Short Abstract

Pulsed thrust method for hover formation flying

A non-continuous thrust method for hover type formation flying has been developed. This method differs from a true hover which requires constant range and bearing from a reference vehicle. The new method uses a pulsed loop, or pogo, maneuver sequence that keeps the follower spacecraft within a defined box in a near hover situation. Equations are developed for the hover maintenance maneuvers. The constraints on the hover location, pulse interval, and maximum/minimum ranges are discussed.

Extended Abstract

Pulsed thrust method for hover formation flying

A non-continuous thrust method for hover type formation flying has been developed. This method differs from a true hover which requires constant range and bearing from a reference vehicle. A true hover typically requires a variable thrust engine to perform hover maneuvers at various ranges over the lifetime of the mission with a decreasing spacecraft mass. The new method uses a pulsed loop, or pogo, maneuver sequence that keeps the follower spacecraft within a defined box in a near hover situation. The constraints on the hover location, pulse interval and maximum/minimum ranges are discussed. This method takes the follower spacecraft through a range of positions defined by a box of varying height and width. The limitations on the pulse interval and box size are driven by the thrust capability of the spacecraft engine used for the hover maneuver.

An analytical solution of the pogo maneuver has been derived. The delta-v required to maintain this formation is:

$$\Delta v = \frac{\left(6n^2 R r_0^{3/2} T_p abs\left(\sin\left(nT_p/2\right)\right)\right)}{\left(\sqrt{\left(R-r_0\right)\left(-3nRT_p + r_0 C_2 + 8R\sin\left(nT_p/2\right)\right)\left(3nRT_p + \left(R-r_0\right)C_2\right)}\right)}$$

where $C_2 = 3nT_p\cos\left(nT_p/2\right) - 8\sin\left(nT_p/2\right)$. In the previous equation, n is the mean motion of the reference satellite, T_p is the period of the pogo, R is the maximum radial offset, and r_0 is the reference satellite circular orbit radius. These parameters are shown in Figure 1.

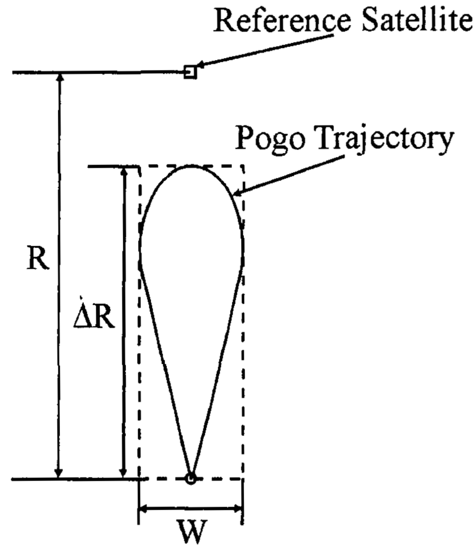

Figure 1 Pogo Maneuver Relative Geometry

Figure 2 shows the trends of the required delta-v to maintain the pogo for increasing period and maximum range during one pogo sequence. The plot is in non-dimensional canonical units for which the gravitational constant, $\mu = 1$ and the circular reference orbit radius, $r_0 = 1$. It can be seen that increasing maximum range increases the required delta-v to maintain the pogo and that the maximum delta-v occurs when the pogo is performed four times for every reference orbit.

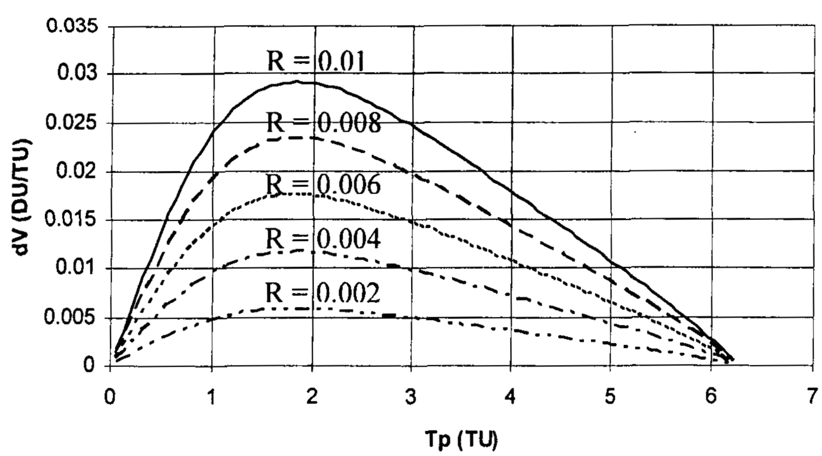

Figure 2 Delta-V Trends

Initial conditions from the analytical equations are used to generate perturbed orbits using the Astrogator module of the Satellite Tool Kit (STK). Hover scenarios for example spacecraft in Low Earth Orbit (LEO), Middle Earth Orbits (MEO) and Geostationary Orbits (GEO) will be presented and discussed. Performance for the perturbed orbits are compared to the theoretical costs of the analytic orbits and also to the true hover costs in terms of mission delta-v, box size and position variance.

Several spacecraft of various weight classes and engine size will be used to demonstrate the capabilities and limitations of this pogo pulsed loop hover implementation.