SPACE LAUNCH SYSTEM LAUNCH WINDOWS AND DAY OF LAUNCH PROCESSES

A. S. Craig,[*] N. Ahmad[†]

Lunar missions benefit from varying the launch azimuth as a function of launch time to allow longer launch windows with minimum performance impacts. This variable azimuth approach allows the vehicle to track the Moon's apparent motion due to Earth's rotation . The Space Launch System (SLS) Block 1 vehicle design requires the mission to launch into an elliptical parking orbit to provide sufficient energy to insert Orion into a trans-lunar trajectory. The primary benefit of varying the launch azimuth, and as a result the parking orbit inclination, allows the SLS Interim Cryogenic Propulsion Stage (ICPS) to perform its Trans-Lunar Injection (TLI) burn closer to perigee and take advantage of performing a burn in a location where the burn will primarily raise apogee.

INTRODUCTION

Lunar missions benefit from varying the launch azimuth as a function of launch time to allow longer launch windows with minimum performance impacts. This variable azimuth approach allows the vehicle to track the Moon's apparent motion due to Earth's rotation . The Space Launch System (SLS) Block 1 vehicle design requires the mission to launch into an elliptical parking orbit to provide sufficient energy to insert Orion into a trans-lunar trajectory. The primary benefit of varying the launch azimuth, and as a result the parking orbit inclination, allows the SLS Interim Cryogenic Propulsion Stage (ICPS) to perform its Trans-Lunar Injection (TLI) burn closer to perigee and take advantage of performing a burn in a location where the burn will primarily raise apogee.

The parking orbit line of apsides for an optimal mission geometry should be pointed where the Moon will be when Orion performs its flyby. As the Moon's declination varies from day to day, the least expensive way of dialing in the line of apsides is to adjust the parking orbit inclination. The launch azimuth is varied to target the parking orbit inclination in the trajectory optimization. Mission targets are then generated using combination of two Three Degree of Freedom (3-DOF) trajectory optimization tools; The Program to Optimize Simulated Trajectories (POST) (Reference 1) for ascent to the parking orbit, and Copernicus (Reference 2) for the trajectory from orbit insertion, through TLI, and past lunar flyby for ICPS disposal in a heliocentric orbit.

The SLS guidance team is responsible for processing all of the 3-DOF optimized trajectories for every day in a launch period and for every launch period. This process is used to provide the original flight software initialization loads, called ILOADS. Later, during the prelaunch countdown, the process is exercised again to provide Day of Launch ILOAD Update (DOLILU) parameters

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[*] Aerospace Engineer, Guidance Navigation and Mission Design Branch, NASA, Marshall Space Flight Center, Huntsville, AL 35812

[†] Aerospace Engineer, ???? Branch, NASA, Goddard Space Flight Center, Greenbelt, MD 20771

for the Boost Stage (BS) and Core Stage (CS) segments of SLS ascent flight. For the Boost Stage portion of the flight, SLS Guidance is open loop, and optimized 3-DOF trajectories are used to derive the desired azimuth target for the Chi Angle Optimizer (CHANGO) program. CHANGO, a standalone in-house developed tool, uses the processed azimuth target at the end of BS Flight to generate a chi-table, which consists of an optimal set of attitude commands (yaw, pitch, and roll) and engine throttle commands as a function of altitude. Even though CHANGO can generate a table that corresponds to every minute of launch, this would add an excessive burden on Flight Operations and increase risks for potential mistakes in the process. To alleviate these concerns, SLS Guidance team generates only one chi-table for every single day that corresponds to the middle of the Launch Opportunity for that day. To launch at a different time than planned, SLS Guidance uses a spherical trigonometry methodology to compute a Yaw bias that is added to the precomputed chi-table in order to account for launch slips. At the end of BS flight, when CS Guidance is activated, similar adjustments to plane targets are performed such that both targeted right ascension of ascending node (RAAN) and Inclination are adjusted to account for launch slips. Inclination, RAAN and Yaw biases are curve fitted to fifth order polynomial in order to utilize up to +/- 2 hour of launch capability.

REFERENCES

[1] S. Striepe, *Program to Optimize Simulated Trajectories (POST2), Vol. 2: Utilization Manual, Ver 3.0*. NESC, NASA Langley Research Center, May 2014.

[2] J. Williams, *Copernicus Version 4.6 Users Guide*. NASA Johnson Space Center, April 2018.