

Research Article

Repeated Shadow Track Orbits for Space-SunSetter Missions

Ahmed Gad and Ossama Abdelkhalik

*Department of Mechanical Engineering-Engineering Mechanics, Michigan Tech University, 815 R.L. Smith Bldg,
1400 Townsend Dr., Houghton, MI 49931, USA*

Correspondence should be addressed to Ahmed Gad, ahgadels@mtu.edu

Received 14 May 2009; Accepted 10 September 2009

Recommended by Tal Shima

This paper introduces a new set of orbits, the “Repeated Shadow Track Orbits.” In these orbits, the shadow of a spacecraft on the Earth visits the same locations periodically every desired number of days. The J_2 perturbation is utilized to synchronize the spacecraft shadow motion with both the Earth rotational motion and the Earth-Sun vector rotation. Motivation for the design of new shadow track orbits comes from the need to save energy. The general mathematical model to design a Repeated Shadow Track Orbit (RSTO) is presented within this paper. RSTOs’ conditions are formulated and numerically solved. Results show the feasibility of RSTOs. An optimization process is also developed to maximize the shadow duration over a given site. A Genetic Algorithm (GA) technique is utilized for optimization.

Copyright © 2009 A. Gad and O. Abdelkhalik. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Extremely large space structures are proposed for solar sail and space-based solar power generation missions. Solar sails, the size of San Francisco, are proposed to collect momentum from the solar radiation, for deep space missions [1]. Solar Power Satellites (SPSs) are also large space structures orbiting the Earth. SPSs are proposed to generate electricity in space and transmit it to receivers on the Earth using either microwave or laser transmissions [2]. For the purpose of cooling the Earth, and thereby reducing the global warming, it is also suggested to put a huge number of satellites at the first Lagrangian point between the Earth and the Sun, to provide shade for the Earth [3].

A great numbers of studies were conducted by NASA and the Department of Energy (DOE) during the seventies of the last century on the feasibility of the SPSs concept. The Office of Technology Assessment evaluated these studies and did not recommend immediate action toward implementation due to the technical challenges and high cost of the proposed mission at that time [4]. In mid nineties, NASA took a fresh look at the concept; however they did not recommend, even discourage, further investments in this direction [5]. Yet, an active interest toward implementing this concept can be seen nationally [6] and internationally [7, 8].

Aiming at reducing the cost of the generated electricity from SPSs, in this paper it is suggested to have multiple objectives for the same SPSs. SPSs orbiting Earth can provide shadow on ground for the Earth cooling purposes, generate electricity using its huge solar arrays, and save energy devoted to air conditioning in the shaded areas. Nations from the warm regions may participate in the cost of an SPS to get its shadow, if it can be provided to them on a regular basis. More than 70% of the operational expenses, for many buildings and facilities in warm regions, is dedicated for air conditioning [9]. It has been observed that the main reason for these extremely high operational expenses is the direct solar rays from the Sun [9]. The SPSs will serve as a Space SunSetter for these regions participating in SPSs missions only. A Space SunSetter will significantly reduce the operational expenses of every building in the shaded area.

There are two concepts for Space SunSetter under investigation. The first is to design a huge spacecraft orbiting the Earth. The main challenge in this concept is to find an appropriate orbit satisfying a repeated shadow track over a specific region on Earth’s surface. The second concept is a stationary Space SunSetter. This concept depends on the idea of Space Elevator [10, 11]. The purpose of this paper is to investigate the feasibility of the first concept. In this