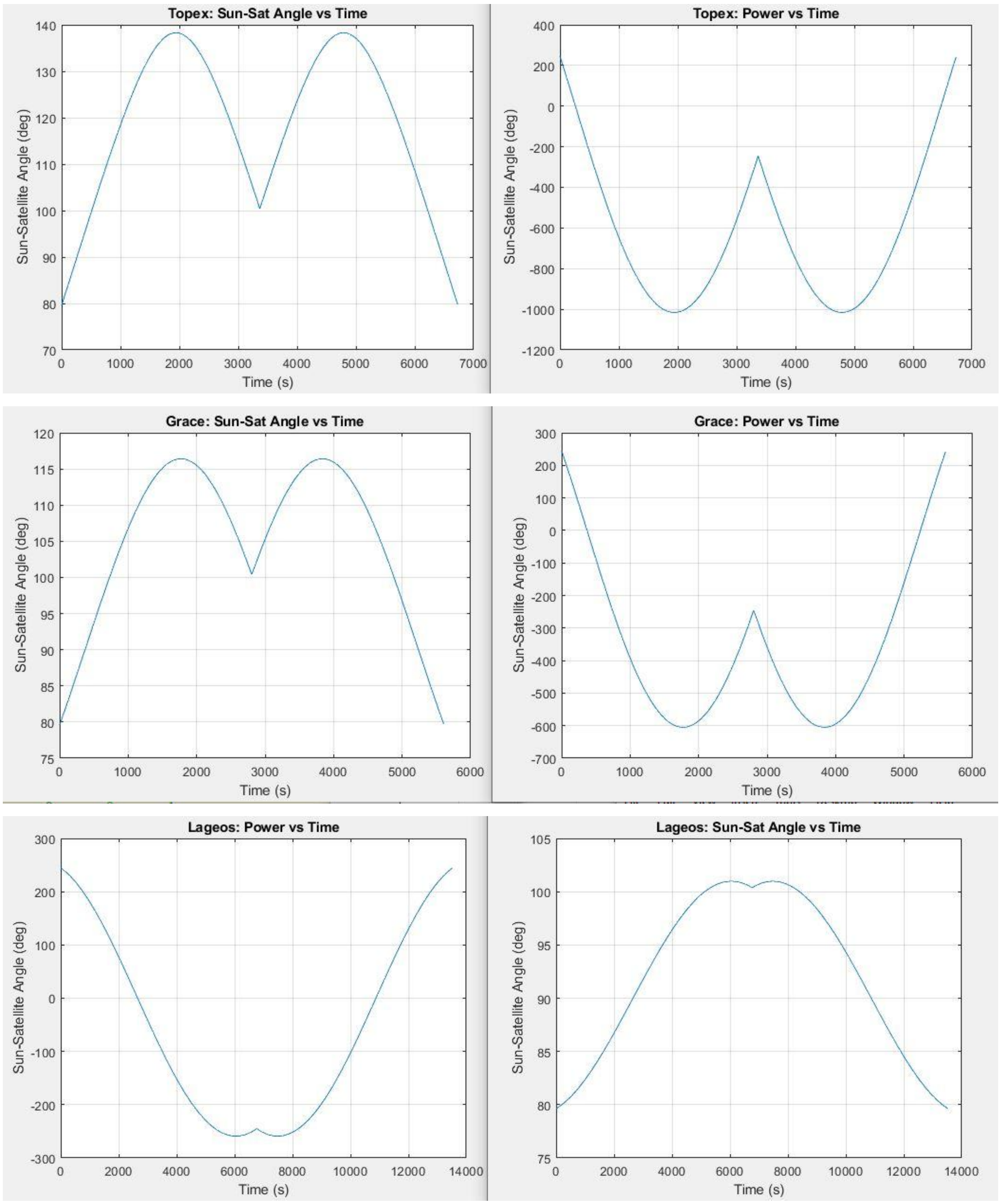
Homework Assignment #07 (Sun, Earth and the Orbit)

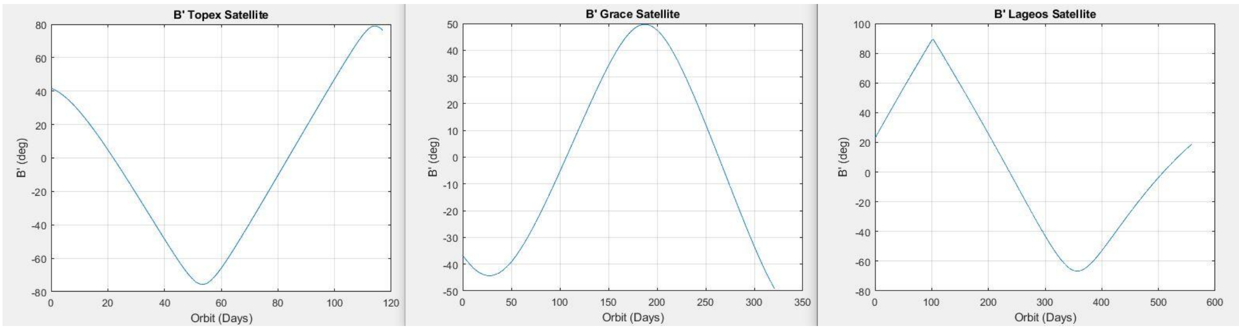
[Answer, Code]

I'M VERY SORRY

Problem 1.

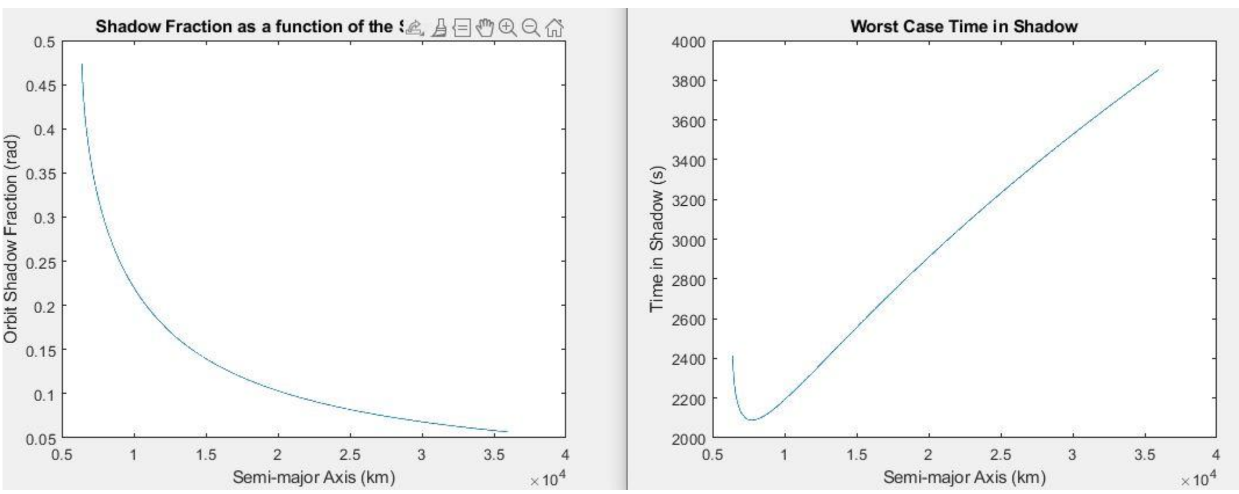
a. & b.





Problem 2.

a. & b.



c.

The orbit fraction plot shows an exponential decrease as the semi-major axis increases. However, this can be misleading as the satellite actually spends more time in orbit and thus more time in shadow as the semi-major axis increases. Therefore it makes the most sense to base the battery power storage system design off the time in shadow graph.

d.

The battery system design should not change very much as the difference in time spent in shadow from is minimal. The difference in time in shadow for about 7500 km to 36000 km is just under 30 min. Enough to be accounted for, but not enough to endorse significant change.

CODE:

```
%% Applied Orbital HW#7
clear all
%constants
mu = 3.986004415*10^14;
ae = 6378136.3;
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we = 7.292115*10^-5;
g=9.81;
j2=1.082*10^-3;

%%Preallocations
n = zeros(1,4);
bigWbar = zeros(1,4);
wbar = zeros(1,4);
Mbar = zeros(1,4);
Cs = zeros(1,4);
T_kepler = zeros(1,4);
bigW = zeros(4,361);
beta = zeros(4,361);
%% Problem 1
%      1      2      3      4
%   [Topex   Grace   ERS-1   Lageos]
a = [7705    6820    7156    12271]*1000; % m
e = [0.001   0.0016  0.001   0.004]; %
i = [65.99   89.02   98.6    109.83]*pi/180; % rad

% Calculating B' Angle:
%   calculating precession rates
bigWs = (360/365.2426); %deg/day
for j=1:4
n(j) = sqrt(mu/a(j)^3);
bigWbar(j) = -1.5*n(j)*(ae/a(j))^2*j2/sqrt(1-e(j)^2)*cos(i(j));
wbar(j) = -0.75*n(j)*(ae/a(j))^2*j2/(1-e(j)^2)^2*(1-5*(cos(i(j)))^2);
Mbar(j) = n(j)*(1-(0.75*(ae/a(j))^2*j2/(1-e(j)^2)^(3/2)*(1-3*(cos(i(j)))^2)));
T_kepler(j) = (2*pi)*sqrt((a(j)^3)/mu);
end
Omega = (bigWbar)*180/pi*60*60*24;
wbarDays = (wbar)*180/pi*60*60*24;
MbarDays = (Mbar)*180/pi*60*60*24;
for j=1:4
Cs(j) = 360/(Omega(j) - bigWs);
end
SunCycle_Duration = Cs
%Topex Satellite Beta Prime
n = 0;         %Meaning Jan 1 2000
```

```
for j = 1:abs(Cs(1))+1
    L = wrapTo360(280.460 + 0.9856474*n);              %[deg]
    g = wrapTo360(357.528 + 0.9856003*n);              %Mean Anomaly [deg]
    lambda = L + 1.915*sind(g) + 0.020*sind(2*g);      %[deg]
    eps = 23.439 - 0.0000004*n;                        %[deg]

    %RA = (atan(cosd(eps)*tand(lambda)))*(180/pi);   %[deg]
    %Dec = (asin(sind(eps)*sind(lambda)))*(180/pi);  %[deg]
    ehat_sun = [cosd(lambda);cosd(eps)*sind(lambda);sind(eps)*sind(lambda)];

    capOmega1 = Omega(1)*n;
    ehat_h = [sind(capOmega1)*sin(i(1));-cosd(capOmega1)*sin(i(1));cos(i(1))];
    beta_prime1(j) = 90 - acosd(dot(ehat_sun,ehat_h));
    n = n + 1;
end
figure(1)
timescale1=0:abs(Cs(1));
plot(timescale1,beta_prime1)
xlabel('Orbit (Days)')
ylabel("B' (deg)")
title("B' Topex Satellite")
grid on

%Grace Satellite Beta Prime
for j = 1:abs(Cs(2))+1
    L = wrapTo360(280.460 + 0.9856474*n);              %[deg]
    g = wrapTo360(357.528 + 0.9856003*n);              %Mean Anomaly [deg]
    lambda = L + 1.915*sind(g) + 0.020*sind(2*g);      %[deg]
    eps = 23.439 - 0.0000004*n;                        %[deg]

    %RA = (atan(cosd(eps)*tand(lambda)))*(180/pi);   %[deg]
    %Dec = (asin(sind(eps)*sind(lambda)))*(180/pi);  %[deg]
    ehat_sun = [cosd(lambda);cosd(eps)*sind(lambda);sind(eps)*sind(lambda)];

    capOmega2(j) = Omega(2)*n;
    ehat_h = [sind(capOmega2(j))*sin(i(1));-cosd(capOmega2(j))*sin(i(1));cos(i(1))];
    beta_prime2(j) = 90 - acosd(dot(ehat_sun,ehat_h));
    n = n + 1;
end
figure(2)
```

```
plot(0:abs(Cs(2)),beta_prime2)
xlabel('Orbit (Days)')
ylabel("B' (deg)")
title("B' Grace Satellite")
grid on

%Lageos Satellite Beta Prime
for j = 1:abs(Cs(4))+1
   L = wrapTo360(280.460 + 0.9856474*n);             %[deg]
   g = wrapTo360(357.528 + 0.9856003*n);             %Mean Anomaly [deg]
   lambda = L + 1.915*sind(g) + 0.020*sind(2*g);      %[deg]
   eps = 23.439 - 0.0000004*n;                    %[deg]

   %RA = (atan(cosd(eps)*tand(lambda)))*(180/pi);   %[deg]
   %Dec = (asin(sind(eps)*sind(lambda)))*(180/pi);  %[deg]
   ehat_sun = [cosd(lambda);cosd(eps)*sind(lambda);sind(eps)*sind(lambda)];

   capOmega4(j) = Omega(4)*n;
   ehat_h = [sind(capOmega4(j))*sin(i(1));-cosd(capOmega4(j))*sin(i(1));cos(i(1))];
   beta_prime4(j) = 90 - acosd(dot(ehat_sun,ehat_h));
   n = n + 1;
end
figure(3)
plot(0:abs(Cs(4)),beta_prime4)
xlabel('Orbit (Days)')
ylabel("B' (deg)")
title("B' Lageos Satellite")
grid on

%When RAAN is 0 the calculations become easier, the initial RAAN for the
%beta prime calculations is 0, so the first term of the Beta prime for each
%satellite is easiest.
%   Topex Sun-Sat Angle
A = 1; %m^2
K = 1360; %W/m^2
OmSat = 0;
nDay1 = 0;
Chosen_Beta_Prime = [beta_prime1(1) beta_prime2(1) 0 beta_prime4(1)]

   L1 = wrapTo360(280.460 + 0.9856474*nDay1);             %[deg]
```

```
    g1 = wrapTo360(357.528 + 0.9856003*nDay1);            %Mean Anomaly [deg]
    lambda = L1 + 1.915*sind(g1) + 0.020*sind(2*g1);      %[deg]
    eps = 23.439 - 0.0000004*nDay1;                       %[deg]
ehsun = [cosd(lambda);cosd(eps)*sind(lambda);sind(eps)*sind(lambda)];

ehh1 = [sin(OmSat)*sin(i(1)) -cos(OmSat)*sin(i(1)) cos(i(1))];

dt1 = 0:T_kepler(1)/360:T_kepler(1);
    Mo = 0;
    for j = 1:length(dt1)
        M = Mo + Mbar(1)*dt1(j);
        E = kepler(M,e(1));
        nu = E2nu(E,e(1));
        oe_topex = [a(1) e(1) i(1) 0 0 nu];
        rv_topex = hw6oe2rv(oe_topex,mu);
        eh_r_topex = rv_topex(1:3)./norm(rv_topex(1:3));
        psi_topex(j) = acosd(dot(eh_r_topex,ehsun));
        I_topex(j) = A*K*cosd(psi_topex(j));
    end
figure(4)
plot(dt1,psi_topex)
title('Topex: Sun-Sat Angle vs Time')
xlabel('Time (s)')
ylabel('Sun-Satellite Angle (deg)')
grid on
figure(5)
plot(dt1,I_topex)
title('Topex: Power vs Time')
xlabel('Time (s)')
ylabel('Sun-Satellite Angle (deg)')
grid on

%Grace Sat Sun
ehh2 = [sin(OmSat)*sin(i(2)) -cos(OmSat)*sin(i(2)) cos(i(2))];

dt2 = 0:T_kepler(2)/360:T_kepler(2);
    Mo = 0;
    for j = 1:length(dt2)
        M = Mo + Mbar(2)*dt2(j);
        E = kepler(M,e(2));
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```
        nu = E2nu(E,e(2));
        oe_Grace = [a(2) e(2) i(2) 0 0 nu];
        rv_Grace = hw6oe2rv(oe_Grace,mu);
        eh_r_Grace = rv_Grace(1:3)./norm(rv_Grace(1:3));
        psi_Grace(j) = acosd(dot(ehsun,eh_r_Grace));
        I_Grace(j) = A*K*cosd(psi_Grace(j));
    end
figure(6)
plot(dt2,psi_Grace)
title('Grace: Sun-Sat Angle vs Time')
xlabel('Time (s)')
ylabel('Sun-Satellite Angle (deg)')
grid on
figure(7)
plot(dt2,I_Grace)
title('Grace: Power vs Time')
xlabel('Time (s)')
ylabel('Sun-Satellite Angle (deg)')
grid on
%Grace Sat Sun
ehh4 = [sin(OmSat)*sin(i(4)) -cos(OmSat)*sin(i(4)) cos(i(4))];

dt4 = 0:T_kepler(4)/360:T_kepler(4);
    Mo = 0;
    for j = 1:length(dt4)
        M = Mo + Mbar(4)*dt4(j);
        E = kepler(M,e(4));
        nu = E2nu(E,e(4));
        oe_4 = [a(4) e(4) i(4) 0 0 nu];
        rv_4 = hw6oe2rv(oe_4,mu);
        eh_r_4 = rv_4(1:3)./norm(rv_4(1:3));
        psi_4(j) = acosd(dot(ehsun,eh_r_4));
        I_4(j) = A*K*cosd(psi_4(j));
    end
figure(8)
plot(dt4,psi_4)
title('Lageos: Sun-Sat Angle vs Time')
xlabel('Time (s)')
ylabel('Sun-Satellite Angle (deg)')
grid on
```

```
figure(9)
plot(dt4,I_4)
title('Lageos: Power vs Time')
xlabel('Time (s)')
ylabel('Sun-Satellite Angle (deg)')
grid on
%% Problem 2: SHADOW
%       1       2       3       4
%   [Topex   Grace   ERS-1   Lageos]
a = [7705    6820    7156    12271]*1000; % m
akm = [7705    6820    7156    12271]; % m
e = [0.001   0.0016  0.001   0.004]; %
i = [65.99   89.02   98.6    109.83]*pi/180; % rad

%Ranges of Semimajor Axis in (km)
a_func = 6400:36000;
for j=1:length(a_func)
f(j) = (1/pi)*asin(ae/(a_func(j)*1000));
nAgainLOL = sqrt(mu/(a_func(j)*1000)^3);
p = 2*pi/nAgainLOL;
tS(j) = f(j)*p;
end

figure(10)
plot(a_func,f)
title("Shadow Fraction as a function of the Semi-major Axis")
xlabel("Semi-major Axis (km)")
ylabel("Orbit Shadow Fraction (rad)")

%Time in Shadow:

figure(11)
plot(a_func, tS)
title("Worst Case Time in Shadow")
xlabel("Semi-major Axis (km)")
ylabel("Time in Shadow (s)")
```