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Author: Mr. William Kennedy
Booz Allen Hamilton, United States

ANALYTICAL TECHNIQUES FOR ASSESSING GATEWAY AND OTHER SPACECRAFT ANTENNA LINE-OF-SIGHT

Abstract

Building on the legacy of the International Space Station, NASA's Gateway will inaugurate a sustainable crewed presence beyond low Earth orbit in cis-lunar space. The Near Rectilinear Halo Orbit (NRHO) of the Gateway offers numerous operational benefits in terms of its Earth access via Orion, the degree of lunar visibility and surface access it provides, and favorable conditions for station-keeping. To minimize burns during station-keeping and conserve propellant, the Gateway will continually align itself to a solar pressure equilibrium attitude with the Sun; this is convenient for solar array orientation and power generation, but causes difficulties in terms of communication line-of-sight with the Earth, Moon, and visiting vehicles, which appear to be rotating about the Gateway's local frame as the Gateway maintains alignment with the Sun. A fixed antenna on the Gateway is continually subject to a moving receiver and can find itself obstructed by the Gateway's own geometry if not placed carefully. As the Gateway has progressed through its design iterations and configuration changes, high-gain antenna, S-band, GPS, UHF, and wireless communication links on the Gateway have had to be assessed for line-of-sight capability to their respective targets. To test a position for antenna placement on the Gateway and understand to what degree it can have a line-of-sight view of its target's viewing window without being obstructed by the Gateway's own geometry, the Möller-Trumbore intersection algorithm is used alongside 3D triangulated CAD model meshes to iterate through ray tracing on a sphere with the Gateway at its center. The Möller-Trumbore algorithm determines whether a ray intersects a triangle and is tailored for efficient computation in that it forgoes the intermediary step of having to calculate and store plane information for each triangle. This allows for significant memory savings in triangle meshes while reducing computation time and producing results with higher precision. This process has determined optimal locations for over eight antenna placements on the Gateway, such as the GPS antenna, which can achieve an 87% line-of-sight link to Earth-orbiting GPS satellites given the Gateway's assembly-complete geometry and nominal NRHO pointing attitude. The line-of-sight coverage sphere can then be visualized with CAD software to determine the necessary pitch and yaw angles Gateway must fly off its nominal sun-pointing attitude to ensure continuous line-of-sight coverage. This process has had direct impact on the writing of communication requirements for NASA and international partner-owned Gateway elements.