AAE 532 – Orbit Mechanics
Problem Set 10
Due: 2459194.1875 (UT)

Problem 2: Recall the 2015 movie "The Martian" where the character Mark Watney must be rescued from Mars. The astrodynamicist designs the critical transfer trajectory to send the spacecraft Hermes from Earth to Mars and enable the rescue. [Are there any other movies where the astrodynamicist is the star and 'saves the day'?!!]

Recall that Rich Purnell (the astrodynamicist) spent extensive time exploring Lambert arcs and incorporating an Earth gravity assist that could satisfy all the requirements! Let's explore the possible Earth-to-Mars transfer arcs. Assume that Earth and Mars move along circular coplanar orbits. For the Earth-to-Mars transfer, initially ignore the local fields; the relative two-body problem involves only solar gravity.

(a) Consider first a transfer with a transfer angle of 120 degrees and a time of flight of 160 days. Given this space triangle, is the transfer elliptic or hyperbolic? A transfer of what type then emerges?

(b) Produce the transfer and include the following:
$type, a, p, e, \mathcal{E}, v_{dep}, v_{arr}, \theta^*_{dep}, \theta^*_{arr}, \gamma_{dep}, \gamma_{arr}$. As usual, supply all the appropriate justifications for these results. Include the r_p and r_a distances for the transfer ellipse. Does the difference in the true anomalies equal the transfer angle?

(c) Determine the maneuvers at departure $\left|\Delta\bar{v}_{dep}\right|, \alpha_{dep}$ and arrival $\left|\Delta\bar{v}_{arr}\right|, \alpha_{arr}$.
Transform the maneuvers to VNB coordinates.

(d) Plot the transfer using either GMAT or Matlab. (Recall that GMAT gives you a chance to check your results.) Include the orbit of Earth; then apply the maneuver. After the suitable transfer angle, apply the second maneuver. Include the Mars orbit as well.

(f) Now consider the Earth local field. [In the movie, a vehicle was launched from Earth to rendezvous with the Hermes rescue vehicle at Earth closest approach to receive additional supplies for the return trip to Mars.]
The transfer computed in (b)-(c) requires a $\bar{v}_{\infty/\oplus}$ relative to Earth in the Earth local view. What is the magnitude of this $\bar{v}_{\infty/\oplus}$? Assume that the pass distance at the Earth is required to be at 1000 km altitude. What is the velocity magnitude at closest approach along the hyperbolic path?
Of course, a diagram of the local view is necessary. Should the rescue vehicle pass ahead or behind Earth?
Is it reasonable to attempt to rendezvous with the rendezvous vehicle moving at such a speed?

(g) In the Mars local field, what is the speed at periapsis if the Mars pass distance is 500 km altitude? [Recall that Mark Watney was required to achieve nearly this necessary speed as a result of his launch from the Martian surface to be rescued…hmmmm…..good thing that it is only a movie!]