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HIGH-ACCURACY ASYMMETRIC CIRCUMLUNAR FREE RETURN TRAJECTORY DESIGN WITH HIGH-LATITUDE LANDING FOR CHINA

Abstract

China has officially confirmed preliminary planning on manned lunar landing as a policy objective for the next five years. The Apollo program landed the first humans on the Moon, primarily employing Earth-Moon axis-symmetric circumlunar free return trajectories during initial translunar phase. Without additional propulsion, the spacecraft reenters near the Earth's equator. China's human lunar exploration should also employ circumlunar free return trajectories due to safety and flight time, but launching at Wenchang and landing at relatively high-latitude Siziwang Banner requires a curved-surfaced asymmetric trajectory caused by its high inclination approach to the Earth.

This paper investigated the path from the launch to landing site via such a nominal trajectory simulated under a full gravitational model. To be useful in engineering applications, the trajectory covered these phases: ascent, Earth orbit, translunar, transearth, skip reentry and descent. Detailed design methodology and parameters were given, and the latter were based on actual data from literature. Nowadays, computers run many times faster than before, so directly using a high-accuracy full model becomes easy. For this model, the study found the best control parameters are launch epoch, translunar injection right ascension (in Earth Moon BBR coordinates) and delta-v, while the final equality constraints are perilune altitude, reentry flight path angle and landing longitude. With suitable stopping conditions for each phase and differential corrections, a free return trajectory satisfying all constraints including launch location, launch azimuth, parking orbit altitude, perilune altitude, reentry altitude, reentry flight path angle and landing location could be obtained. Subsequent free returns required no trial and error to generate their initial guesses, but simply increments of approximately half or one day in launch epoch. Early in the design, the multiple differential corrections used 2 to 3 options of delta right ascension and declination (between the spacecraft and the Moon with respect to the Earth), lunar b-plane target horizontal and vertical components, perigee altitude, perilune altitude, and perigee velocity azimuth (in Earth fixed coordinates) as equality constraints. As the landing site has high latitude, the reentry range required tends to be unrealistically long, so the range was minimized, and the control and related parameters were determined.

Tailored to the need of high-latitude landing for China's manned moon program, this study identified the control parameters, constructed the scheme of differential corrections and optimized the reentry range, resulting in highly accurate models of feasible asymmetric circumlunar free return nominal trajectories that meet all basic constraints.