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```
%Section - 01
%Aero 421 FP7: 6/9/25
```

Workspace Prep

```
%warning off
format long       %Allows for more accurate decimals
close all;        %Clears all
clear all;        %Clears Workspace
clc;              %Clears Command Window
```

Mass properties for normal operations phase

```
zbar = 0.23438;
cm = [0; 0; zbar];
mw = 1.4;
total_mass = 640;
total_mass = total_mass + 3*mw;
J = [812.0396 0 0
0 545.3729 0
0 0 627.7083];
eps = [0;sqrt(0.5);0];
eta = sqrt(0.5);
q_c = [eps; eta];
I_w1 = diag([0.6, 0.6 ,1.2]); % z-axis
I_w2 = diag([0.6, 1.2 , 0.6]); % y-axis
I_w3 = diag([1.2, 0.6 ,0.6]); % x-axis

r_w1 = [0,0,10];
r_w2 = [0,10,0];
r_w3 = [10,0,0];

I_w1 = I_w1 - mw*vcross(r_w1)*vcross(r_w1);
I_w2 = I_w2 - mw*vcross(r_w2)*vcross(r_w2);
I_w3 = I_w3 - mw*vcross(r_w3)*vcross(r_w3);
I_s = diag([1.2, 1.2, 1.2]);
J = J + I_w1 + I_w2 + I_w3;
ts = 100; % settling time
```

```
zeta = 0.65; % Damping ratio
wn = log(0.02*sqrt(1-zeta^2))/-zeta/ts;
beta = atan(sqrt(1-zeta^2)/zeta);
tr = (pi-beta)/wn/sqrt(1-zeta^2);
syms Mp1
eqn = zeta == sqrt(log(Mp1)^2/(pi^2 + log(Mp1)^2));
Mp = double(solve(eqn, Mp1));
Kp = 2*J*eye(3)*wn^2;
Kd = J*eye(3)*2*zeta*wn;
max_T = 1; %Nms
```

Disturbances

```
Areas = 4*ones(6,1);
normals = [1 0 0; -1 0 0; 0 1 0; 0 -1 0; 0 0 1; 0 0 -1];
cps = [1 0 0; -1 0 0; 0 1 0; 0 -1 0; 0 0 1; 0 0 -1];

% Append geometric properties for Solar Panel 1
Areas1 = 6*ones(2,1);
normals1 = [0 0 1; 0 0 -1];
cps1 = [0 2.5 0.005/2; 0 2.5 -0.005/2]; % Fix this

% Append geometric properties for Solar Panel 2
Areas2 = 6*ones(2,1);
normals2 = [0 0 1; 0 0 -1];
cps2 = [0 -2.5 0.005/2; 0 -2.5 -0.005/2]; % Do I need to use actual position
of geo-center, or just the axis?

% Append geometric properties for Sensor
Areas3 = [0.25*ones(4,1); 0.25*0.25];
normals3 = [1 0 0; 0 1 0; -1 0 0; 0 -1 0; 0 0 1];
cps3 = [0 0.25/2 1.5; 0.25/2 0 1.5; -0.25/2 0 1.5; 0 -0.25/2 1.5; 0 0 2];

% now subtract the center of mass to get the location of the rho vectors
% with respect to the center of mass
normals = normals - [0  0 zbar];
normals1 = normals1 - [0  0 zbar];
normals2 = normals2 - [0  0 zbar];
normals3 = normals3 - [0  0 zbar];

cps = cps - cm';
cps1 = cps1 - cm';
cps2 = cps2 - cm';
cps3 = cps3 - cm';


% Now build the matrix
surfaceProperties = [Areas cps normals;
                    Areas1 cps1 normals1;
                    Areas2 cps2 normals2;
                    Areas3 cps3 normals3];
```

Orbital Dynamics

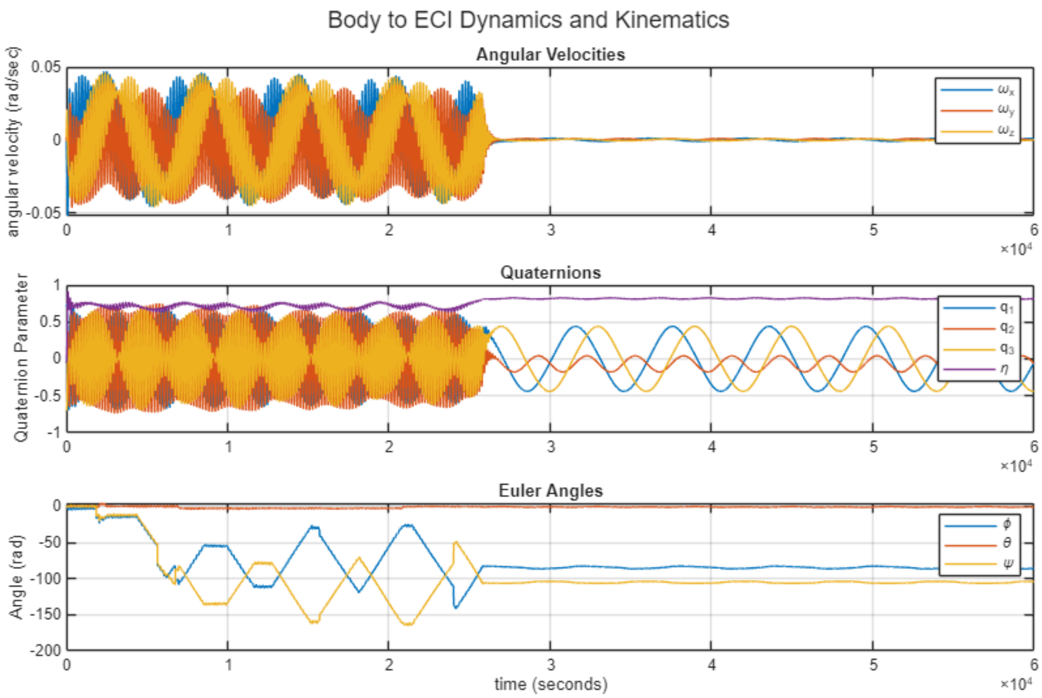
```
% Define the sun in F_ECI and residual dipole moment in F_b
sun_ECI = [0 0 -1];

% Current JD - has to be on the solar equinox, why? - we'll use 3/20/2024
% from https://aa.usno.navy.mil/data/JulianDate
% Need this so we can convert from F_ECEF to F_ECI and to F_b for the
% magnetic field model
JD_0 = 2460390;

m_b = [0; 0; -0.5];

% Spacecraft Orbit Properties (given)
mu = 398600; % km^3/s^2
h = 53335.2; % km^2/s
e = 0; % none
Omega = 0*pi/180; % radians
inc = 98.43*pi/180; % radians
omega = 0*pi/180; % radians
nu = 0*pi/180; % radians

a = h^2/mu/(1 - e^2);
orbital_period = 2*pi*sqrt(a^3/mu);

% Torque free scenario (Given)
T = [0;0;0];

% Set/Compute initial conditions
% intial orbital position and velocity
[r_ECI_0, v_ECI_0] = coes2rvd(a,e,rad2deg(inc),0,omega,nu,mu);

% Compute inital F_LVLH basis vectors in F_ECI components based on F_LVLH
% definition

rV = r_ECI_0; %Position Vector km
vV = v_ECI_0; %Vel Vector km/s

Zlvlh = -(rV/norm(rV));
Ylvlh = -(cross(rV,vV)/norm(cross(rV,vV)));
Xlvlh = cross(Ylvlh,Zlvlh);

%Creating Matrix with new vectors

C_LVLH_ECI_0 = [Xlvlh, Ylvlh, Zlvlh];

% Initial Euler angles relating F_body and F_LVLH (given)
phi_0 = 0;
theta_0 = 0;
psi_0 = 0;
E_b_LVLH_0 = [phi_0; theta_0; psi_0];

% Initial Quaternion relating F_body and F_LVLH (given)
```

```
q_b_LVLH_0 = [0; 0; 0; 1];

% Compute initial C_LVLH_ECI_0, C_b_LHVL_0, and C_b_ECI_0 rotaiton matrices
%C_LVLH_ECI_0 = [x_LVLH'; y_LVLH'; z_LVLH'];
C_b_LVLH_0 =
rotx(rad2deg(phi_0))'*roty(rad2deg(theta_0))'*rotz(rad2deg(psi_0))';
C_b_ECI_0 = C_b_LVLH_0*C_LVLH_ECI_0;

% Initial Euler angles relating body to ECI
E_b_ECI_0 = C2EulerAngles(C_b_ECI_0);

% Initial quaternion relating body to E
q_b_ECI_0 = rotm2quat(C_b_ECI_0);

% Initial body rates of spacecraft (given)
w_b_ECI_0 = [0.001; -0.001; 0.002];

% Set simulation time period
N = 10; % Number of Orbits
tspan = orbital_period*N;
%tspan = 300;

% Simulate!
out = sim('AERO421_FP7.slx');
```

Plot Results

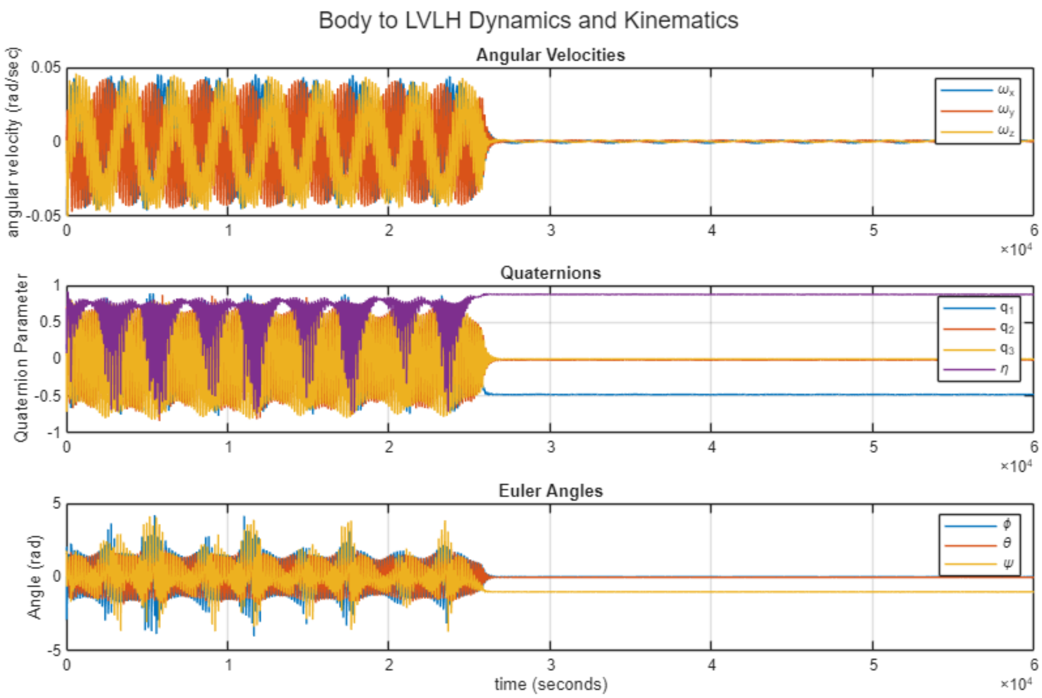
```
q_b_ECI = squeeze(out.q_b_ECI.signals.values);
E_b_ECI = squeeze(out.E_b_ECI.signals.values);
w_b_ECI = squeeze(out.w_b_ECI.signals.values);

figure('Name','Body to ECI')
subplot(3,1,1)
plot(out.tout, w_b_ECI)
title('Angular Velocities')
ylabel('angular velocity (rad/sec)')
legend('\omega_x','\omega_y','\omega_z')
grid on

subplot(3,1,2)
plot(out.tout, q_b_ECI)
title('Quaternions')
ylabel('Quaternion Parameter')
legend('q_1','q_2','q_3','\eta')
grid on

subplot(3,1,3)
plot(out.tout, E_b_ECI)
title('Euler Angles')
xlabel('time (seconds)')
ylabel('Angle (rad)')
legend('\phi','\theta','\psi')
grid on
```

```
sgtitle('Body to ECI Dynamics and Kinematics')
```

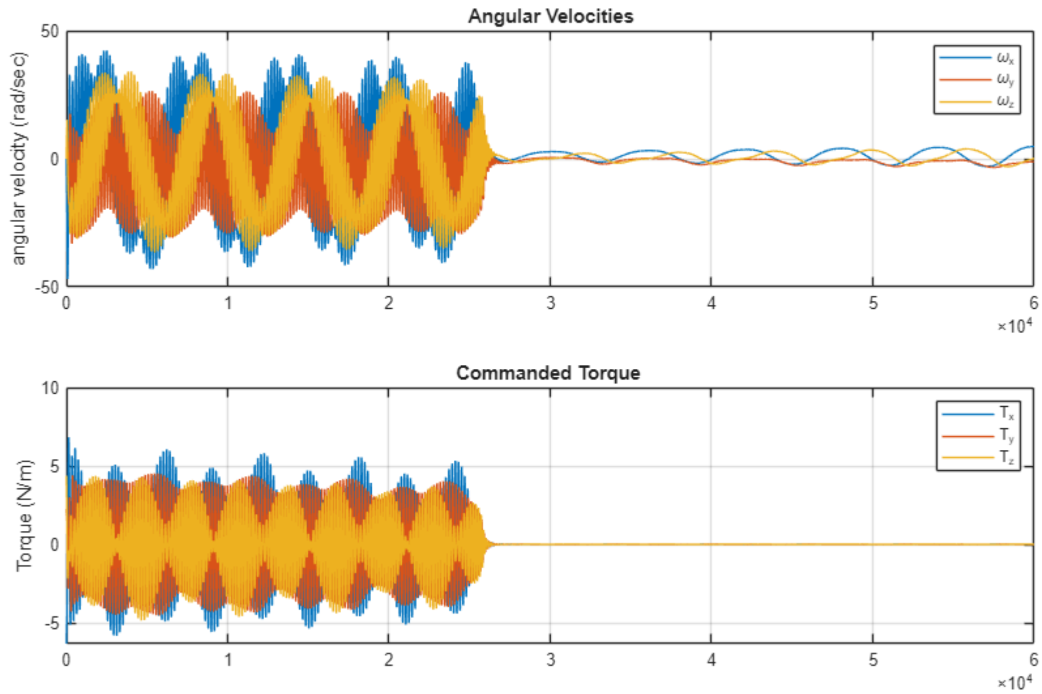



```
q_b_LVLH = squeeze(out.q_b_LVLH.signals.values);
E_b_LVLH = squeeze(out.E_b_LVLH.signals.values);
w_b_LVLH = squeeze(out.w_b_LVLH.signals.values);


figure('Name','Body to LVLH')
subplot(3,1,1)
plot(out.tout, w_b_LVLH)
title('Angular Velocities')
ylabel('angular velocity (rad/sec)')
legend('\omega_x','\omega_y','\omega_z')
grid on

subplot(3,1,2)
plot(out.tout, q_b_LVLH)
title('Quaternions')
ylabel('Quaternion Parameter')
legend('q_1','q_2','q_3','\eta')
grid on

subplot(3,1,3)
plot(out.tout, E_b_LVLH)
title('Euler Angles')
xlabel('time (seconds)')
ylabel('Angle (rad)')
legend('\phi','\theta','\psi')
```

```
grid on

sgtitle('Body to LVLH Dynamics and Kinematics')
```




```
wheelz = squeeze(out.RWheel.signals.values);
torque = squeeze(out.M_c.signals.values);

figure('Name','Reaction Wheels')
subplot(2,1,1)
plot(out.tout(:,1), wheelz)
title('Angular Velocities')
ylabel('angular velocity (rad/sec)')
legend('\omega_x','\omega_y','\omega_z')
grid on

subplot(2,1,2)
plot(out.tout(:,1), torque)
title('Commanded Torque ')
ylabel('Torque (N/m)')
legend('T_x','T_y','T_z')
grid on
```




```
torqueMag = sqrt(sum(torque.^2, 1));
```

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