Aerodynamic Trim Control on a Lunar Return Capsule using Flaps

Orion, NASA’s new spaceship, will use a capsule design, like Apollo, to return astronauts from the moon. Returning from the moon, such craft must dissipate nearly twice the energy of a typical Space Shuttle re-entry. A safe return will require engineering solutions to manage heat and deceleration, as well as target alternate landing sites.

The Manned Lunar Return Capsule

Atmospheric “Skip” Entry

Whereas the Apollo missions used a direct entry, Orion will use a “Skip” entry. After entering the atmosphere, the vehicle will pull up and exit back into space. The subsequent “skip” occurs as the vehicle coasts under negligible drag. The vehicle then reenters the atmosphere with a less energetic trajectory, and proceeds to the final landing site.

Effect of Lift on Skip Reentry

To perform a precise and targeted skip entry, a vehicle must produce some amount of lift. The lift-to-drag ratio (L/D) is often used to quantify a vehicle’s capabilities. Using a simplified planar analysis, the characteristics of a skip entry can be discovered.

The available bank angle is a measure of how much the capsule can roll to the right or left while still achieving a down-range landing site. This rolling can alleviate heating and deceleration loads by modifying the trajectory. Cross-range is required to reach an alternate landing site not along the original path.

L/D Cliff

These charts suggest that as a vehicle’s L/D ratio drops below 0.3, skip entry is no longer a feasible option.

Lift-to-Drag Ratio of a Capsule

Based on NASA pictures of Orion and Apollo, a capsule shape was extrapolated for study, using an Apollo c.g. location. A flap of 1 square meter was added, extending 90° from the sidewall, just behind the heat shield.

Capsules, like Apollo and Orion, create lift by moving the center of gravity (c.g.) away from the centerline. If the c.g. cannot be offset far enough to produce a L/D ratio greater than 0.3, one option is to use a flap. A flap will cause the capsule to trim at a higher angle of attack, which will increase the L/D ratio.

Results

With the addition of a flap, the trim L/D ratio increased from 0.26 to 0.31. This would increase the cross range by up to 300 km, and move the capsule safely away from the L/D “cliff.”

Flap Dimensions

Mass estimates based on the X-38 flap design suggest such a flap would add 150kg to the capsule. Further study is planned, including heating and trajectory analysis.