Homework 10

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AE 313
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AE 313 Homework 10
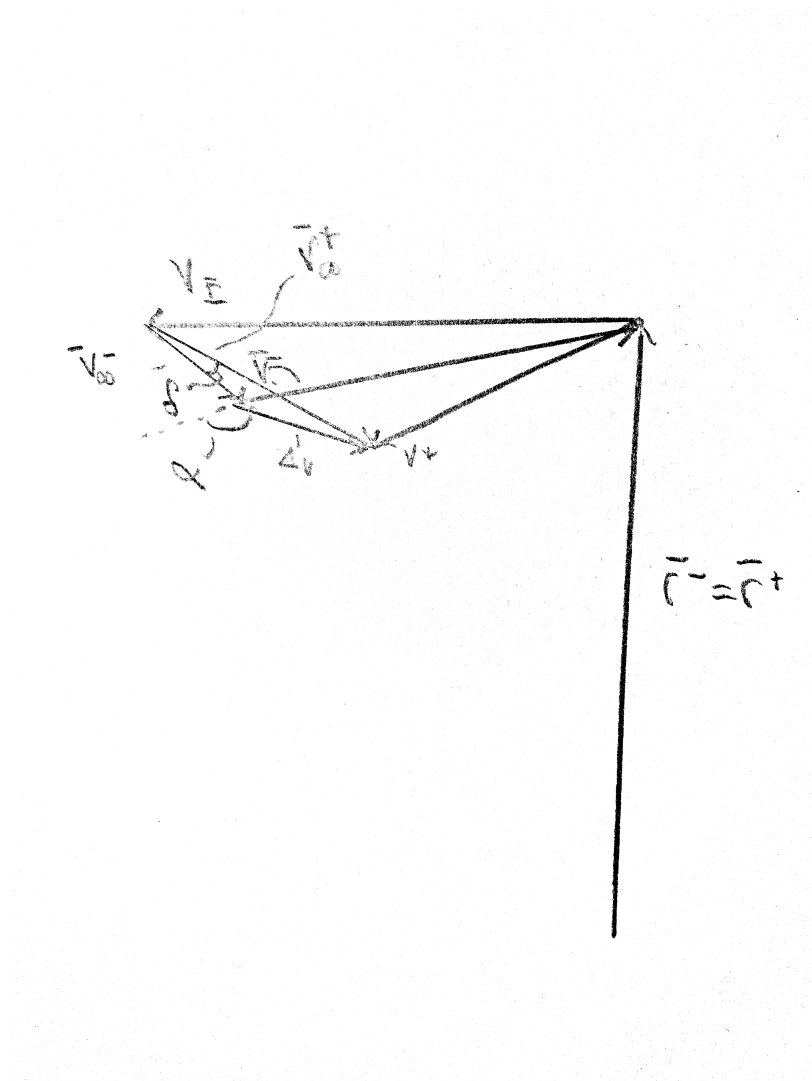
1. Draw the Jupiter-centered vector diagram of the fly-by.

Figure 1: Fly-by diagram

2. Find θ^{*-}

```
1  ta_clipper1m = atan2d( r_clipper1*v_clipper1m^2/MU('Jupiter') * cosd(
       FPA_clipper1m)*sind(FPA_clipper1m),...
2      r_clipper1*v_clipper1m^2/MU('Jupiter') * cosd(FPA_clipper1m) − 1);
```

$\theta^{*-} = -12.3219°$
This angle is correct due to use of atan2. It is negative because the orbit is descending.

3. Determine the following: $r_{p/europa}, \alpha$

```
1  periapsis_europa = a_europa*(1-e_europa);
2  ...
3  alpha = -alpha;
```

$$r_{p/europa \to clipper} = \quad 1.3594 \cdot 10^3 \; km$$
$$\alpha = \qquad\qquad -116.1968°$$

α is negative due to the problem statement. 4. Does the spacecraft gain or lose energy?

Why?
Geometrically, the spacecraft must lose energy. Observing 'delta' it can be determined that the spacecraft must have lost energy since 'delta' directs the dv vector opposing the initial velocity

5. Does the spacecraft pass "ahead" or "behind"? Prove it with drawings. (Hint: Draw behind pass vs. ahead pass. How does v_{inf} change?)
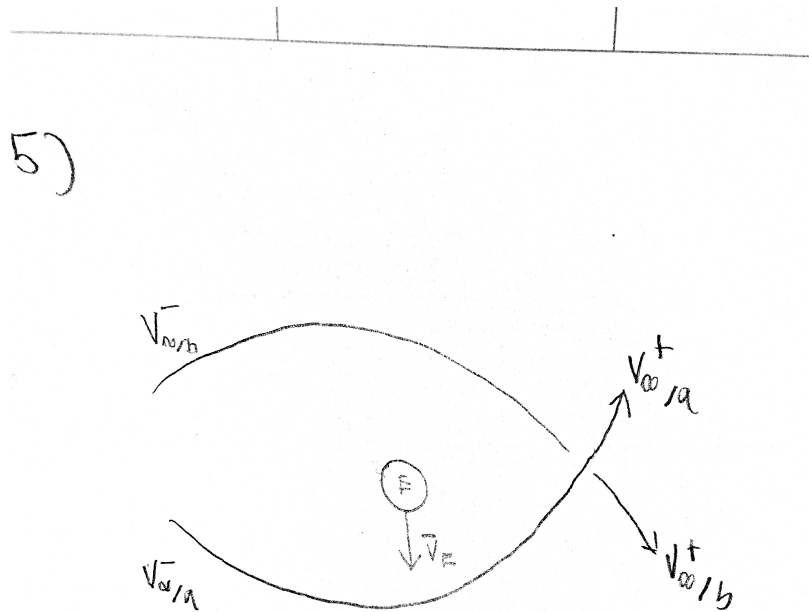

Figure 2: Infinite Diagram

The ahead pass correctly matches the orbit described. We also know it has to be an ahead because the orbit is losing energy. 6. Determine the characteristics of the new

Jupiter orbit:

```
1  r_clipper2 = r_clipper1;
2  ...
3  dAOP = ta_clipper2 - ta_clipper1m;
```

$$
\begin{aligned}
r^+ &= \quad 6.6490 \cdot 10^5 \ km & v^+ &= \quad 16.8374 \ km/s \\
\gamma^+ &= \quad -7.8811° & \theta^{*+} &= \quad -23.1067° \\
a^+ &= \quad 1.2976 \cdot 10^6 \ km & e^+ & \quad 0.5021 \\
\Delta\omega &= \quad -10.7848°
\end{aligned}
$$

Since we know $\alpha < 0$ we know that $\Delta\gamma < 0$ so we can determine that the relationship $\gamma^+ = \gamma^- + \Delta\gamma$ where $\Delta\gamma$ is negative. We know θ^{*+}'s sign is correct due to the fact that we used $atan2$ in its formulation.

7. In GMAT, plot the new and old Clipper orbits and the orbit of Europa. Draw the orbit properties.
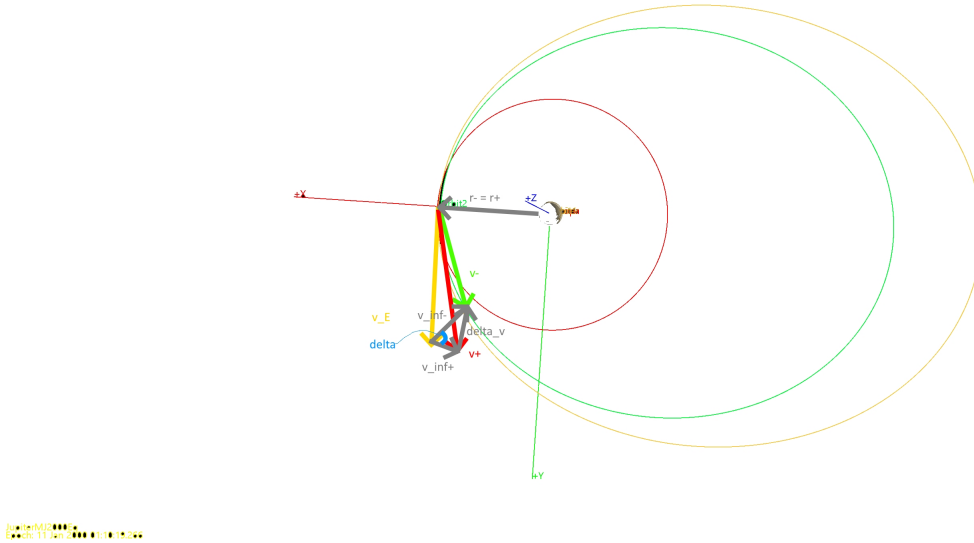

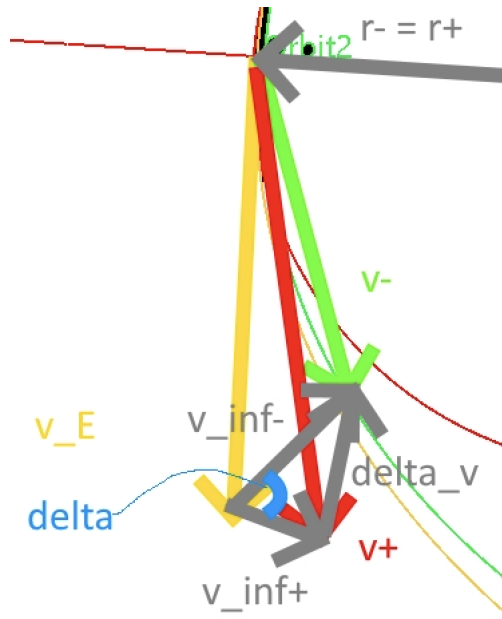Figure 3: GMAT with orbital properties

Figure 4: Detailed View

8. Clipper's mission could involve over 45 fly-bys of Europa. If the goal is to return to Europa, would you have the spacecraft perform the fly by?

I would not have the spacecraft perform this fly-by. The radius of clipper at periapsis around Europa is 1359km while the radius of Europa is 1561km. This is an impact trajectory. Another path would need to be chosen to avoid clipper impact with Europa.

```matlab
1  clc; clear;
2  % Constants
3  planets = {'Sun', 'Moon', 'Mercury', 'Venus', 'Earth', 'Mars', 'Jupiter',
       'Saturn', 'Uranus', 'Neptine', 'Pluto'};
4  rad_list = [695990.0, 1739.2, 2439.7, 6051.9, 6378.0, 3397.0, 71492.0,
       60268.0, 25559.0, 25269.0, 1162.0];
5  mu_list = [132712440000.0, 4902.8, 22032.0, 324860.0, 398600.0, 42828.0,
       126713000.0, 37941000.0, 5794500.0, 6836500.0, 981.6];
6  sma_list = [0.0, 384400.0, 57910000.0, 108210000.0, 149600000.0,
       227920000.0, 778570000.0, 1433530000.0, 2872460000.0, 4495060000.0,
       5906380000.0];
7  R = containers.Map(planets,rad_list);
8  MU = containers.Map(planets,mu_list);
9  r = containers.Map(planets,sma_list);
10 %%%%%%%
11
12 MU_europa = 3202.7;
13 a_europa = 671200;
14 R_europa = 1561.0;
15 e_europa = 0.00938;
16
17 a_clipper = 21.6*R('Jupiter');
18 e_clipper = 0.5731;
19
20 % Europa conditions
21 r_europa = 664904.144;
22 v_europa = sqrt(2*MU('Jupiter')/r_europa - MU('Jupiter')/a_europa);
23 FPA_europa = 0; %periapsis
24
25
26 % 2. Find ta_clipper1m
27 periapsis_europa = a_europa*(1-e_europa);
28 r_clipper1 = periapsis_europa;
29
30 v_clipper1m = 17.294;
31 FPA_clipper1m = -4.5205; %deg | from worksheet 4-3-19
32
33 ta_clipper1m = atan2d( r_clipper1*v_clipper1m^2/MU('Jupiter') * cosd(
       FPA_clipper1m)*sind(FPA_clipper1m),...
34     r_clipper1*v_clipper1m^2/MU('Jupiter') * cosd(FPA_clipper1m) - 1);
35
36 % 3. determine periapsis_clipper_europa, alpha1
37 delta = 17.4; % deg | from worksheet 4-3-19
```

```matlab
38
39  % inf vel rel to europa
40  v_inf = sqrt(v_europa^2 + v_clipper1m^2 - 2*v_europa*v_clipper1m*cosd(
        FPA_clipper1m));
41  a_clipper_europa1m = -MU_europa/v_inf^2;
42  e_clipper_europa1m = 1/sind(delta/2);
43  periapsis_clipper_europa1m = a_clipper_europa1m * (1-e_clipper_europa1m);
44
45  dv = 1.1; % km/s | from problem statement
46  nu = acosd( dv/(2*v_inf) ); % positive by inspection
47  offset_angle = acosd( (v_europa^2 - v_inf^2 - v_clipper1m^2)/(-2*v_inf*
        v_clipper1m) ); % positive by inspection
48  alpha = 180 - nu + offset_angle;
49  if alpha > 0
50      alpha = -alpha; %we are told alpha is negative
51  end
52
53  % 4. Does the spacecraft lose energy?
54  % Geometrically, the spacecraft must lose energy. Observing `delta` it can
55  % be determined that the spacecraft must have lost energy since `delta`
56  % directs the dv vector opposing the initial velocity
57
58  % 5. Ahead or behind
59  % Observing the same diagram from problem one we can see that the v_inf
60  % after the gravity assist is directed more towards jupiter. This implies
61  % that it is an ahead pass. It is not necessary to draw a diagram in the
62  % europa centered view because all information is included in the jupiter
63  % centered view.
64
65  % 6. find r_clipper2 v_clipper2 FPA_clipper2 ta_clipper2 a_clipper2
66  % e_clipper2 dAOP
67  r_clipper2 = r_clipper1;
68  new_nu = 180 - alpha;
69  v_clipper2 = sqrt( dv^2 + v_clipper1m^2 - 2*dv*v_clipper1m*cosd(new_nu) );
70  FPA_clipper2 = acosd( (v_inf^2 - v_europa^2 - v_clipper2^2)/(-2*v_europa*
        v_clipper2) );
71  % dFPA = FPA_clipper2 - FPA_clipper1m not correct
72
73  FPA_clipper2 = abs(FPA_clipper2)*sign(alpha);
74
75  ta_clipper2 = atan2d(r_clipper2*v_clipper2^2/MU('Jupiter')*cosd(
        FPA_clipper2)*sind(FPA_clipper2),...
76      r_clipper2*v_clipper2^2/MU('Jupiter')*cosd(FPA_clipper2)-1);
77  if sign(FPA_clipper2) > 0
```

```matlab
78        ta_clipper2 = ta_clipper2 + 180;
79  end
80
81  energy = v_clipper2^2/2 - MU('Jupiter')/r_clipper2;
82  a_clipper2 = -MU('Jupiter')/(2*energy);
83
84  e_clipper2 = sqrt( (r_clipper2*v_clipper2^2/MU('Jupiter') - 1)^2*cosd(
        FPA_clipper2)^2 + sind(FPA_clipper2)^2 );
85
86  dAOP = ta_clipper2 - ta_clipper1m;
```