Gary barnhard - More info re trajectories

From: Eric Dahlstrom <Eric.Dahlstrom@InternationalSpace.com>
To: Gary Barnhard <Barnhard@barnhard.com>
Date: 2/5/2016 10:14 PM
Subject: More info re trajectories
Cc: Ethan Shinen Chew <spacefelix@gmail.com>

Gary,
Here is a bit of text that can be used related to the trajectories.

I started looking for diagrams that showed similar trajectories, and I discovered these other references by teams that are designing the NASA funded lunarcube missions. I have attached a screenshot of one of their figures. The difference for ACS is that we go out to 4M km first.

- Eric

The Alpha Cubesat mission intends to first achieve the 4 million km Deep Space Derby objective, and then return to the Moon to enter lunar orbit and achieve the second objective. Alpha Cubesat seeks to demonstrate the flexibility of maneuvers within cis-lunar space using a cubesat form factor and the associated reduced cost. We anticipate this capability will be useful for many future missions of small spacecraft.

The plan to travel to 4M km and then return to the Moon means our mission is perfectly suited to use the exterior transfer Weak Stability Boundary class of trajectories identified by Dr. Edward Belbruno. This class of trajectories reduces the energy (and delta-velocity) needed to maneuver in the Earth-Moon system, and to enter into ballistic capture into a high elliptical lunar orbit. From that initial elliptical lunar orbit, ACS would reduce the aposelene to achieve the target elliptical lunar orbit. The use of the Weak Stability Boundary ballistic capture, along with maneuvers between constant energy stable and unstable manifolds within the Earth-Moon-Sun system, enable extensive maneuvers and orbit changes with very low delta-v. Several missions have already demonstrated the success of this approach, including Hiten, SMART-1, Grail, and others. Alpha Cubesat seeks to demonstrate the use of these techniques with low cost cubesat systems.

Similar low delta-v trajectories (making use of Weak Stability Boundary ballistic capture and stable and unstable manifolds) have been identified in other studies, including those supporting NASA sponsored lunar cubesat missions [Ref 1,2,3]. A variety of independent trajectory analysis tools are available that can be used to find these optimal solutions.

[1] Folta, David, Donald Dichmann, Pamela Clark, Amanda Haapala, Kathleen Howell, “Lunar Cube Transfer Trajectory Options”, AAS/AIAA Space Flight Mechanics Meeting; 25th, 20150001351, GSFC-E-DAA-TN19549, Jan 11, 2015.
http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150001351.pdf

[2] Folta, David, Donald Dichmann, Pamela Clark, Amanda Haapala, Kathleen Howell, “LunarCube Transfer Trajectory Options”, 4th International Workshop on LunarCubes, Oct 2014.
http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150001297.pdf

[3] Folta, David C., Natasha Bosanac, Davide Guzzetti, and Kathleen C. Howell, “An Earth-Moon System Trajectory Design Reference Catalog”, IAA-AAS-DyCoSS2-03-02, 2014.
https://engineering.purdue.edu/people/kathleen.howell.1/Publications/Conferences/2014_IAA_FolBosGuzHow.pdf

Also, a couple of Ed Belbruno’s references have links.

Belbruno, E.; Gidea, M.; Topputo, F., Weak Stability Boundary and Manifolds, SIAM J. Appl. Dyn. Sys., Vol. 9, No. 2, pp 1061-1089, 2010.
http://edbelbruno.com/wp-content/uploads/2016/01/Belbruno-WSB2010-1.pdf

Post, K.; Belbruno, E.; Topputo, F., Efficient Cis-Lunar Trajectories, in Proceedings: GLEX- 2012.02.3.6x12248, Washington, D.C., May 22-24, 2012.
http://edbelbruno.com/wp-content/uploads/2016/01/Belbruno-Efficient-Cis-Lunar-Trajectories2012-1.pdf

(The figure below is figure 19 on page 14 of Folta reference 1)

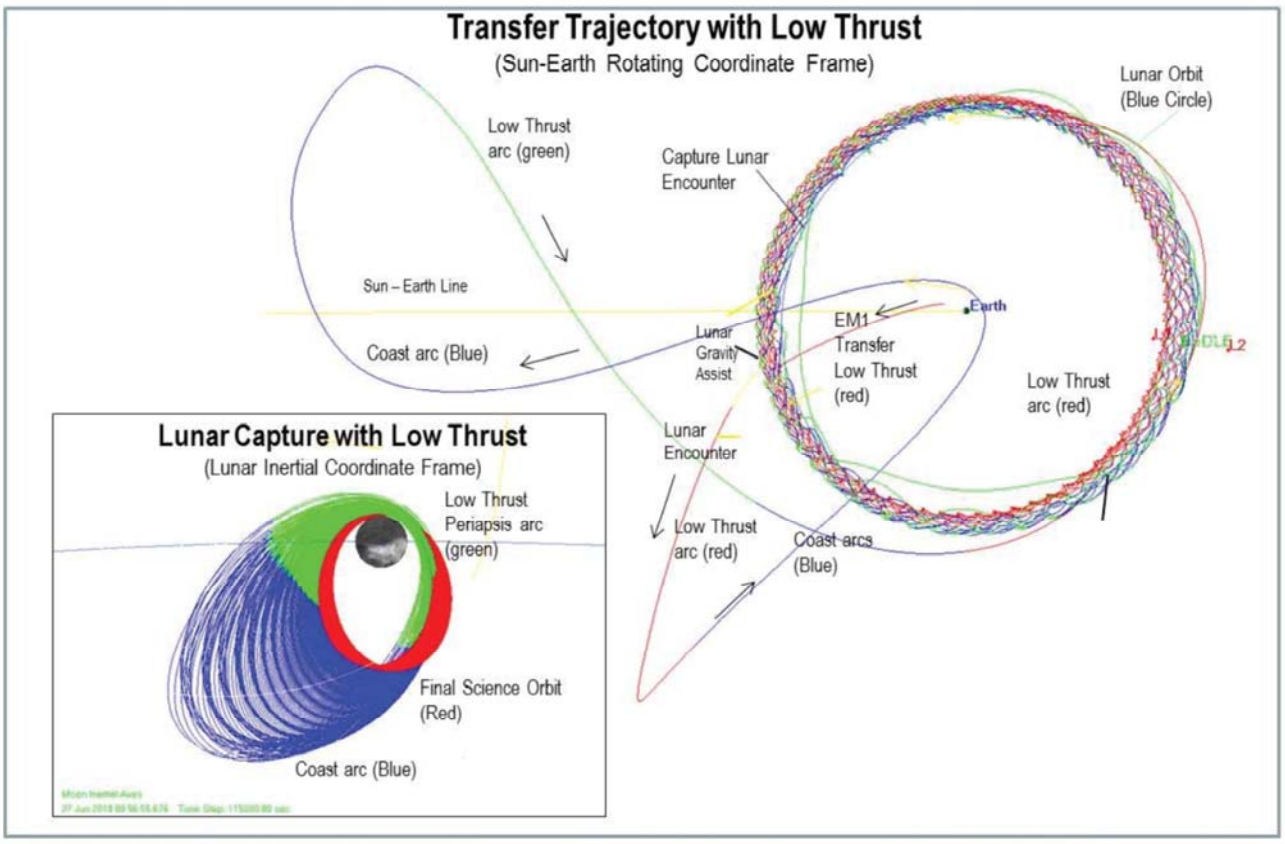

Figure 19. ARTEMIS-Like Transfer Design with Decreased EM-1 Velocity