Contents

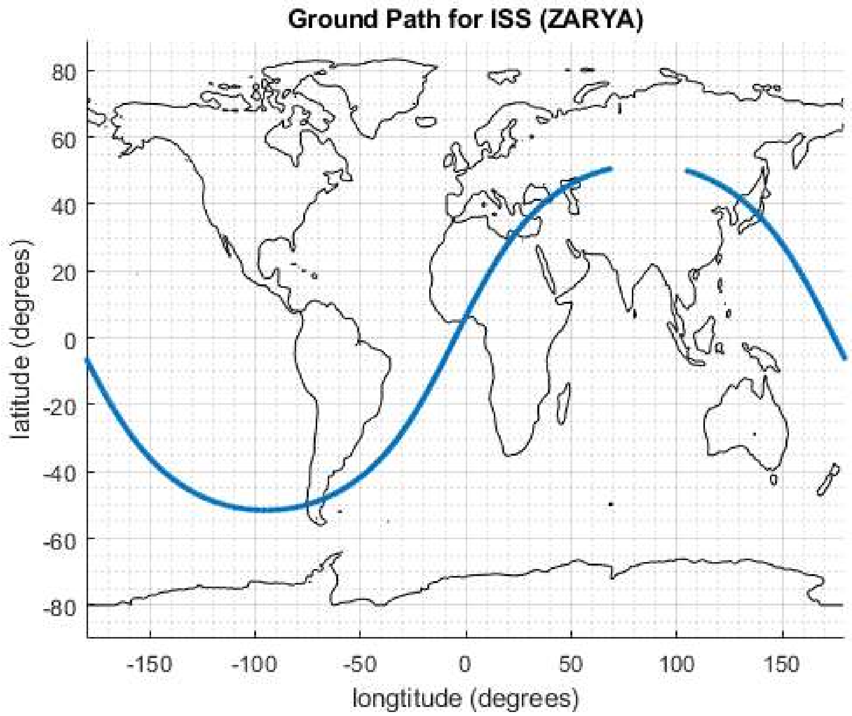

```
% AERSP 450 HW 1 Problem 4
% Made by Nicholas Luis, PSU ID: 930841391

close all;
```

ISS (ZARYA)

1 25544U 98067A 24259.04042691 -.00020782 00000+0 -36841-3 0 9993 2 25544 51.6359 230.2949 0007613 354.9391 85.5828 15.49088255472489

```
clear; clc;

MU = 3.986 * (10^5); % km^3 / s^2
PI = 3.141592654;

% Orbit Data from the TLE
n = 15.49088255; % Revolutions per day
e = 0.0007613; % Eccentricity
M0 = 85.5828; % Initial Mean Anomaly
w = 354.9391; % Argument of perigee
i = 51.6359; % Inclination
W = 230.2949; % Right ascension of ascending node
ERA = [0, 36, 10]; % GMST based on the provided website using epoch data

T = 86400/n; % Period of orbit (in seconds per 1 revolution)
a = ((T/(2*PI))^2 * MU)^(1/3);
t = linspace(0,T,500); % Incremental time
t0 = t(1);
M = M0 + n.*(t/86400).*360; % Mean anomaly at every point in the orbit

% Converting M (mean anomaly) to E (eccentric anomaly) and f (true anomaly)
E = zeros(size(M));
for iter = 1 : length(M)
    E(iter) = mean2true(M(iter), e);
end
E0 = E(1);
f0 = 2*atan( sqrt((1+e)/(1-e)) * tan(E(1)/2) ) * (180/PI);

% Getting initial radius and speed using derived equations
p = a*(1-e^2);
r0 = p / (1+e*cosd(f0));
v0 = sqrt(2*MU/r0 - MU/a);

% Calculating Langrange Coefficients using Block 2 (elliptic orbit)
F = zeros(1,length(E));
G = zeros(1,length(E));
for iter = 1 : length(E)
    F(iter) = 1 - (a/r0).*(1-cosd(E(iter)-E0));
    G(iter) = (t(iter)-t0) - sqrt(a^3/MU).*((E(iter)-E0).*(PI/180)-sind(E(iter)-E0));
end

% Getting initial position and velocity vectors in perifocal frame
r = zeros(length(t), 3);
r(1,:) = [r0*cosd(f0), r0*sind(f0), 0]; % e, p, h hat directions
v = zeros(length(t), 3);
v(1,:) = [-sqrt(MU/p)*sind(f0), sqrt(MU/p)*(e+cosd(f0)), 0]; % e, p, h hat directions
```

```matlab
% Calculating 1-orbit-worth of future positions
for iter = 2 : length(t) % Start at t = 2 because we already have initial conditions
    r(iter,:) = F(iter)*r(1,:) + G(iter)*v(1,:);
end

% Rotation Matrices
R3W = [cosd(W), -sind(W), 0;
       sind(W),  cosd(W), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by W (Right ascension of ascending node) degrees
R1i = [1, 0      ,        0;
       0, cosd(i), -sind(i);
       0, sind(i),  cosd(i) ]; % Rotation around axis 1 by i (inclination) degrees
R3w = [cosd(w), -sind(w), 0;
       sind(w),  cosd(w), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by w (argument of perigee) degrees

R_IP = R3w*(R1i*R3W);
ERA_degrees = [ERA(1)*15, ERA(2)*15/60, ERA(3)*15/60/60];
gamma0 = sum(ERA_degrees);

% Rotating position vectors to get it in ECEF frame (at every point in time)
for iter = 1 : length(t) % Start at t = 2 because we already have initial conditions
    g = gamma0 - (15/3600)*t(iter);
    R3g = [cosd(g), -sind(g), 0;
           sind(g),  cosd(g), 0;
           0      ,  0      , 1 ]; % Rotation around axis 3 by g (GMST angle) degrees
    R_EI = R_IP*R3g;
    r(iter,:) = R_EI*r(iter,:)';
end

% Converting position to lattitude and longitude
longitude = zeros(length(r),1);
latitude = zeros(length(r),1);
for iter = 1 : length(r)
    %longitude(iter) = (180/PI)*atan(r(iter, 2) / r(iter, 1)); % longtude equation using ECEF coords
    longitude(iter) = (180/PI)*atan2(r(iter, 2), r(iter, 1));
    latitude(iter) = (180/PI)*atan(r(iter, 3) / sqrt(r(iter, 1)^2 + r(iter, 2)^2 )); % lattitude equation using ECEF coords
end

figure(1)
hold on
load('topo.mat','topo');
topoplot = [topo(:,181:360),topo(:,1:180)];
contour(-180:179,-90:89,topoplot,[0,0],'black');
grid on
grid minor
plot(longitude,latitude,'.','LineWidth',2)
xlabel("longtitude (degrees)")
ylabel("latitude (degrees)")
title('Ground Path for ISS (ZARYA)')
hold off
```

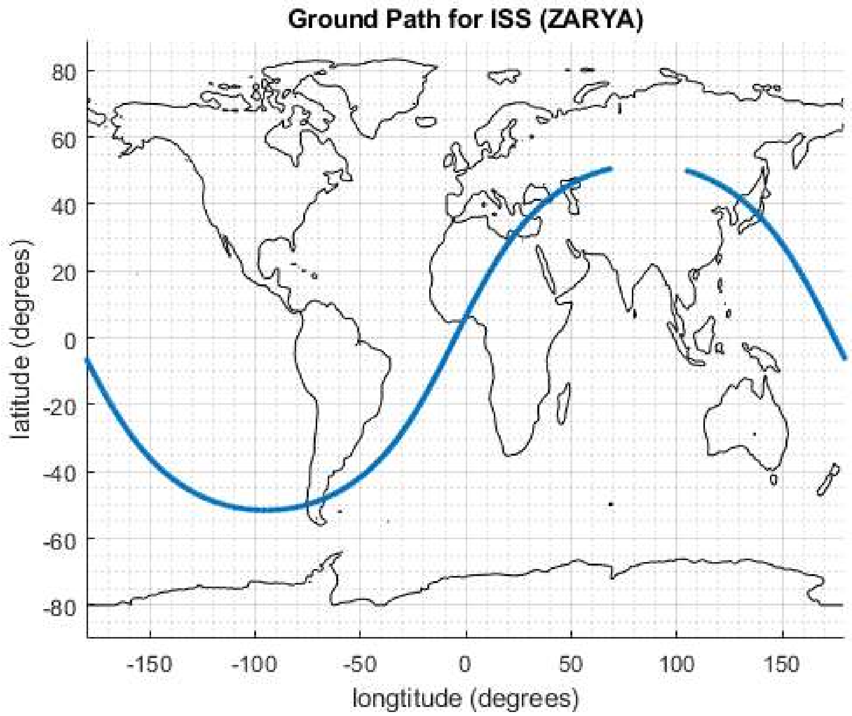


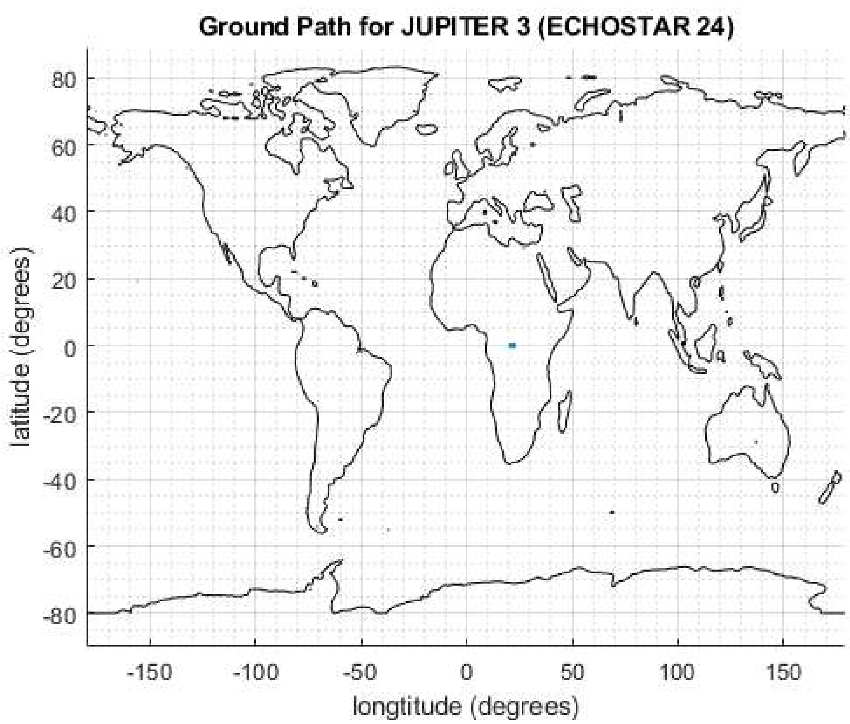
JUPITER 3 (ECHOSTAR 24) : This is the heaviest commericial satellite ever launched, let alone in geostationary

1 57479U 23108A 24257.28463005 -.00000150 00000+0 00000+0 0 9999 2 57479 0.0225 150.4751 0001204 19.0167 190.5107 1.00269368 4212

```
clear;

MU = 3.986 * (10^5); % km^3 / s^2
PI = 3.141592654;

% Orbit Data from the TLE
n = 1.00269368; % Revolutions (times 360 degrees) per day
e = 0.0001204; % Eccentricity
M0 = 190.5107; % Initial Mean Anomaly
w = 19.0167; % Argument of perigee
i = 0.0225; % Inclination
W = 150.4751; % Right ascension of ascending node
ERA = [06, 24, 51]; % GMST based on the provided website using epoch data

T = 86400/n; % Period of orbit (in seconds per 1 revolution)
a = ((T/(2*PI))^2 * MU)^(1/3);
t = linspace(0,T,500); % Incremental time
t0 = t(1);
M = M0 + n.*(t/86400).*360; % Mean anomaly at every point in the orbit

% Converting M (mean anomaly) to E (eccentric anomaly) and f (true anomaly)
E = zeros(size(M));
for iter = 1 : length(M)
    E(iter) = mean2true(M(iter), e);
end
E0 = E(1);
f0 = 2*atan( sqrt((1+e)/(1-e)) * tan(E(1)/2) ) * (180/PI);

% Getting initial radius and speed using derived equations
p = a*(1-e^2);
r0 = p / (1+e*cosd(f0));
v0 = sqrt(2*MU/r0 - MU/a);

% Calculating Langrange Coefficients using Block 2 (elliptic orbit)
F = zeros(1,length(E));
G = zeros(1,length(E));
for iter = 1 : length(E)
    F(iter) = 1 - (a/r0).*(1-cosd(E(iter)-E0));
```

```
    G(iter) = (t(iter)-t0) - sqrt(a^3/MU).*((E(iter)-E0).*(PI/180)-sind(E(iter)-E0));
end

% Getting initial position and velocity vectors in perifocal frame
r = zeros(length(t), 3);
r(1,:) = [r0*cosd(f0), r0*sind(f0), 0]; % e, p, h hat directions
v = zeros(length(t), 3);
v(1,:) = [-sqrt(MU/p)*sind(f0), sqrt(MU/p)*(e+cosd(f0)), 0]; % e, p, h hat directions

% Calculating 1-orbit-worth of future positions
for iter = 2 : length(t) % Start at t = 2 because we already have initial conditions
    r(iter,:) = F(iter)*r(1,:) + G(iter)*v(1,:);
end

% Rotation Matrices
R3W = [cosd(W), -sind(W), 0;
       sind(W),  cosd(W), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by W (Right ascension of ascending node) degrees
R1i = [1, 0      ,        0;
       0, cosd(i), -sind(i);
       0, sind(i),  cosd(i) ]; % Rotation around axis 1 by i (inclination) degrees
R3w = [cosd(w), -sind(w), 0;
       sind(w),  cosd(w), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by w (argument of perigee) degrees

R_IP = R3w*(R1i*R3W);
ERA_degrees = [ERA(1)*15, ERA(2)*15/60, ERA(3)*15/60/60];
gamma0 = sum(ERA_degrees);

% Rotating position vectors to get it in ECEF frame (at every point in time)
for iter = 1 : length(t) % Start at t = 2 because we already have initial conditions
    g = gamma0 - (15/3600)*t(iter);
    R3g = [cosd(g), -sind(g), 0;
           sind(g),  cosd(g), 0;
           0      ,  0      , 1 ]; % Rotation around axis 3 by g (GMST angle) degrees
    R_EI = R_IP*R3g;
    r(iter,:) = R_EI*r(iter,:)';
end

% Converting position to lattitude and longitude
longitude2 = zeros(length(r),1);
latitude2 = zeros(length(r),1);
for iter = 1 : length(r)
    %longitude(iter) = (180/PI)*atan(r(iter, 2) / r(iter, 1)); % longtude equation using ECEF coords
    longitude2(iter) = (180/PI)*atan2(r(iter, 2), r(iter, 1));
    latitude2(iter) = (180/PI)*atan(r(iter, 3) / sqrt(r(iter, 1)^2 + r(iter, 2)^2 )); % lattitude equation using ECEF coords
end

figure(2)
hold on
load('topo.mat','topo');
topoplot = [topo(:,181:360),topo(:,1:180)];
contour(-180:179,-90:89,topoplot,[0,0],'black');
grid on
grid minor
plot(longitude2,latitude2,'.','LineWidth',2)
%plot(longitude2(1:10),latitude2(1:10),'.','LineWidth',2)
xlabel("longtitude (degrees)")
ylabel("latitude (degrees)")
title('Ground Path for JUPITER 3 (ECHOSTAR 24)')
hold off
```





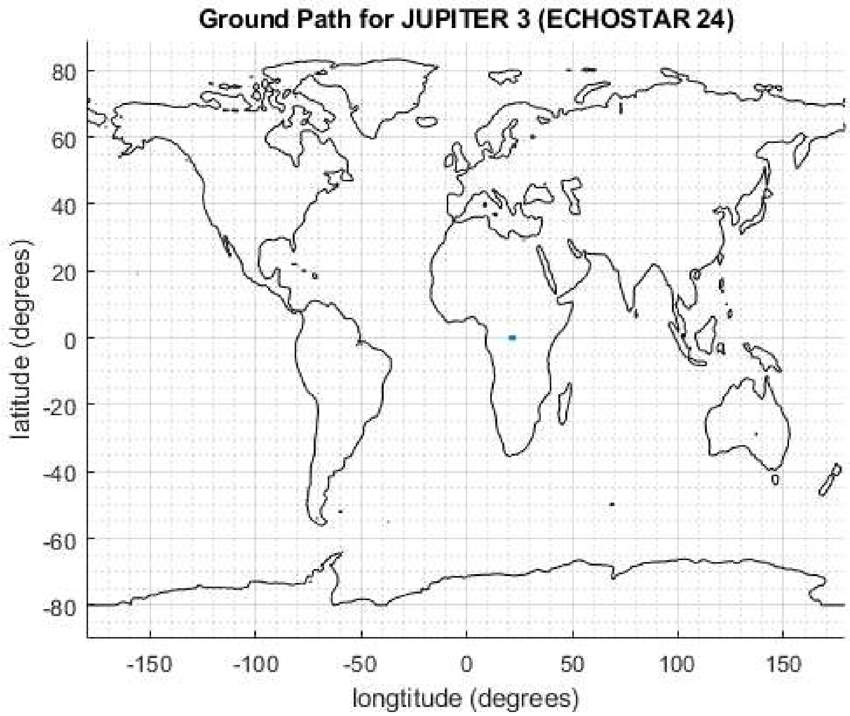
MOLNIYA 1-91

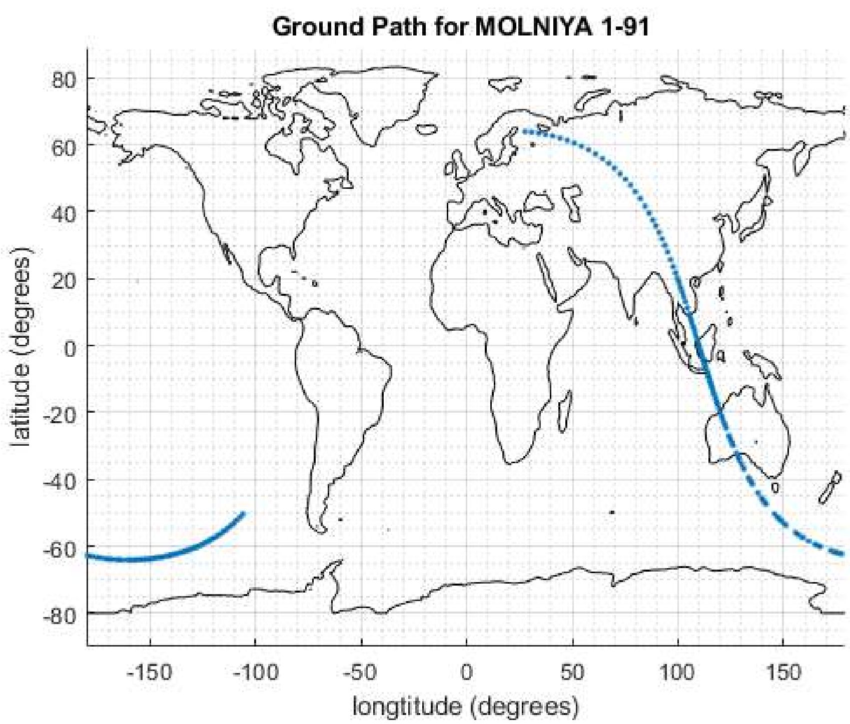
1 25485U 98054A 24258.47584262 -.00000047 00000+0 00000+0 0 9999 2 25485 64.1500 21.4697 6821298 289.9022 12.2134 2.36441173198427

```
clear;

MU = 3.986 * (10^5); % km^3 / s^2
PI = 3.141592654;

% Orbit Data from the TLE
n = 2.36441173; % Revolutions (times 360 degrees) per day
e = 0.6821298; % Eccentricity
M0 = 12.2134; % Initial Mean Anomaly
w = 289.9022; % Argument of perigee
```

```
i = 64.1500; % Inclination
W = 21.4697; % Right ascension of ascending node
ERA = [11, 04, 53]; % GMST based on the provided website using epoch data

T = 86400/n; % Period of orbit (in seconds per 1 revolution)
a = ((T/(2*PI))^2 * MU)^(1/3);
t = linspace(0,T,500); % Incremental time
t0 = t(1);
M = M0 + n.*(t/86400).*360; % Mean anomaly at every point in the orbit

% Converting M (mean anomaly) to E (eccentric anomaly) and f (true anomaly)
E = zeros(size(M));
for iter = 1 : length(M)
    E(iter) = mean2true(M(iter), e);
end
E0 = E(1);
f0 = 2*atan( sqrt((1+e)/(1-e)) * tan(E(1)/2) ) * (180/PI);

% Getting initial radius and speed using derived equations
p = a*(1-e^2);
r0 = p / (1+e*cosd(f0));
v0 = sqrt(2*MU/r0 - MU/a);

% Calculating Langrange Coefficients using Block 2 (elliptic orbit)
F = zeros(1,length(E));
G = zeros(1,length(E));
for iter = 1 : length(E)
    F(iter) = 1 - (a/r0).*(1-cosd(E(iter)-E0));
    G(iter) = (t(iter)-t0) - sqrt(a^3/MU).*((E(iter)-E0).*(PI/180)-sind(E(iter)-E0));
end

% Getting initial position and velocity vectors in perifocal frame
r = zeros(length(t), 3);
r(1,:) = [r0*cosd(f0), r0*sind(f0), 0]; % e, p, h hat directions
v = zeros(length(t), 3);
v(1,:) = [-sqrt(MU/p)*sind(f0), sqrt(MU/p)*(e+cosd(f0)), 0]; % e, p, h hat directions

% Calculating 1-orbit-worth of future positions
for iter = 2 : length(t) % Start at t = 2 because we already have initial conditions
    r(iter,:) = F(iter)*r(1,:) + G(iter)*v(1,:);
end

% Rotation Matrices
R3W = [cosd(W), -sind(W), 0;
       sind(W),  cosd(W), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by W (Right ascension of ascending node) degrees
R1i = [1, 0      ,        0;
       0, cosd(i), -sind(i);
       0, sind(i),  cosd(i) ]; % Rotation around axis 1 by i (inclination) degrees
R3w = [cosd(w), -sind(w), 0;
       sind(w),  cosd(w), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by w (argument of perigee) degrees

R_IP = R3w*(R1i*R3W);
ERA_degrees = [ERA(1)*15, ERA(2)*15/60, ERA(3)*15/60/60];
gamma0 = sum(ERA_degrees);

% Rotating position vectors to get it in ECEF frame (at every point in time)
for iter = 1 : length(t) % Start at t = 2 because we already have initial conditions
    g = gamma0 - (15/3600)*t(iter);
    R3g = [cosd(g), -sind(g), 0;
           sind(g),  cosd(g), 0;
           0      ,  0      , 1 ]; % Rotation around axis 3 by g (GMST angle) degrees
    R_EI = R_IP*R3g;
    r(iter,:) = R_EI*r(iter,:)';
end

% Converting position to lattitude and longitude
longitude3 = zeros(length(r),1);
latitude3 = zeros(length(r),1);
```

```
for iter = 1 : length(r)
    %longitude(iter) = (180/PI)*atan(r(iter, 2) / r(iter, 1)); % longtude equation using ECEF coords
    longitude3(iter) = (180/PI)*atan2(r(iter, 2), r(iter, 1));
    latitude3(iter) = (180/PI)*atan(r(iter, 3) / sqrt(r(iter, 1)^2 + r(iter, 2)^2 )); % lattitude equation using ECEF coords
end

figure(3)
hold on
load('topo.mat','topo');
topoplot = [topo(:,181:360),topo(:,1:180)];
contour(-180:179,-90:89,topoplot,[0,0],'black');
grid on
grid minor
plot(longitude3,latitude3,'.','LineWidth',2)
xlabel("longtitude (degrees)")
ylabel("latitude (degrees)")
title('Ground Path for MOLNIYA 1-91 ')
hold off
```





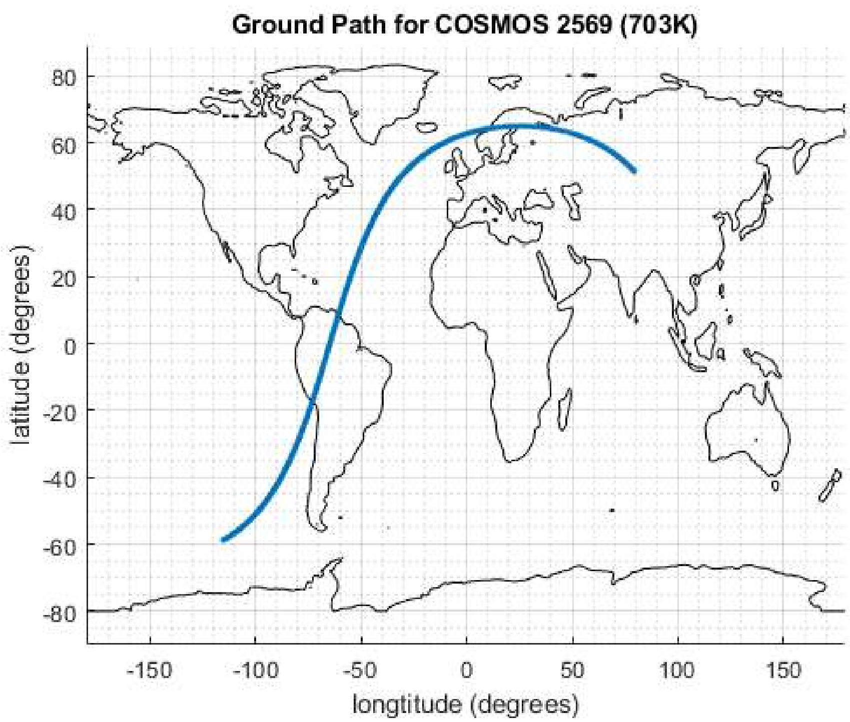
COSMOS 2569 (703K)

1 57517U 23114A 24258.24908306 .00000071 00000+0 00000+0 0 9995 2 57517 64.9566 94.2948 0008739 295.2308 64.7601 2.13103887 8606

```
clear;

MU = 3.986 * (10^5); % km^3 / s^2
PI = 3.141592654;

% Orbit Data from the TLE
n = 2.13103887; % Revolutions (times 360 degrees) per day
e = 0.0008739; % Eccentricity
M0 = 64.7601; % Initial Mean Anomaly
w = 295.2308; % Argument of perigee
```

```
i = 64.9566; % Inclination
W = 94.2948; % Right ascension of ascending node
ERA = [05, 37, 27]; % GMST based on the provided website using epoch data

T = 86400/n; % Period of orbit (in seconds per 1 revolution)
a = ((T/(2*PI))^2 * MU)^(1/3);
t = linspace(0,T,500); % Incremental time
t0 = t(1);
M = M0 + n.*(t/86400).*360; % Mean anomaly at every point in the orbit

% Converting M (mean anomaly) to E (eccentric anomaly) and f (true anomaly)
E = zeros(size(M));
for iter = 1 : length(M)
    E(iter) = mean2true(M(iter), e);
end
E0 = E(1);
f0 = 2*atan( sqrt((1+e)/(1-e)) * tan(E(1)/2) ) * (180/PI);

% Getting initial radius and speed using derived equations
p = a*(1-e^2);
r0 = p / (1+e*cosd(f0));
v0 = sqrt(2*MU/r0 - MU/a);

% Calculating Langrange Coefficients using Block 2 (elliptic orbit)
F = zeros(1,length(E));
G = zeros(1,length(E));
for iter = 1 : length(E)
    F(iter) = 1 - (a/r0).*(1-cosd(E(iter)-E0));
    G(iter) = (t(iter)-t0) - sqrt(a^3/MU).*((E(iter)-E0).*(PI/180)-sind(E(iter)-E0));
end

% Getting initial position and velocity vectors in perifocal frame
r = zeros(length(t), 3);
r(1,:) = [r0*cosd(f0), r0*sind(f0), 0]; % e, p, h hat directions
v = zeros(length(t), 3);
v(1,:) = [-sqrt(MU/p)*sind(f0), sqrt(MU/p)*(e+cosd(f0)), 0]; % e, p, h hat directions

% Calculating 1-orbit-worth of future positions
for iter = 2 : length(t) % Start at t = 2 because we already have initial conditions
    r(iter,:) = F(iter)*r(1,:) + G(iter)*v(1,:);
end

% Rotation Matrices
R3W = [cosd(W), -sind(W), 0;
       sind(W),  cosd(W), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by W (Right ascension of ascending node) degrees
R1i = [1, 0      ,         0;
       0, cosd(i), -sind(i);
       0, sind(i),  cosd(i) ]; % Rotation around axis 1 by i (inclination) degrees
R3w = [cosd(w), -sind(w), 0;
       sind(w),  cosd(w), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by w (argument of perigee) degrees

R_IP = R3w*(R1i*R3W);
ERA_degrees = [ERA(1)*15, ERA(2)*15/60, ERA(3)*15/60/60];
gamma0 = sum(ERA_degrees);

% Rotating position vectors to get it in ECEF frame (at every point in time)
for iter = 1 : length(t) % Start at t = 2 because we already have initial conditions
    g = gamma0 - (15/3600)*t(iter);
    R3g = [cosd(g), -sind(g), 0;
           sind(g),  cosd(g), 0;
           0      ,  0      , 1 ]; % Rotation around axis 3 by g (GMST angle) degrees
    R_EI = R_IP*R3g;
    r(iter,:) = R_EI*r(iter,:)';
end

% Converting position to lattitude and longitude
longitude4 = zeros(length(r),1);
latitude4 = zeros(length(r),1);
```

```
for iter = 1 : length(r)
    %longitude(iter) = (180/PI)*atan(r(iter, 2) / r(iter, 1)); % longtude equation using ECEF coords
    longitude4(iter) = (180/PI)*atan2(r(iter, 2), r(iter, 1));
    latitude4(iter) = (180/PI)*atan(r(iter, 3) / sqrt(r(iter, 1)^2 + r(iter, 2)^2 )); % lattitude equation using ECEF coords
end

figure(4)
hold on
load('topo.mat','topo');
topoplot = [topo(:,181:360),topo(:,1:180)];
contour(-180:179,-90:89,topoplot,[0,0],'black');
grid on
grid minor
plot(longitude4,latitude4,'.','LineWidth',2)
xlabel("longtitude (degrees)")
ylabel("latitude (degrees)")
title('Ground Path for COSMOS 2569 (703K)')
hold off
```



STARLETTE

1 07646U 75010A 24258.93756172 -.00000102 00000+0 34095-4 0 9995 2 07646 49.8222 111.7558 0205657 107.9496 254.3932 13.82332614505978

```
clear;

MU = 3.986 * (10^5); % km^3 / s^2
PI = 3.141592654;

% Orbit Data from the TLE
n = 13.82332614; % Revolutions (times 360 degrees) per day
e = 0.0205657; % Eccentricity
M0 = 254.3932; % Initial Mean Anomaly
w = 107.9496; % Argument of perigee
i = 49.8222; % Inclination
W = 111.7558; % Right ascension of ascending node
ERA = [22, 11, 35]; % GMST based on the provided website using epoch data

T = 86400/n; % Period of orbit (in seconds per 1 revolution)
a = ((T/(2*PI))^2 * MU)^(1/3);
t = linspace(0,T,500); % Incremental time
t0 = t(1);
```

```
M = M0 + n.*(t/86400).*360; % Mean anomaly at every point in the orbit

% Converting M (mean anomaly) to E (eccentric anomaly) and f (true anomaly)
E = zeros(size(M));
for iter = 1 : length(M)
    E(iter) = mean2true(M(iter), e);
end
E0 = E(1);
f0 = 2*atan( sqrt((1+e)/(1-e)) * tan(E(1)/2) ) * (180/PI);

% Getting initial radius and speed using derived equations
p = a*(1-e^2);
r0 = p / (1+e*cosd(f0));
v0 = sqrt(2*MU/r0 - MU/a);

% Calculating Langrange Coefficients using Block 2 (elliptic orbit)
F = zeros(1,length(E));
G = zeros(1,length(E));
for iter = 1 : length(E)
    F(iter) = 1 - (a/r0).*(1-cosd(E(iter)-E0));
    G(iter) = (t(iter)-t0) - sqrt(a^3/MU).*((E(iter)-E0).*(PI/180)-sind(E(iter)-E0));
end

% Getting initial position and velocity vectors in perifocal frame
r = zeros(length(t), 3);
r(1,:) = [r0*cosd(f0), r0*sind(f0), 0]; % e, p, h hat directions
v = zeros(length(t), 3);
v(1,:) = [-sqrt(MU/p)*sind(f0), sqrt(MU/p)*(e+cosd(f0)), 0]; % e, p, h hat directions

% Calculating 1-orbit-worth of future positions
for iter = 2 : length(t) % Start at t = 2 because we already have initial conditions
    r(iter,:) = F(iter)*r(1,:) + G(iter)*v(1,:);
end

% Rotation Matrices
R3W = [cosd(W), -sind(W), 0;
       sind(W),  cosd(W), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by W (Right ascension of ascending node) degrees
R1i = [1, 0      ,         0;
       0, cosd(i), -sind(i);
       0, sind(i),  cosd(i) ]; % Rotation around axis 1 by i (inclination) degrees
R3w = [cosd(w), -sind(w), 0;
       sind(w),  cosd(w), 0;
       0      ,  0      , 1 ]; % Rotation around axis 3 by w (argument of perigee) degrees

R_IP = R3w*(R1i*R3W);
ERA_degrees = [ERA(1)*15, ERA(2)*15/60, ERA(3)*15/60/60];
gamma0 = sum(ERA_degrees);

% Rotating position vectors to get it in ECEF frame (at every point in time)
for iter = 1 : length(t) % Start at t = 2 because we already have initial conditions
    g = gamma0 - (15/3600)*t(iter);
    R3g = [cosd(g), -sind(g), 0;
           sind(g),  cosd(g), 0;
           0      ,  0      , 1 ]; % Rotation around axis 3 by g (GMST angle) degrees
    R_EI = R_IP*R3g;
    r(iter,:) = R_EI*r(iter,:)';
end

% Converting position to lattitude and longitude
longitude5 = zeros(length(r),1);
latitude5 = zeros(length(r),1);
for iter = 1 : length(r)
    %longitude(iter) = (180/PI)*atan(r(iter, 2) / r(iter, 1)); % longtude equation using ECEF coords
    longitude5(iter) = (180/PI)*atan2(r(iter, 2), r(iter, 1));
    latitude5(iter) = (180/PI)*atan(r(iter, 3) / sqrt(r(iter, 1)^2 + r(iter, 2)^2 )); % lattitude equation using ECEF coords
end

figure(5)
hold on
```

```
load('topo.mat','topo');
topoplot = [topo(:,181:360),topo(:,1:180)];
contour(-180:179,-90:89,topoplot,[0,0],'black');
grid on
grid minor
plot(longitude5,latitude5,'.','LineWidth',2)
xlabel("longtitude (degrees)")
ylabel("latitude (degrees)")
title('Ground Path for STARLETTE')
hold off
```

Newton-Raphson Function

```
function Ef1 = mean2true(M, e) %Inputs a single number, Outputs a single number

    Ef0 = M; % Initial guess
    Ef1 = M + 1; % Ensures that loop exit condition is not prematurely called
    safety = 0;
    while ((abs(Ef1-Ef0) > 0.001) && (safety < 5000)) % Loops until the difference is negligible
        safety = safety + 1;
        Ef0 = Ef1;
        f = Ef0 - e*sin(Ef0) - M;
        f_prime = 1 - e*sin(Ef0);
        Ef1 = Ef0 - (f / f_prime);
    end
end
```

Published with MATLAB® R2021b