_to;
deda_lan=4.44*((KA*Klamda*Kh*((cosd(LAMDA_W))^(1/2)))^1.19)*CLAW_lan;

CMalphaf=Kf*(total_length*(d+wall_thick*2)^2)/(c_bar_W*area_W)*pi/180;

eta_h=0.9;
```

```
xnp_cruise=double(c_bar_W*(LCS_W_cruise*x_W/c_bar_W-CMalphaf+eta_h*LCS_H*(1-
deda_cruise)*area_H/area_W*x_H/c_bar_W)/(LCS_W_cruise+eta_h*LCS_H*(1-
deda_cruise)*area_H/area_W));
xnp_to=double(c_bar_W*(LCS_W_to*x_W/c_bar_W-CMalphaf+eta_h*LCS_H*(1-
deda_to)*area_H/area_W*x_H/c_bar_W)/(LCS_W_to+eta_h*LCS_H*(1-
deda_to)*area_H/area_W));
xnp_lan=double(c_bar_W*(LCS_W_lan*x_W/c_bar_W-CMalphaf+eta_h*LCS_H*(1-
deda_lan)*area_H/area_W*x_H/c_bar_W)/(LCS_W_lan+eta_h*LCS_H*(1-
deda_lan)*area_H/area_W));

xnp_cruise_mac_pos=double((xnp_cruise-c_bar_xpos_W)/c_bar_W);
xnp_to_mac_pos=double((xnp_to-c_bar_xpos_W)/c_bar_W);
xnp_lan_mac_pos=double((xnp_lan-c_bar_xpos_W)/c_bar_W);

cgP0F0_mac_pos=double((x_cg_P0F0-c_bar_xpos_W)/c_bar_W);
cgP0F1_mac_pos=double((x_cg_P0F1-c_bar_xpos_W)/c_bar_W);
cgP1F0_mac_pos=double((x_cg_P1F0-c_bar_xpos_W)/c_bar_W);
cgP1F1_mac_pos=double((x_cg_P1F1-c_bar_xpos_W)/c_bar_W);

%back to front
p=0:250;
x_cg_p=nose_length+cabin_length-(cabin_length*p/250)/2;
x_cg_PbackF0=(x_cg_p.*p/250*(passengers+overhead*luggage)+p/250.*x_cg_lug*(1-
overhead)*luggage+x_cg_W*(Ww+Wfs+Wes)+x_cg_H*Wht+x_cg_V*Wvt+x_cg_E*(Weng+Winl
)+x_cg_F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+Wec*x_cg_WEC+(Wfc+Whydr)*
x_cg_FC+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg_FURN*Wfurn+x_cg_AC*Wac
+x_cg_AI*Wai)./(Wempty+p/250*cargo);
cgPbackF0_mac_pos=double((x_cg_PbackF0-c_bar_xpos_W)/c_bar_W);

%front to back
x_cg_p=nose_length+(cabin_length*p/250)/2;
x_cg_PfrontF0=(x_cg_p.*p/250*(passengers+overhead*luggage)+p/250.*x_cg_lug*(1
-
overhead)*luggage+x_cg_W*(Ww+Wfs+Wes)+x_cg_H*Wht+x_cg_V*Wvt+x_cg_E*(Weng+Winl
)+x_cg_F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+Wec*x_cg_WEC+(Wfc+Whydr)*
x_cg_FC+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg_FURN*Wfurn+x_cg_AC*Wac
+x_cg_AI*Wai)./(Wempty+p/250*cargo);
cgPfrontF0_mac_pos=double((x_cg_PfrontF0-c_bar_xpos_W)/c_bar_W);

%back to front after fuel
x_cg_pp=nose_length+cabin_length-(cabin_length*p/250)/2;
x_cg_PpF1=(x_cg_pp.*p/250*(passengers+overhead*luggage)+p/250.*x_cg_lug*(1-
overhead)*luggage+x_cg_W*(Ww+Wfs+final_fuel_fraction*W0+Wes)+x_cg_H*Wht+x_cg_
V*Wvt+x_cg_E*(Weng+Winl)+x_cg_F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+We
c*x_cg_WEC+(Wfc+Whydr)*x_cg_FC+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg
_FURN*Wfurn+x_cg_AC*Wac+x_cg_AI*Wai)./(Wempty+p/250*cargo+final_fuel_fraction
*W0);
cgPpF1_mac_pos=double((x_cg_PpF1-c_bar_xpos_W)/c_bar_W);

%front to back after fuel
x_cg_ppf=nose_length+(cabin_length*p/250)/2;
x_cg_PpfF1=(x_cg_ppf.*p/250*(passengers+overhead*luggage)+p/250.*x_cg_lug*(1-
overhead)*luggage+x_cg_W*(Ww+Wfs+final_fuel_fraction*W0+Wes)+x_cg_H*Wht+x_cg_
V*Wvt+x_cg_E*(Weng+Winl)+x_cg_F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+We
c*x_cg_WEC+(Wfc+Whydr)*x_cg_FC+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg
```

```
_FURN*Wfurn+x_cg_AC*Wac+x_cg_AI*Wai)./(Wempty+p/250*cargo+final_fuel_fraction
*W0);
cgPpfF1_mac_pos=double((x_cg_PpfF1-c_bar_xpos_W)/c_bar_W);

pb=find(cgPpF1_mac_pos==max(cgPpF1_mac_pos));

Kn_P0F1=xnp_to_mac_pos-cgP0F1_mac_pos;
Kn_P0F0=xnp_lan_mac_pos-cgP0F0_mac_pos;

Kn_P1F1=xnp_to_mac_pos-cgP1F1_mac_pos;
Kn_P1F0=xnp_lan_mac_pos-cgP1F0_mac_pos;



p2=2:2:84;
x_cg_p2(1)=nose_length+cabin_length;
x_cg_p2(2:43)=nose_length+cabin_length-(cabin_length*p2/84)/2;
x_cg_p2(44:85)=((84*x_cg_p2(42)+p2.*(nose_length+cabin_length-
(cabin_length*p2/84)/2)))./(84+p2);
x_cg_p2(86:127)=((2*84*x_cg_p2(84)+p2.*(nose_length+cabin_length-
(cabin_length*p2/84)/2)))./(2*84+p2);
p2=0:2:252;
x_cg_Pback2F0=(x_cg_p2.*p2/250*(passengers+overhead*luggage)+p2/250.*x_cg_lug
*(1-
overhead)*luggage+x_cg_W*(Ww+Wfs+Wes)+x_cg_H*Wht+x_cg_V*Wvt+x_cg_E*(Weng+Winl
)+x_cg_F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+Wec*x_cg_WEC+(Wfc+Whydr)*
x_cg_FC+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg_FURN*Wfurn+x_cg_AC*Wac
+x_cg_AI*Wai)./(Wempty+p2/252*cargo);
cgPback2F0_mac_pos=double((x_cg_Pback2F0-c_bar_xpos_W)/c_bar_W);

p2=2:2:84;
x_cg_p2(1)=nose_length;
x_cg_p2(2:43)=nose_length+(cabin_length*p2/84)/2;
x_cg_p2(44:85)=((84*x_cg_p2(42)+p2.*(nose_length+(cabin_length*p2/84)/2)))./(
84+p2);
x_cg_p2(86:127)=((2*84*x_cg_p2(84)+p2.*(nose_length+(cabin_length*p2/84)/2)))
./(2*84+p2);
p2=0:2:252;
x_cg_Pfront2F0=(x_cg_p2.*p2/250*(passengers+overhead*luggage)+p2/250.*x_cg_lu
g*(1-
overhead)*luggage+x_cg_W*(Ww+Wfs+Wes)+x_cg_H*Wht+x_cg_V*Wvt+x_cg_E*(Weng+Winl
)+x_cg_F*(Wfus+Wel+Whg)+Wmlg*x_cg_MLG+Wnlg*x_cg_NLG+Wec*x_cg_WEC+(Wfc+Whydr)*
x_cg_FC+x_cg_APU*WAPU+x_cg_inst*Winst+x_cg_AV*Wav+x_cg_FURN*Wfurn+x_cg_AC*Wac
+x_cg_AI*Wai)./(Wempty+p2/252*cargo);
cgPfront2F0_mac_pos=double((x_cg_Pfront2F0-c_bar_xpos_W)/c_bar_W);



figure(1)
hold on
grid on
grid minor
set(gca,'XMinorTick','on','YMinorTick','on')

xnpl=plot(100*[xnp_cruise_mac_pos,xnp_cruise_mac_pos],[0,W0/0.95],'k');
set(xnpl,'LineWidth',2)
xnpl=plot(100*[xnp_to_mac_pos,xnp_to_mac_pos],[0,W0/0.95],'k--');
```

```
set(xnpl,'LineWidth',2)
xnpl=plot(100*[xnp_lan_mac_pos,xnp_lan_mac_pos],[0,W0/0.95],'k:');
set(xnpl,'LineWidth',2)


plot(100*cgPfrontF0_mac_pos,Wempty+p/250*cargo,'g')
plot(100*cgPbackF0_mac_pos,Wempty+p/250*cargo,'r')


plot(100*cgPfront2F0_mac_pos,Wempty+p2/252*cargo,'g--')
plot(100*cgPback2F0_mac_pos,Wempty+p2/252*cargo,'r--')

plot(100*[cgP1F0_mac_pos,cgP1F1_mac_pos],[Wempty+cargo,W0],'b')

plot(100*(cgP0F0_mac_pos+(cgP0F1_mac_pos-
cgP0F0_mac_pos)*cruise_start_f/(W0*final_fuel_fraction)),Wempty+cruise_start_
f,'b+')
plot(100*(cgP0F0_mac_pos+(cgP0F1_mac_pos-
cgP0F0_mac_pos)*cruise_end_f/(W0*final_fuel_fraction)),Wempty+cruise_end_f,'r
+')



plot(100*[cgPbackF0_mac_pos(pb),cgPpF1_mac_pos(pb)],[(pb-1)/250*cargo,(pb-
1)/250*cargo+W0*final_fuel_fraction]+Wempty,'b')

plot([-100,100],[Wempty,Wempty],'k--');
plot([-100,100],[Wempty+cargo,Wempty+cargo],'k--');
plot([-100,100],[W0,W0],'k--');
plot([-100,100],[W0-cargo,W0-cargo],'k--');

plot(100*cgPpF1_mac_pos,p/250*cargo+Wempty+W0*final_fuel_fraction,'r')
plot(100*cgPpfF1_mac_pos,p/250*cargo+Wempty+W0*final_fuel_fraction,'g')

plot(100*cgP0F0_mac_pos,Wempty,'k*')
plot(100*cgPbackF0_mac_pos(pb),Wempty+(pb-1)/250*cargo,'k*')
plot(100*cgP1F0_mac_pos,Wempty+cargo,'k*')
plot(100*cgP0F1_mac_pos,Wempty+W0*final_fuel_fraction,'k*')
plot(100*cgPpF1_mac_pos(pb),Wempty+(pb-
1)/250*cargo+W0*final_fuel_fraction,'k*')
plot(100*cgP1F1_mac_pos,W0,'k*')



plot(100*(cgP1F0_mac_pos+(cgP1F1_mac_pos-
cgP1F0_mac_pos)*cruise_end_f/(W0*final_fuel_fraction)),Wempty+cruise_end_f+ca
rgo,'r+')
plot(100*(cgP1F0_mac_pos+(cgP1F1_mac_pos-
cgP1F0_mac_pos)*cruise_start_f/(W0*final_fuel_fraction)),Wempty+cruise_start_
f+cargo,'b+')

plot(100*[cgP0F0_mac_pos,cgP0F1_mac_pos],[Wempty,W0-cargo],'b')
```

```
axis([10,70,double(Wempty)*.9,double(W0)/0.95])
xlabel('C.G Position - Percent MAC')
ylabel('Weight (kg)')
legend('Xnp Cruise','Xnp Take-Off','Xnp Landing','Scenario 1','Scenario
2','Scenario 3','Scenario 4','Fuel','Cruise Start','Cruise End')
hold off

%------------------------TRIM----------------------

%%%%CM_cg
twist_W=-4;
ro_35k=0.379597;
a_35k=296.535;
M_cruise=.8;
q=.5*ro_35k*(a_35k*M_cruise)^2;

CM0_air=-0.04;

CLdesign=W0*9.81/(q*area_W);
Cd_cruise=0.0255;
Cd_to=0.1948;
Cd_lan=0.3061;

iW=5;
alpha_0W=-1.5;
alpha_0H=0;

CL_deltaE_cruise=4.8*(1-deda_cruise)*area_H/area_W;
CL_deltaE_to=4.8*(1-deda_to)*area_H/area_W;
CL_deltaE_lan=4.8*(1-deda_lan)*area_H/area_W;
deltaE=0;

Zt=z_cg_P1F1-z_cg_E;

T_cruise = q*area_W*Cd_cruise;
T_to = q*area_W*Cd_to;
T_lan = q*area_W*Cd_lan;

for iH=-10:1:10
    for alpha=-10:1:10

        CM0_W_cruise(iH+11,alpha+11) =
(CM0_air*((AR_W*(cosd(LAMDA_W))^2)/(AR_W+(2*cosd(LAMDA_W))))-
0.001*twist_W*CLAW_cruise);
        CL_W_cruise(iH+11,alpha+11) = LCS_W_cruise*(alpha+iW-alpha_0W);
        CL_H_cruise(iH+11,alpha+11) = LCS_H*((alpha+iW-alpha_0W)*(1-
deda_cruise)+(iH-iW)-(alpha_0H-alpha_0W))+CL_deltaE_cruise*deltaE;

        CM_cg_cruise(iH+11,alpha+11) = -CL_W_cruise(iH+11,alpha+11)*((x_W-
(x_cg_P1F1+x_cg_P1F0)/2)/c_bar_W) + CM0_W_cruise(iH+11,alpha+11) +
CMalphaf*alpha - eta_h*CL_H_cruise(iH+11,alpha+11)*(area_H/area_W)*((x_H -
(x_cg_P1F1+x_cg_P1F0)/2)/c_bar_W) + ((Zt*T_cruise)/(q*area_W*c_bar_W));
```

```
        CL_cruise(iH+11,alpha+11) = CL_W_cruise(iH+11,alpha+11) +
eta_h*(area_H/area_W)*CL_H_cruise(iH+11,alpha+11);

        %-------------------------------------------------------------------
------------------

        CM0_W_to(iH+11,alpha+11) =
(CM0_air*((AR_W*(cosd(LAMDA_W))^2)/(AR_W+(2*cosd(LAMDA_W))))-
0.001*twist_W*CLAW_to);
        CL_W_to(iH+11,alpha+11) = LCS_W_to*(alpha+iW-alpha_0W);
        CL_H_to(iH+11,alpha+11) = LCS_H*((alpha+iW-alpha_0W)*(1-deda_to)+(iH-
iW)-(alpha_0H-alpha_0W))+CL_deltaE_to*deltaE;

        CM_cg_to(iH+11,alpha+11) = -CL_W_to(iH+11,alpha+11)*((x_W-
(x_cg_P1F1+x_cg_P1F0)/2)/c_bar_W) + CM0_W_to(iH+11,alpha+11) + CMalphaf*alpha
- eta_h*CL_H_to(iH+11,alpha+11)*(area_H/area_W)*((x_H -
(x_cg_P1F1+x_cg_P1F0)/2)/c_bar_W) + ((Zt*T_to)/(q*area_W*c_bar_W));

        CL_to(iH+11,alpha+11) = CL_W_to(iH+11,alpha+11) +
eta_h*(area_H/area_W)*CL_H_to(iH+11,alpha+11);

        %-------------------------------------------------------------------
------------------

        CM0_W_lan(iH+11,alpha+11) =
(CM0_air*((AR_W*(cosd(LAMDA_W))^2)/(AR_W+(2*cosd(LAMDA_W))))-
0.001*twist_W*CLAW_lan);
        CL_W_lan(iH+11,alpha+11) = LCS_W_lan*(alpha+iW-alpha_0W);
        CL_H_lan(iH+11,alpha+11) = LCS_H*((alpha+iW-alpha_0W)*(1-
deda_lan)+(iH-iW)-(alpha_0H-alpha_0W))+CL_deltaE_lan*deltaE;

        CM_cg_lan(iH+11,alpha+11) = -CL_W_lan(iH+11,alpha+11)*((x_W-
(x_cg_P1F1+x_cg_P1F0)/2)/c_bar_W) + CM0_W_lan(iH+11,alpha+11) +
CMalphaf*alpha - eta_h*CL_H_lan(iH+11,alpha+11)*(area_H/area_W)*((x_H -
(x_cg_P1F1+x_cg_P1F0)/2)/c_bar_W) + ((Zt*T_lan)/(q*area_W*c_bar_W));

        CL_lan(iH+11,alpha+11) = CL_W_lan(iH+11,alpha+11) +
eta_h*(area_H/area_W)*CL_H_lan(iH+11,alpha+11);
    end
end




figure(2)
hold on
grid on
grid minor


for iH=-10:1:10
    plot(CL_cruise(iH+11,:),CM_cg_cruise(iH+11,:),'r')
end
```

```
plot(CLdesign,0,'k*')

axis([-1,3,-1.5,1.5])
xlabel('CL')
ylabel('CMCG')
hold off

figure(3)
hold on
grid on
grid minor


for iH=-10:1:10
    plot(CL_to(iH+11,:),CM_cg_to(iH+11,:),'g')
end

plot(CLdesign,0,'k*')

axis([-1,3,-1.5,1.5])
xlabel('CL')
ylabel('CMCG')
hold off


figure(4)
hold on
grid on
grid minor


for iH=-10:1:10
    plot(CL_lan(iH+11,:),CM_cg_lan(iH+11,:),'b')
end

plot(CLdesign,0,'k*')

axis([-1,3,-1.5,1.5])
xlabel('CL')
ylabel('CMCG')
hold off



%%
%--------------------------PLOTS-----------------------------
x1=0:-.01:-nose_length;
y1=d/2.*(1-((x1)./nose_length).^2).^.5;

x2=0:.01:tail_length;
y2=d/2.*(1-((x2)./tail_length).^2).^.5;

x3=0:-.01:-3;
```

```
y3=1.65875.*(1-((x3)./3).^2).^.5;

figure(5)
hold on
grid on
grid minor
for i=-1:2:1
    plot(100*[1,2],100*[1,2],'m')
    plot(100*[1,2],100*[1,2],'b')
    plot(100*[1,2],100*[1,2],'c')
    plot(100*[1,2],100*[1,2],'r')
    plot(100,100,'bo')
    plot(100,100,'r+')
%     %wing CG
%     plot(x_cg_W,i*y_cg_W,'r*')

%     %engine CG
%     plot(x_cg_E,i*y_cg_E,'b*')

%     %fuse_cg
%     plot(x_cg_F,0,'k+')

    %totCG
    plot(x_cg_P0F1,0,'bo')

    %xnp
    plot(xnp_cruise,0,'r+')

%     %Main LG CG
%     plot(x_cg_MLG,i*y_cg_MLG,'c*')

    %nose/tail
    plot(x1+nose_length,i*y1,'k')
    plot(x2+nose_length+cabin_length,i*y2,'k')
%     plot(x3+nose_length-3,i*y3,'k')

    %fuselage side
    plot([nose_length,nose_length+cabin_length],i*[d/2,d/2],'k')

%     %seats
%     plot([nose_length+typea_width,nose_length+typea_width],i*[d/2-
.4572*3,d/2],'b')
%
plot([nose_length+typea_width,nose_length+typea_width]+21*seat_pitch,i*[d/2-
.4572*3,d/2],'b')
%
plot([nose_length+typea_width,nose_length+typea_width]+21*seat_pitch+type2_wi
dth,i*[d/2-.4572*3,d/2],'b')
%
plot([nose_length+typea_width,nose_length+typea_width]+42*seat_pitch+type2_wi
dth,i*[d/2-.4572*3,d/2],'b')
%
plot([nose_length+typea_width,nose_length+typea_width+21*seat_pitch],i*[d/2-
.4572*3,d/2-.4572*3],'b')
```

```
%
plot([nose_length+typea_width,nose_length+typea_width+21*seat_pitch]+21*seat_
pitch+type2_width,i*[d/2-.4572*3,d/2-.4572*3],'b')
%
%     %toiletsfront
%     plot([nose_length,nose_length],i*[d/2,d/2-1],'--','color',[0,.7,0])
%     plot([nose_length-1,nose_length-1],i*[1.628,d/2-1],'color',[0,.7,0])
%     plot([nose_length-1,nose_length],i*[d/2-1,d/2-1],'color',[0,.7,0])
%
%     %galley
%     plot([nose_length-1,nose_length-1],i*[1.628,0],'--r')
%     plot([nose_length-3,nose_length-3],i*[1.526,.5],'r')
%     plot([nose_length-3,nose_length-3],i*[.5,0],'--r')
%
%     %toiletsback
%
plot([nose_length,nose_length]+typea_width*2+42*seat_pitch+.508,i*[d/2,0],'--
','color',[0,.7,0])
%
plot([nose_length,nose_length]+typea_width*2+42*seat_pitch+.508+1,i*[1.615,0]
,'color',[0,.7,0])
%
plot([nose_length,nose_length+1]+typea_width*2+42*seat_pitch+.508,i*[d/2-
d/3,d/2-d/3],'color',[0,.7,0])
%
    %main wing
    plot([0,half_span_W*tand(sweep_W)]+x_W-
aero_position_W,i*[0,half_span_W],'k')
    plot([root_c_W,half_span_W*tand(sweep_W)+root_c_W*taper_W]+x_W-
aero_position_W,i*[0,half_span_W],'k')

plot([half_span_W*tand(sweep_W),half_span_W*tand(sweep_W)+root_c_W*taper_W]+x
_W-aero_position_W,i*[half_span_W,half_span_W],'k')

    %horizontal
    plot([0,half_span_H*tand(sweep_H)]+x_H-
aero_position_H,i*[0,half_span_H],'k')
    plot([root_c_H,half_span_H*tand(sweep_H)+root_c_H*taper_H]+x_H-
aero_position_H,i*[0,half_span_H],'k')

plot([half_span_H*tand(sweep_H),half_span_H*tand(sweep_H)+root_c_H*taper_H]+x
_H-aero_position_H,i*[half_span_H,half_span_H],'k')

    %elevator
    plot([(root_c_H-(root_c_H-root_c_H*taper_H)*el_span_start)*(1-
el_c_percent)+half_span_H*tand(sweep_H)*el_span_start,(root_c_H-(root_c_H-
root_c_H*taper_H)*(el_span_start+el_span_length))*(1-
el_c_percent)+half_span_H*tand(sweep_H)*(el_span_start+el_span_length)]+x_H-
aero_position_H,i*[el_span_start*half_span_H,(el_span_start+el_span_length)*h
alf_span_H],'c')
    plot([(root_c_H-(root_c_H-root_c_H*taper_H)*el_span_start)*(1-
el_c_percent)+half_span_H*tand(sweep_H)*el_span_start,(root_c_H-(root_c_H-
root_c_H*taper_H)*el_span_start)+half_span_H*tand(sweep_H)*el_span_start]+x_H
-aero_position_H,i*[el_span_start*half_span_H,el_span_start*half_span_H],'c')
    plot([(root_c_H-(root_c_H-
root_c_H*taper_H)*(el_span_start+el_span_length))*(1-
```

```
el_c_percent)+half_span_H*tand(sweep_H)*(el_span_start+el_span_length),(root_
c_H-(root_c_H-
root_c_H*taper_H)*(el_span_start+el_span_length))+half_span_H*tand(sweep_H)*(
el_span_start+el_span_length)]+x_H-
aero_position_H,i*[(el_span_start+el_span_length)*half_span_H,(el_span_start+
el_span_length)*half_span_H],'c')

    %doors
    plot([0,typea_width]+nose_length,i*[d/2,d/2],'r')
    plot([-typea_width,0]+nose_length+cabin_length,i*[d/2,d/2],'r')
    plot([0,type2_width]+nose_length+cabin_length/2-
type2_width/2,i*[d/2,d/2],'r')

    %vert
    vert=plot([0,root_c_V]+aero_position_H-Vert_Pos-aero_position_V+x_H-
aero_position_H,[0,0],'k');
    set(vert,'LineWidth',2)

    %sparsW&CG

plot([f_spar*root_c_W,half_span_W*tand(sweep_W)+f_spar*root_c_W*taper_W]+x_W-
aero_position_W,i*[0,half_span_W],'k--')

plot([a_spar*root_c_W,half_span_W*tand(sweep_W)+a_spar*root_c_W*taper_W]+x_W-
aero_position_W,i*[0,half_span_W],'k--')


%     %c_bar_W
%     cbar=plot([0,c_bar_W]+x_W-
c_bar_W/4,[0,0]+i*half_span_W*c_bar_bpos_W*cosd(dihedral_W),'k');
%     set(cbar,'LineWidth',2)

    %engine
    plot([-
engine_length/2,engine_length/2]+x_cg_E,[engine_width/2,engine_width/2]+i*y_c
g_E,'b')
    plot([-engine_length/2,engine_length/2]+x_cg_E,[-engine_width/2,-
engine_width/2]+i*y_cg_E,'b')
    plot([-engine_length/2,-engine_length/2]+x_cg_E,[-
engine_width/2,engine_width/2]+i*y_cg_E,'b')
    plot([engine_length/2,engine_length/2]+x_cg_E,[-
engine_width/2,engine_width/2]+i*y_cg_E,'b')


%     %vert_CG
%     plot(x_cg_V,0,'r*')
%
%     %horiz_CG
%     plot(x_cg_H,y_cg_H*i,'r*')

    %Main LG
    plot(x_cg_MLG+[-Mlg_length/2,Mlg_length/2],i*y_cg_MLG+[-Mlg_width/2,-
Mlg_width/2],'m')
    plot(x_cg_MLG+[-
Mlg_length/2,Mlg_length/2],i*y_cg_MLG+[Mlg_width/2,Mlg_width/2],'m')
```

```
    plot(x_cg_MLG+[-Mlg_length/2,-Mlg_length/2],i*y_cg_MLG+[-
Mlg_width/2,Mlg_width/2],'m')
    plot(x_cg_MLG+[Mlg_length/2,Mlg_length/2],i*y_cg_MLG+[-
Mlg_width/2,Mlg_width/2],'m')


    %Nose LG
    plot(x_cg_NLG+[-Nlg_length/2,Nlg_length/2],i*y_cg_NLG+[-Nlg_width/2,-
Nlg_width/2],'m')
    plot(x_cg_NLG+[-
Nlg_length/2,Nlg_length/2],i*y_cg_NLG+[Nlg_width/2,Nlg_width/2],'m')
    plot(x_cg_NLG+[-Nlg_length/2,-Nlg_length/2],i*y_cg_NLG+[-
Nlg_width/2,Nlg_width/2],'m')
    plot(x_cg_NLG+[Nlg_length/2,Nlg_length/2],i*y_cg_NLG+[-
Nlg_width/2,Nlg_width/2],'m')
%     plot(x_cg_NLG,i*y_cg_NLG,'m*')


end
legend('Landing Gear','Engines','Elevators','Doors','Rearmost CG','Cruise
Xnp')
xlabel('X (m)')
ylabel('Y (m)')
axis([-5,60,-30,30])
pbaspect([65,60,1])
hold off


%-------------------------------------------------------------------------


figure(6)
hold on
grid on
grid minor

%wingCG
plot(x_cg_W,z_cg_W,'r*')

%engine CG
plot(x_cg_E,z_cg_E,'b*')

%fuse_cg
plot(x_cg_F,z_cg_F,'k+')

%totCG
plot(x_cg_P0F1,z_cg_P0F1,'bo')

%xnp
plot(xnp_cruise,wing_height+c_bar_bpos_W*half_span_W*sind(dihedral_W),'r+')

%Main LG CG
plot(x_cg_MLG,z_cg_MLG,'c*')
```

```
%hori
hori=plot([0,r_c_H]+x_H-aero_position_H+(d/2)*tand(sweep_H),[0,0],'k');
set(hori,'LineWidth',2)
plot([0,100*cosd(60)]+x_H-
aero_position_H+(d/2)*tand(sweep_H),[0,100*sind(60)],'r')
plot([0,100*cosd(30)]+r_c_H+x_H-
aero_position_H+(d/2)*tand(sweep_H),[0,100*sind(30)],'r')

%tail
plot(x2+8.2+cabin_length,y2,'k')
plot(x2+8.2+cabin_length,-y2,'k')

%nose
plot(x1+nose_length,y1,'k')
plot(x1+nose_length,-y1,'k')

%fus
plot([8.2,8.2+cabin_length],[d/2,d/2],'k')
plot([8.2,8.2+cabin_length],-[d/2,d/2],'k')

%vert
plot([0,span_V*tand(sweep_V)]+aero_position_H-Vert_Pos-aero_position_V+x_H-
aero_position_H,[0,span_V],'b')
plot([root_c_V,span_V*tand(sweep_V)+root_c_V*taper_V]+aero_position_H-
Vert_Pos-aero_position_V+x_H-aero_position_H,[0,span_V],'b')
plot([span_V*tand(sweep_V),span_V*tand(sweep_V)+root_c_V*taper_V]+aero_positi
on_H-Vert_Pos-aero_position_V+x_H-aero_position_H,[span_V,span_V],'b')
plot([root_c_V*(1-rudder_size),root_c_V*(1-
rudder_size)*taper_V+span_V*tand(sweep_V)]+aero_position_H-Vert_Pos-
aero_position_V+x_H-aero_position_H,[0,span_V],'b')

%main wing
main=plot([0,root_c_W]+x_W-aero_position_W,[0,0]+wing_height,'k');
set(main,'LineWidth',2)

%doors
plot([nose_length,nose_length+typea_width],[-.5,-.5],'m')
plot([nose_length,nose_length+typea_width],[-.5,-.5]+typea_height,'m')
plot([nose_length,nose_length],[-.5,-.5+typea_height],'m')
plot([nose_length,nose_length]+typea_width,[-.5,-.5+typea_height],'m')

plot([nose_length,nose_length+typea_width]+cabin_length-typea_width,[-.5,-
.5],'m')
plot([nose_length,nose_length+typea_width]+cabin_length-typea_width,[-.5,-
.5]+typea_height,'m')
plot([nose_length,nose_length]+cabin_length-typea_width,[-.5,-
.5+typea_height],'m')
plot([nose_length,nose_length]+typea_width+cabin_length-typea_width,[-.5,-
.5+typea_height],'m')

plot([0,0]+nose_length+cabin_length/2-type2_width/2,[0,type2_height],'m')
plot([0,0]+nose_length+cabin_length/2+type2_width/2,[0,type2_height],'m')
plot([0,type2_width]+nose_length+cabin_length/2-type2_width/2,[0,0],'m')
plot([0,type2_width]+nose_length+cabin_length/2-
type2_width/2,[type2_height,type2_height],'m')
```

```
%engineCG
plot([-
engine_length/2,engine_length/2]+x_cg_E,[engine_width/2,engine_width/2]+engin
e_height,'b')
plot([-engine_length/2,engine_length/2]+x_cg_E,[-engine_width/2,-
engine_width/2]+engine_height,'b')
plot([-engine_length/2,-engine_length/2]+x_cg_E,[-
engine_width/2,engine_width/2]+engine_height,'b')
plot([engine_length/2,engine_length/2]+x_cg_E,[-
engine_width/2,engine_width/2]+engine_height,'b')


%horiz_CG
plot(x_cg_H,z_cg_H,'r*')

%vert_CG
plot(x_cg_V,z_cg_V,'r*')

%Main LG
plot(x_cg_MLG+[-Mlg_length/2,Mlg_length/2],z_cg_MLG+[-Mlg_height/2,-
Mlg_height/2],'c')
plot(x_cg_MLG+[-
Mlg_length/2,Mlg_length/2],z_cg_MLG+[Mlg_height/2,Mlg_height/2],'c')
plot(x_cg_MLG+[-Mlg_length/2,-Mlg_length/2],z_cg_MLG+[-
Mlg_height/2,Mlg_height/2],'c')
plot(x_cg_MLG+[Mlg_length/2,Mlg_length/2],z_cg_MLG+[-
Mlg_height/2,Mlg_height/2],'c')

%Nose LG
plot(x_cg_NLG+[-Nlg_length/2,Nlg_length/2],z_cg_NLG+[-Nlg_height/2,-
Nlg_height/2],'c')
plot(x_cg_NLG+[-
Nlg_length/2,Nlg_length/2],z_cg_NLG+[Nlg_height/2,Nlg_height/2],'c')
plot(x_cg_NLG+[-Nlg_length/2,-Nlg_length/2],z_cg_NLG+[-
Nlg_height/2,Nlg_height/2],'c')
plot(x_cg_NLG+[Nlg_length/2,Nlg_length/2],z_cg_NLG+[-
Nlg_height/2,Nlg_height/2],'c')
plot(x_cg_NLG,z_cg_NLG,'c*')

    upsweep=10;
    plot(total_length,tail_length*tand(upsweep),'y*')

    downsweep=0;
    plot(0,-nose_length*tand(downsweep),'y*')

legend('W/HT/VT CG','Engine CG','Fuselage CG','Total CG','Xnp','Landing Gear
CG')
axis([0,60,-5,20])
pbaspect([60,25,1])
hold off
```

```
xn1=0:-.01:-nose_length;
yn1=((d+2*wall_thick)/2+nose_length*tand(downsweep)).*(1-
((xn1)./nose_length).^2).^.5;

yn2=((d+2*wall_thick)/2-nose_length*tand(downsweep)).*(1-
((xn1)./nose_length).^2).^.5;
figure(7)
hold on
grid on
grid minor

plot(xn1+nose_length,yn1-nose_length*tand(downsweep),'k')

plot(xn1+nose_length,-yn2-nose_length*tand(downsweep),'k')

window_bot=0.5;
window_height=.8;

[~,idx]=min(abs(yn1-(window_bot)-nose_length*tand(downsweep)));

plot([-14.8,0]+xn1(idx)+nose_length,[z_ground,yn1(idx)-
nose_length*tand(downsweep)],'b--')

[~,idx2]=min(abs(yn1-(window_bot+window_height)-
nose_length*tand(downsweep)));

plot(xn1(idx2)+nose_length+[0,-10*cosd(20)],yn1(idx2)-
nose_length*tand(downsweep)+[0,10*sind(20)],'r--')

plot([xn1(idx)+nose_length,3.5],[window_bot,window_bot],'m')
plot([xn1(idx2)+nose_length,3.5],[window_bot,window_bot]+window_height,'m')
plot([3.5,3.5],[window_bot,window_bot+window_height],'m')

window_angle_ratio=atand((window_height)/(xn1(idx2)-xn1(idx)));

plot([-15,8.2],[0,0]+z_ground,'k')

[~,idx3]=min(abs(yn2-.5));

plot([xn1(idx3)+nose_length,8.2],[0,0]-.5,'k')


axis([-15,8.2,-4,3])
pbaspect([23,7,1])

hold off
```

```
figure(8)
hold on
grid on
grid minor
for i=-1:2:1
    %nose/tail
    plot(x1+nose_length,i*y1,'k')
    plot([nose_length+typea_width,nose_length+typea_width],i*[d/2-
.4572*3,d/2],'b')
    plot([nose_length-3,nose_length-3],i*[1.75875-.1,.5],'r')
    plot([nose_length-1,nose_length-1],i*[1.75875,d/2-1],'color',[0,.7,0])
    plot([0,typea_width]+nose_length,i*[d/2,d/2],'c')
    plot([0,type2_width]+nose_length+cabin_length/2-
type2_width/2,i*[d/2,d/2],'m')


    plot(x2+nose_length+cabin_length,i*y2,'k')
    plot(x3+nose_length-3,i*y3,'k')

    %fuselage side
    plot([nose_length,nose_length+cabin_length],i*[d/2,d/2],'k')

    %seats

plot([nose_length+typea_width,nose_length+typea_width]+21*seat_pitch,i*[d/2-
.4572*3,d/2],'b')

plot([nose_length+typea_width,nose_length+typea_width]+21*seat_pitch+type2_wi
dth,i*[d/2-.4572*3,d/2],'b')

plot([nose_length+typea_width,nose_length+typea_width]+42*seat_pitch+type2_wi
dth,i*[d/2-.4572*3,d/2],'b')

plot([nose_length+typea_width,nose_length+typea_width+21*seat_pitch],i*[d/2-
.4572*3,d/2-.4572*3],'b')

plot([nose_length+typea_width,nose_length+typea_width+21*seat_pitch]+21*seat_
pitch+type2_width,i*[d/2-.4572*3,d/2-.4572*3],'b')

    %toiletsfront
    plot([nose_length,nose_length],i*[d/2,d/2-1],'--','color',[0,.7,0])
    plot([nose_length-1,nose_length],i*[d/2-1,d/2-1],'color',[0,.7,0])

    %galley
    plot([nose_length-1,nose_length-1],i*[1.75875,0],'--r')
    plot([nose_length-3,nose_length-3],i*[.5,0],'--r')

    %toiletsback

plot([nose_length,nose_length]+typea_width*2+42*seat_pitch+.508,i*[d/2,0],'co
lor',[0,.7,0])

plot([nose_length,nose_length]+typea_width*2+42*seat_pitch+.508+1,i*[1.615,0]
,'color',[0,.7,0])
```

```
    plot([nose_length,nose_length+1]+typea_width*2+42*seat_pitch+.508,i*[d/2-
d/3,d/2-d/3],'color',[0,.7,0])

    %doors
    plot([-typea_width,0]+nose_length+cabin_length,i*[d/2,d/2],'c')

%     plot([0,10*sind(35)]+2.5,i*[0,10*cosd(35)],'r')
end
xlabel('X Position from Nose (m)')
ylabel({'Y Position','from Fuselage','Centerline(m)'})
legend('Fuselage Inner Walls','Seats','Galley','Lavatories','Type A
Exit','Type II Exits')
axis([-2,total_length+2,-3,3])
pbaspect([total_length+4,6,1])
hold off
```