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```
% Celestial Body Locations at specified dates:
%
% Orbital Mechanics Final Project
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%
% File History:
% Written 4/23 - Logan
% Worked on code - all group memebers

clear all; close all; clc;
Constants;
mu_Sun = Sun.mu;

% Project Report 1 - Part 4:

% Date          Body    J2000 x (km)    J2000 y (km)
% Oct 18, 1989  Earth
% Feb 10, 1990  Venus
% Dec 8, 1990   Earth
% Oct 29, 1991  Gaspra
% Dec 8, 1992   Earth
% Dec 7, 1995   Jupiter

% Gaspra on 10/29:
% $$SOE
% 2448558.500000000 = A.D. 1991-Oct-29 00:00:00.0000 TDB
%  X = 7.483782491348745E+07 Y =-3.208504326714966E+08 Z =
 1.166109205102742E+07
%  VX= 1.842791612316331E+01 VY= 7.909174576743062E+00 VZ=
 1.103827165877077E+00
%  LT= 1.099657577321358E+03 RG= 3.296690480634949E+08
 RR=-3.475258296818651E+00

Dates{1} = MakeDate(1989,10,18);
Dates{2} = MakeDate(1990,2,10);
Dates{3} = MakeDate(1990,12,8);
Dates{4} = MakeDate(1991,10,29);
Dates{5} = MakeDate(1992,12,8);
Dates{6} = MakeDate(1995,12,7);

velocity_array = ones(5,4);
```

```
PlanetOrder = {'Earth','Venus','Earth','Gaspra','Earth','Jupiter'};
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
% Table 1:
disp('Table 1:')
disp([pad('Date ',12,'right'), '| ', ...
    pad('Body',8,'right'), '| ', ...
    pad('J2000 x (km)',13,'right'),'| ', ...
    pad('J2000 y (km)',13,'right')])
for Lv1 = 1:6
    [J2kx,J2ky] = GetPos(PlanetOrder{Lv1}, Dates{Lv1});
    if Lv1 ==4
        J2kx = 7.483782491348745E+07;
        J2ky = -3.208504326714966E+08;
    end
    disp([pad(datestr(Dates{Lv1}), 12,'right'), '| ',...
        pad(PlanetOrder{Lv1},8,'right'), '| ', ...
        pad(sprintf('%.0f',J2kx),12,'left'), ' |', ...
        pad(sprintf('%.0f',J2ky),13,'left')])
end

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
% Table 2:

% Define Planet Orbital Elements (COE), Locations (r) and Velocity
 Vectors
% (v) at specified times:
COE = {};
r = {};
v = {};
for Lv1 = 1:6
    if ~strcmpi(PlanetOrder{Lv1}, 'Gaspra')
        [COE{Lv1}, r{Lv1}, v{Lv1},~] =
 EZ_States(PlanetOrder{Lv1},Dates{Lv1});
    else
        %  X = 7.483782491348745E+07 Y =-3.208504326714966E+08 Z =
 1.166109205102742E+07

        % EZ_States/planet_elements_and_sv does not work for Gaspra:
        % [h e RA incl w TA a w_hat L M E]
        COE{Lv1} = [];
        r{Lv1} = [7.483782491348745e7, -3.208504326714966e8, 0];
        v{Lv1} = [];

    end
end

% Table Header:
disp(' ')
disp('Table 2:')
head = [pad('Dates',14,'right'), '| ', ...
    pad('',10), '| ', ...
    pad('J2000 vx-',10,'right'), '| ', ...
```

```
    pad('J2000 vy-',10,'right'), '| ', ...
    pad('J2000 vx+',10,'right'), '| ', ...
    pad('J2000 vy+ (km/s)',10,'right')
    ];
disp(head)
% Find the transfer Conic(s):
coe_transfer = {};
for Lv1 = 1:5
    try
        [~,r1,~, ~] = EZ_States(PlanetOrder{Lv1},Dates{Lv1});
        [~,r2,~, ~] = EZ_States(PlanetOrder{Lv1+1},Dates{Lv1+1});
    end
    t1 = datevec(Dates{Lv1});
    t2 = datevec(Dates{Lv1+1});
    deltaT = etime(t2,t1);
    [V1,V2] = lambert(r1,r2,deltaT, 'pro', mu_Sun);
    velocity_array(Lv1,1) = V1(1);
    velocity_array(Lv1,2) = V1(2);
    velocity_array(Lv1,3) = V2(1);
    velocity_array(Lv1,4) = V2(2);

    coe_transfer{Lv1} = coe_from_sv(r1,V1, mu_Sun);
    coe_end_of_conic{Lv1} = coe_from_sv(r2,V2, mu_Sun);

    flatline = pad('',80,'-');
    disp(flatline)
    row1 = [pad(datestr(Dates{Lv1}), 12,'right'), '- | ',...
        pad(PlanetOrder{Lv1},8,'both'), '- | ', ...
        pad('',10),'| ', pad('',10),'| ', pad('',10),'|'];
    disp(row1)
    row2 = [pad(datestr(Dates{Lv1+1}), 12,'right'), '  | ',...
        pad(PlanetOrder{Lv1+1},8,'both'), '  | ', ...
        pad(sprintf('%.4f',V1(1)),9,'left'), ' |', ...
        pad(sprintf('%.4f',V1(2)),10,'left'), ' |', ...
        pad(sprintf('%.4f',V2(1)),10,'left'), ' |', ...
        pad(sprintf('%.4f',V2(2)),9,'left')
        ];
    disp(row2)
end

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
% Table 3:

disp(' ')
disp('Table 3:')
head = [pad('Dates',14,'right'), '| ', ...
    pad('',10), '| ', ...
    pad('RAAN (deg)',10,'right'), '| ', ...
    pad('a (km)',10,'right'), '| ', ...
    pad('e',10,'right'), '| ', ...
    pad('omega (deg)',10,'right')
    ];
disp(head)
```

```
for Lv1 = 1:5
    coe = coe_transfer{Lv1};
    % [h e RA incl w TA a];
    RAAN = rad2deg(coe(3));
    a = coe(end);
    e = coe(2);
    omega = rad2deg(coe(5));

    row1 = [pad(datestr(Dates{Lv1}), 12,'right'), '- | ',...
        pad(PlanetOrder{Lv1},8,'both'), '- | ', ...
        pad('',10),'| ', pad('',10),'| ', pad('',10),'|'];
    row2 = [pad(datestr(Dates{Lv1+1}), 12,'right'), '  | ',...
        pad(PlanetOrder{Lv1+1},8,'both'), '  | ', ...
        pad(sprintf('%.1f',RAAN),9,'left'), ' |', ...
        pad(sprintf('%.0f',a),10,'left'), ' |', ...
        pad(sprintf('%.4f',e),10,'left'), ' |', ...
        pad(sprintf('%.1f',omega),9,'left')
        ];

    flatline = pad('',80,'-');
    disp(flatline)
    disp(row1)
    disp(row2)
end

% coe_transfer{Lv1} = [h e RA incl w TA a];


% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
% Plots:
% Venus, Earth, and Jupiter, Heliocentric over timespan on mission:
PlanetOrbits = figure();
hold on; axis equal; grid on;
% plotOrbit2D(e, a, theta_start, theta_end, fig)
% Venus: Mission duration > 1 Venus year, plot full orbit:
[coe,~,~,~] = EZ_States('Venus',Dates{1});
e = coe(2);
a = coe(7);
theta1 = 0;
theta2 = 360;
Venus_orbit = plotOrbit2D(e, a, theta1, theta2, PlanetOrbits);
Venus_orbit.Color = 'g';
% Earth: Mission duration > 1 Earth year, plot full orbit:
[coe,~,~,~] = EZ_States('Earth',Dates{1});
e = coe(2);
a = coe(7);
Earth_orbit = plotOrbit2D(e, a, theta1, theta2, PlanetOrbits);
Earth_orbit.Color = 'b';
% Jupiter: Year = 11.86 Earth Years, ~ 1/2 orbit expected
[coe,~,~,~] = EZ_States('Jupiter',Dates{1});
e = coe(2);
a = coe(7);
theta1 = coe(6);
```

```
[coe,~,~,~] = EZ_States('Jupiter',Dates{6});
theta2 = coe(6);
Jupiter_orbit = plotOrbit2D(e, a, theta1, theta2, PlanetOrbits);
Jupiter_orbit.Color = 'r';
legend('Venus Orbit','Earth Orbit','Jupiter Partial
 Orbit','Location','southeast')
title("Planetary orbits from Oct 18, 1989 to Dec 7, 1995")
hold off

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%
```

Table 1:

Date	Body	J2000 x (km)	J2000 y (km)
18-Oct-1989	Earth	135369333	62367893
10-Feb-1990	Venus	-97127385	46148380
08-Dec-1990	Earth	36261453	142833699
29-Oct-1991	Gaspra	74837825	-320850433
08-Dec-1992	Earth	35024627	143132477
07-Dec-1995	Jupiter	-60600576	-786782265

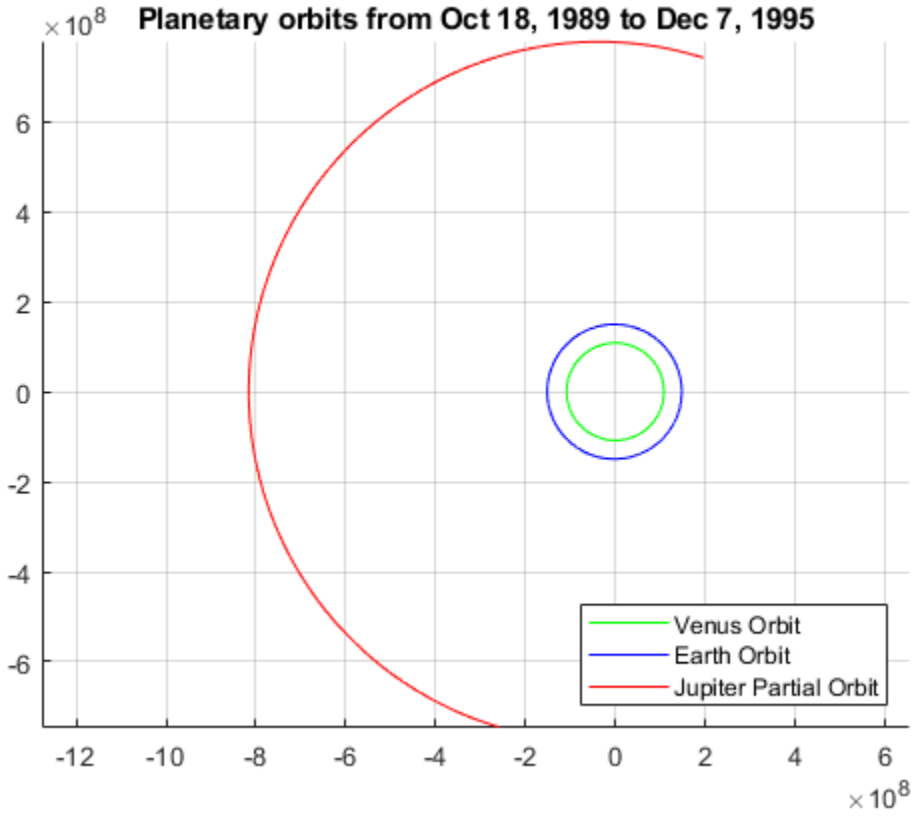
Table 2:

Dates			J2000 vx-	J2000 vy-	J2000 vx+	J2000 vy+ (km/s)
18-Oct-1989 - 10-Feb-1990	Earth - Venus		-10.6725	24.5250	-11.0290	-35.7941
10-Feb-1990 - 08-Dec-1990	Venus - Earth		-13.1089	-37.3997	-30.0241	-1.4053
08-Dec-1990 - 29-Oct-1991	Earth - Gaspra		-6.3937	-25.1848	6.3937	25.1848
29-Oct-1991 - 08-Dec-1992	Gaspra - Earth		-7.2649	-28.6163	7.2649	28.6163
08-Dec-1992 - 07-Dec-1995	Earth - Jupiter		-38.2127	7.6428	7.3203	0.3681

Table 3:

Dates			RAAN (deg)	a (km)	e	omega (deg)
18-Oct-1989 - 10-Feb-1990	Earth - Venus		0.0	124559844	0.1977	0.0
10-Feb-1990 -	Venus -					

```
08-Dec-1990   |  Earth    |       0.0 | 147832303 |    0.2911 |
 0.0
-------------------------------------------------------------------------------
08-Dec-1990 - |  Earth  - |           |           |           |
29-Oct-1991   |  Gaspra   |       0.0 |       Inf |    1.0000 |
 0.0
-------------------------------------------------------------------------------
29-Oct-1991 - |  Gaspra - |           |           |           |
08-Dec-1992   |  Earth    |       0.0 |       Inf |    1.0000 |
 0.0
-------------------------------------------------------------------------------
08-Dec-1992 - |  Earth  - |           |           |           |
07-Dec-1995   | Jupiter   |       0.0 | 469551289 |    0.6869 |
 0.0
```



Transfer 1

```
u_v = 324859;
v_spacecraft_minus = [velocity_array(1,3) velocity_array(1,4)];
v_venus = [v{2}(1) v{2}(2)];
v_spacecraft_minus_norm = norm([velocity_array(1,3)
 velocity_array(1,4)])
v_venus_norm = norm([v{2}(1) v{2}(2)])
disp("Spacecraft is moving faster than Venus");

gamma = @(theta,e) atan(e*sin(theta)/(1+e*cos(theta)));
```

```
flight_path_angle = gamma(coe_end_of_conic{1}(6),coe_end_of_conic{1}
(2))

v_inf = v_spacecraft_minus - v_venus;

v_inf = norm(v_inf)

a = u_v/(v_inf)^2

e = Venus.minPeriapsis/a +1;

flyby = 2*asin(1/e)

delta_v = sqrt(2*v_inf^2+2*v_inf^2*cos(flyby))

%{
figure1 = figure();
hold on;
title("Venus Flyby");
%velocity vectors
p1 = [0,0];                                          % first
p2 = [velocity_array(1,3) velocity_array(1,4)];   % Second
dp = p2-p1;                                          % Difference
quiver(p1(1),p1(2),dp(1),dp(2),0,'red')           % incoming velocity

p1 = [0 0];    % first
p2 = [v{2}(1) v{2}(2)];   % Second
dp = p2-p1;                                          % Difference
quiver(p1(1),p1(2),dp(1),dp(2),1,'black')         % Venus velocity

p1 = [v{2}(1) v{2}(2)];    % first
p2 = [velocity_array(1,3) velocity_array(1,4)];   % Second
dp = p2-p1;                                          % Difference
quiver(p1(1),p1(2),dp(1),dp(2),1,'cyan')         % Venus centered
 incoming

legend("Incoming Velocity","Venus Velocity")

grid on;
hold off;
%}


v_spacecraft_minus_norm =

   37.4547


v_venus_norm =

   35.2400

Spacecraft is moving faster than Venus
```

```
flight_path_angle =

   -0.1447


v_inf =

    5.7872


a =

   9.6998e+03


flyby =

    0.6209


delta_v =

   11.0210
```

Transfer 2

```
u_e = Earth.mu;
v_spacecraft_minus = [velocity_array(2,3) velocity_array(2,4)];
v_earth = [v{3}(1) v{3}(2)];
v_spacecraft_minus_norm = norm(v_spacecraft_minus)
v_earth_norm = norm(v_earth)
disp("Earth is moving faster than the spacecraft.");

gamma = @(theta,e) atan(e*sin(theta)/(1+e*cos(theta)));

flight_path_angle = gamma(coe_end_of_conic{2}(6),coe_end_of_conic{2}
(2))

v_inf = v_spacecraft_minus - v_earth;

v_inf = norm(v_inf)

a = u_e/(v_inf)^2

e = Earth.minPeriapsis/a +1;

flyby = 2*asin(1/e)

delta_v = sqrt(2*v_inf^2+2*v_inf^2*cos(flyby))

%{
```

```
figure2 = figure();
hold on;
title("Earth Flyby 1")
%velocity vectors
p1 = [0,0];                                          % first
p2 = [velocity_array(2,3) velocity_array(2,4)];   % Second
dp = p2-p1;                                          % Difference
quiver(p1(1),p1(2),dp(1),dp(2),0,'red')           % incoming velocity

p1 = [0 0];    % first
p2 = [v{2}(1) v{2}(2)];   % Second
dp = p2-p1;                                          % Difference
quiver(p1(1),p1(2),dp(1),dp(2),1,'black')         % Venus velocity

p1 = [v{2}(1) v{2}(2)];    % first
p2 = [velocity_array(1,3) velocity_array(1,4)];   % Second
dp = p2-p1;                                          % Difference
quiver(p1(1),p1(2),dp(1),dp(2),1,'cyan')         % Venus centered
 incoming
grid on;
hold off;
%}
```

```
v_spacecraft_minus_norm =

   30.0569


v_earth_norm =

   30.2327

Earth is moving faster than the spacecraft.

flight_path_angle =

   -0.2954


v_inf =

    8.6497


a =

   5.3277e+03


flyby =

    0.9196
```

```
delta_v =

   15.5027
```

Transfer 3

```
u_e = Earth.mu;
v_spacecraft_minus = [velocity_array(4,3) velocity_array(4,4)];
v_earth = [v{5}(1) v{5}(2)];
v_spacecraft_minus_norm = norm(v_spacecraft_minus)
v_earth_norm = norm(v_earth)
disp("Earth is moving faster than the spacecraft.");

gamma = @(theta,e) atan(e*sin(theta)/(1+e*cos(theta)));

flight_path_angle = gamma(coe_end_of_conic{4}(6),coe_end_of_conic{4}
(2))

v_inf = v_spacecraft_minus - v_earth;

v_inf = norm(v_inf)

a = u_e/(v_inf)^2

e = Earth.minPeriapsis/a +1;

flyby = 2*asin(1/e)

delta_v = sqrt(2*v_inf^2+2*v_inf^2*cos(flyby))

%{
figure3 = figure();
hold on;
title("Earth Flyby 2")
%velocity vectors
p1 = [0,0];     % first
p2 = [velocity_array(4,3) velocity_array(4,4)];
                % Second
dp = p2-p1;                                          % Difference
quiver(p1(1),p1(2),dp(1),dp(2),0,'red')              % incoming velocity
p1 = [0 0];                                           % first
p2 = [velocity_array(5,1) velocity_array(5,2)];      % Second
dp = p2-p1;                                          % Difference
quiver(p1(1),p1(2),dp(1),dp(2),0,'green')            % outgoing velocity
p1 = [velocity_array(4,3) velocity_array(4,4)];      % first
p2 = [velocity_array(5,1) velocity_array(5,2)];      % Second
dp = p2-p1;                                          % Difference
quiver(p1(1),p1(2),dp(1),dp(2),1,'blue')            % delta v
grid on;
hold off;
%}
```

```
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
% Functions:
function [J2000x, J2000y] = GetPos(Planet,DateTime)
try
    [~,r,~, ~] = EZ_States(Planet,DateTime);
    J2000x = r(1);
    J2000y = r(2);
catch
    J2000x = 0;
    J2000y = 0;
end
end
```

```
v_spacecraft_minus_norm =

   29.5241


v_earth_norm =

   30.2346

Earth is moving faster than the spacecraft.

flight_path_angle =

    1.5708


v_inf =

   42.5959


a =

  219.6856


flyby =

    0.0637


delta_v =

   85.1486
```

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