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Author: Mr. Callum S. Arnot
University of Strathclyde, United Kingdom, callum.arnot@strath.ac.uk

Prof. Colin R. McInnes
University of Glasgow, United Kingdom, colin.mcinnes@glasgow.ac.uk

ARTIFICIAL HORSESHOE ORBITS USING LOW THRUST PROPULSION

Abstract

Horseshoe orbits, occurring naturally in three-body systems, can be generated artificially with the application of continuous low thrust. In this paper, the Clohessy-Wiltshire equations are rendered into cylindrical polar form, and with the addition of continuous low thrust they are used to generate spacecraft constellations which follow artificial horseshoe orbits around a circular reference orbit. Elliptical reference orbits are also considered through the use of time-varying transformations for the Clohessy-Wiltshire equations. A general thrust law is derived using the concept of an artificial potential field centred on an attractor on the reference orbit, and the effects of introducing additional attractor points and time-varying artificial potential are examined. Phased constellations of spacecraft, including constellations on nested horseshoe orbits around the same reference orbit and those on displaced-plane non-Keplerian orbits, are also analysed and categorised. Constellation reconfiguration is explored by implementing low thrust transfers between horseshoe orbits. The stability of such orbits is assessed, and the implications of utilising different propulsion technologies, such as solar sails and electrostatic thrusters, are reviewed. It is shown that the thrust magnitude and ΔV requirements for artificial horseshoe orbits are modest and achievable for certain Earth orbiting cases, and that the applications for such novel spacecraft constellations are potentially diverse.