TRANSFERS TO EARTH-MOON L2 HALO ORBITS USING LUNAR PROXIMITY AND INVARIANT MANIFOLDS

A Thesis

Submitted to the Faculty

of

Purdue University

by

Dawn Perry Gordon

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science in Aeronautics and Astronautics

August 2008

Purdue University

West Lafayette, Indiana

ACKNOWLEDGMENTS

I would like to thank Professor Howell for her invaluable guidance and advice throughout my education here at Purdue. Also, I want to thank my parents, Archie and Martine, for always believing in me even if my own faith wavers. Thank you to my sister, Shaunah, for being my confidante and inspiration, and to my fiancèe, Mike, for his love, support, and seemingly endless patience. To my fellow students, thank you for your aid, advice, and fellowship these past two years. Finally, I would like to thank Purdue for supporting my graduate education through the Knox and Chappelle fellowships.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

ABSTRACT

Gordon, Dawn Perry M.S.A.A., Purdue University, August 2008. Transfers to Earth-Moon L2 Halo Orbits Using Lunar Proximity and Invariant Manifolds. Major Professor: Kathleen C. Howell.

Libration points in the Earth-Moon system have been a topic of great interest in recent years. Not only are the L_1 and L_2 points potential staging nodes for further exploration of nearby bodies, but a satellite placed in an Earth-Moon L_2 halo orbit can maintain continuous line-of-sight communications between the Earth and the far side of the Moon indefinitely. Because of their importance, investigations into transfers from Earth to the vicinity of these points are ongoing, as are strategies to reduce the maneuver costs associated with such transfer trajectories. Preliminary results indicate that one type of potentially low-cost transfer trajectory to L_2 orbits incorporates an insertion maneuver in close proximity to the Moon; the spacecraft is inserted onto the stable manifold associated with the periodic libration point orbit. This type of transfer trajectory is the focus of the current analysis. In particular, the impact of the location of the manifold insertion maneuver near the Moon is examined. Initially, transfers to selected planar Lyapunov orbits are computed using a differential corrections process incorporating a tangential departure from a circular Earth parking orbit as well as a tangential arrival at the manifold insertion point. The maneuver costs resulting from various transfers are analyzed to determine the impact of lunar proximity as well as the conditions that favor lower-cost transfers. The analysis is extended to three-dimensional transfers to selected low-amplitude halo orbits. The methodology to compute both planar and three-dimensional transfers is similar; however, these three-dimensional transfers are no longer constrained to arrive tangentially at the manifold insertion point. After computing several transfers with varying sets of parameters, the effect of lunar proximity as well as any favorable

conditions leading to lower maneuver costs is noted. Key parameters that influence the maneuver costs include the lunar altitude and the position along the manifold surface when the maneuver occurs as well as the size of the L_2 libration point orbit. All of these elements can be exploited in transfer design.

1. Introduction

Since before recorded history, humans have looked to the stars. Many astronomers and mathematicians have devoted their time and talents to the study of the solar system and beyond, in hopes of reaching a better understanding of the workings of the universe. Prior to the 1950's, these investigations were all theoretical; there was, after all, no vehicle capable of traveling beyond the Earth's atmosphere. It was not until after the launch of Sputnik in 1952, that space became accessible. Now, the study of astrodynamics is not just a theoretical exercise; it is part of a critical foundation for real-world applications as well.

In recent years, one particular type of mission has drawn great interest, that is, scientific exploration in the vicinity of the libration points, particularly in the Sun-Earth system. Focus has lately shifted to also include the Earth-Moon system. With such scenarios, trajectories to libration point orbits are a high priority. These low-cost transfers are enabled by the use of invariant manifolds with an energy level of the same magnitude as the orbit itself. Once on a manifold, a spacecraft will asymptotically approach the orbit requiring no orbit insertion maneuver. In fact, for missions to libration point orbits, the transfer design has evolved from the familiar Earth-to-orbit concept to an Earth-to-manifold strategy. However, in the Earth-Moon system, the manifolds that asymptotically approach the libration point orbits do not pass close to the Earth. Thus, the design of the Earth-to-manifold transfer is a challenge. However, transfers to an Earth-Moon L_2 libration point orbit via a manifold can still be achieved, for a reduced cost, by introducing a lunar flyby. This investigation combines the use of manifolds and a lunar flyby by computing transfers that incorporate a manifold insertion maneuver in close proximity to the Moon. The effects of lunar proximity on the maneuver costs are determined and scenarios resulting in low-cost transfers are identified.

1.1 Historical Contributions

The present work is only possible because it is built on a solid foundation dating back over 230 years. One of the first stones in that foundation was placed by Euler in 1772 when he published his work on the motion of the Moon, *Theoria Motuum Lunae* [1]. In connection with this work, Euler offered a unique view of the Moon's motion relative to a rotating coordinate frame. His formulation is now represented as the Circular Restricted Three-Body Problem (CR3BP) [2–4].

Euler was not the only mathematician of his time interested in the motion of the heavenly bodies. During the same time period, contributions by Lagrange were also significant. In the same year that Euler published his lunar theory, Lagrange predicted the existence of the Trojan asteroids in the Sun-Jupiter system; he based this prediction on his determination of the triangular libration points in the CR3BP [1]. Lagrange also worked extensively to apply the method of variation of parameters and published *Mécanique Analytique* in 1788 [1].

The next two important contributors were Laplace and Jacobi. Laplace first introduced the concept of a potential function, and his lunar theory, published in 1802, followed Euler's. In 1836, Jacobi identified the only integral of the motion that is currently known to exist in the CR3BP [2].

Poincaré forever changed mathematics and celestial mechanics; in fact, he is widely known as the "father of dynamical systems." His work, *Méthodes Nouvelles de la Méchanique Céleste*, was published in three volumes between 1892 and 1899 [1, 5]. In his works, Poincaré detailed the first significant observations concerning deterministic chaos. He established the concept of nonintegrable dynamics and determined that the CR3BP was not merely unsolved, but fundamentally unsolvable in closed-form [1, 2]. Although a complete set of deterministic equations governs the motion in the CR3BP, Poincaré deduced that the trajectories may still behave chaotically under certain conditions. Yet, he also supported the existence of an infinite number of periodic solutions [1, 5].

At the beginning of the 20th century, other researchers built upon Poincaré's work in qualitative dynamics including Birkhoff in 1915 [3]. The investigation of periodic orbits was continued in 1920 by Moulton but computational tools at the time were limited. Moulton investigated periodic orbits in the vicinity of the collinear libration points by truncating infinite expansions. In-plane and out-of-plane approximations offered insight into the motion relative to the equilibrium points [6]. With the advent of greater computer processing power, numerical studies of the CR3BP have become prominent since the 1960's. Specifically, extensive numerical searches have been undertaken to compute periodic orbits and orbit families [3, 7–9]. Much of the knowledge involving the CR3BP that was available by the mid-1960's, both analytical and numerical, was compiled by Szebehely in his text, *Theory of Orbits*, published in 1967 [3].

From the mathematics community, a significant jump from theoretical analysis in the CR3BP to applications in engineering and NASA mission design occurred in the mid-1960's. Farquhar, a NASA engineer but also a Ph.D. student studying under Breakwell at Stanford, was investigating communications architectures for the Apollo missions. They observed that a useful libration point orbit, one with an out-of-plane component, might exist in the CR3BP for the Earth-Moon application of interest. If true, these orbits could support the planned Apollo 18 mission to land astronauts on the far side of the Moon. Further exploration, using linear approximations relative to L_2, as well as numerical computations, allowed the determination of a periodic halo orbit in 1966. Although Apollo 18 was later canceled, the potential of the halo orbit concept for "real" applications was demonstrated. A basic halo orbit was incorporated into the trajectory for the International Sun Earth Explorer-3 (ISEE-3) satellite, launched toward a Sun-Earth L_1 halo orbit in 1978. The satellite was the first to successfully reach a libration point orbit [10,11]. Since ISEE-3, several missions to Sun-Earth libration point orbits have been accomplished. A current example is the James Webb Space Telescope (JWST), designed for observations of deep space in the infrared spectrum from an L_2 orbit [12]. The James Webb Space Telescope is currently scheduled to launch in 2013.

The Earth-Moon libration points have also been the focus of interest in recent years. Besides mention in the 2004 President's Lunar Initiative, the L_1 and L_2 points may be useful staging nodes for further expansion to the Moon, Mars, or Sun-Earth L_2 orbits [12]. Furthermore, as noted in 1966, Earth-Moon L_2 halo orbits can facilitate constant communications between the Earth and the far side of the Moon, since a satellite placed in one of these orbits maintains continuous line-of-sight to locations on the surface of both bodies [10, 13].

Because of the potential importance of the L_1 and L_2 equilibrium points in the Earth-Moon system, investigations involving transfers from the Earth to these points are critical, as are methods of reducing the maneuver costs associated with such transfer trajectories. Two types of transfers to a libration point are identified by Farquhar et al. [12], that is, direct and indirect. Direct transfers proceed from the Earth to the L_2 or L_1 point without passing close to the Moon, while indirect transfers include a close passage of the Moon, incorporating a maneuver, before continuing to the libration point. Although direct and indirect transfers to the Earth-Moon L_1 point require similar ΔV costs, indirect transfers to the Earth-Moon L_2 point result in much lower ΔV's [12–14].

The direct and indirect classification can be extended to transfers from the Earth to libration point *orbits*. For example, Rausch [15] exploits manifolds to directly enter an L_1 halo orbit. Also, the general direction of motion along the manifolds associated with L_2 orbits can easily encompass a close lunar flyby. With a focus on the equilibrium point, an indirect transfer to the L_2 point requires three maneuvers; one to depart an Earth parking orbit, another when passing the Moon, and a final insertion maneuver at L_2. However, for insertion into an *orbit* in the vicinity of L_2, this last maneuver may be eliminated by use of a manifold associated with the orbit, and the maneuver at the lunar flyby becomes the manifold insertion maneuver [15–17]. Parker and Born [17] numerically investigated various transfers to both L_1 and L_2 halo orbits using manifolds in the Earth-Moon system. The maneuver cost was generally lower for transfer trajectories to L_2 orbits with manifold insertion maneuvers in close proximity to the Moon [17]. The flow along these trajectories is similar to the indirect transfer described by Farquhar et al. [12]. In particular, a region along the family of L_2 halo orbits possesses low out-of-plane amplitudes. These orbits did yield more cost-efficient transfers due to lunar flybys; however, there were few data points in this particular region and there was no attempt to further explore it [17].

1.2 Problem Definition

Transfer trajectories with potentially lower costs, those including manifold insertion maneuvers in close proximity to the Moon, certainly merit further investigation. This analysis is focused on the transfer trajectory and the impact of the location of the manifold insertion maneuver near the Moon, specifically lunar altitude and the orientation relative to the Earth-Moon line. Trajectories departing various low Earth orbits and arriving at orbits in the vicinity of L_2 are computed numerically and maneuver costs are then calculated and compared. Specifically, transfers to selected in-plane Lyapunov orbits as well as selected low-amplitude halo orbits are analyzed.

1.3 Outline

This work is organized in the following manner:

Chapter 2

The background information necessary for later problem formulation and analysis is presented. This includes the equations of motion in the CR3BP, the integral of the motion, and the equilibrium solutions. Also introduced is the state transition matrix and its implementation in a general differential corrections process. Finally, representative periodic orbits and their associated invariant manifolds are presented.

Chapter 3

The targeting process to determine orbit arcs and an analysis of transfer trajectories from the Earth to Earth-Moon L_2 planar orbits comprise Chapter 3. The details of the specific differential corrections process to determine these transfers are summarized. Transfers to selected in-plane orbits, including a manifold insertion maneuver near the Moon, are computed numerically using this process. The maneuver costs are analyzed and compared to determine the impact of lunar proximity as well as conditions favoring lower-cost transfers to the in-plane orbits.

Chapter 4

The analysis from Chapter 3 is extended to three-dimensional halo orbits. A modified differential corrections process is used to numerically determine transfers to selected low-amplitude, L_2 halo orbits. These trajectories also incorporate a manifold insertion maneuver near the Moon. Costs are computed and compared. Similar to the analysis for in-plane transfers, the effect of lunar proximity as well as any favorable conditions leading to lower maneuver costs are noted.

Chapter 5

The final chapter includes a summary of the work presented in preceding chapters. Some recommendations for additional analysis are also offered.

2. Background

Ultimately, a spacecraft trajectory is influenced by many gravitational fields simultaneously including that of the Sun as well as nearby planets and moons. Because the motion in a multi-body regime is not easily understood, it is often desirable to first model the system in terms of only two or three gravitational fields. The relative two-body problem is often employed to initially develop approximations for trajectories because there exists a closed-form analytical solution; however, this model is not always sufficient. For example, design of a transfer to a libration point orbit requires a three-body model because the libration points do not exist when only two bodies are included. The mathematical formulation of the three-body problem includes 18 degrees of freedom, but only 10 integrals are known to exist; it therefore possesses no closed-form solution [18]. The Circular Restricted Three-Body Problem (CR3BP) incorporates a simplified three-body model. Through a set of assumptions, the number of degrees of freedom is reduced to six, but the formulation allows only one integral. Thus, the CR3BP still does not yield a closed-form solution, but it is the simplest, yet unsolved, gravitational problem [2]. Much insight can still be gained from the problem through an examination of the sole integral of motion, the characteristics of the known particular solutions, and the numerical integration originating with specific sets of initial conditions [18]. It is this model that forms the basis for the analysis here.

Because an understanding of the CR3BP is so fundamental to the work presented here, it is examined in more detail. First, the underlying assumptions are noted, the equations of motion are derived, and the integral of the motion is identified. Next, the location of the equilibrium points are discussed and the steps in a differential corrections process to compute periodic solutions relative to these points are clarified.

Finally, the stability of the periodic orbits is discussed and some of the behavior in the neighborhood of the periodic orbits is highlighted.

2.1 The Circular Restricted Three-Body Problem

The derivation of the equations of motion in the three-body problem begins with a set of n particles. From the inverse-square law of gravity, the force on a particle i due to a particle j is

$$\bar{F}_i = -\frac{Gm_i m_j}{r_{ji}^3}\bar{r}_{ji} \tag{2.1}$$

where $i \neq j$ and G is the universal gravitational constant [19]. The relationship between the two particles and their position vectors is apparent in Figure 2.1. Assuming

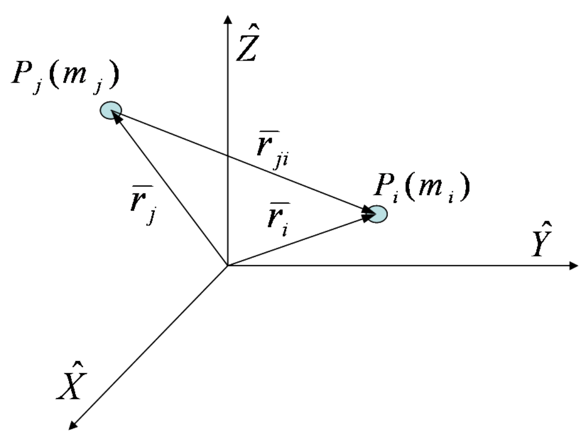

Figure 2.1. Definitions of particles and position vectors in the n-body problem.

constant masses, the law of motion is written, $\bar{F}_i = m_i\ddot{\bar{r}}_i$. Then, summing over all n particles and dividing by m_i, the inertial acceleration of the i^{th} particle, $\ddot{\bar{r}}_i$, due to the existence of the other particles becomes [19]

$$\ddot{\bar{r}}_i = -G\sum_{j=1,j\neq i}^{n}\frac{m_j}{r_{ji}^3}\bar{r}_{ji} \tag{2.2}$$

Now, let $n = 3$ since only three bodies are being considered. The inertial acceleration of body P_3 due to the gravity of the remaining two particles is

$$\ddot{\bar{r}}_3 = -\frac{Gm_1}{r_{13}^3}\bar{r}_{13} - \frac{Gm_2}{r_{23}^3}\bar{r}_{23} \tag{2.3}$$

Vector equations of a form similar to that in Equation 2.3 may also be written for particles P_1 and P_2. These three second-order vector differential equations comprise the general three-body problem.

2.1.1 Assumptions

The general three-body problem cannot be solved in closed-form and is difficult to investigate. However, for many three-body combinations in the solar system, it is possible to impose simplifying assumptions and reduce the general three-body problem to the Restricted Three-Body Problem (R3BP). The first of these assumptions is based on the comparative masses. If one mass is much smaller than the other two, then $m_3 << m_2 < m_1$. Although the motion of P_3 is influenced by P_1 and P_2, the motions of P_1 and P_2 are assumed to be independent of P_3. Such an assumption reflects combinations of interest in astrodynamics. For example, if P_3 reflects a spacecraft, the larger masses, P_1 and P_2, could represent celestial bodies such as the Earth and the Moon. Since P_3 does not influence the motion of P_1 or P_2, these two bodies form an isolated two-body system, denoted the primary system [2, 3]. Since the two primaries represent a two-body problem, these bodies move on conic paths, in general an ellipse, with respect to the barycenter, B, located at a focus. Thus, the elliptic restricted three-body problem is defined. It is usually advantageous to further simplify the primary motion. So, a second assumption is that these conic paths are circular relative to B [2, 3].

With these assumptions, the system in the CR3BP can be represented as in Figure 2.2. An inertial frame, I, comprised of the unit vectors $\hat{X}$, $\hat{Y}$, and $\hat{Z}$, is defined such that $\hat{X}$ and $\hat{Y}$ are in the plane of the primary motion and $\hat{Z} = \hat{X} \times \hat{Y}$. (Unit vectors are indicated with a caret.) Because B is fixed in the inertial frame, a rotating frame, R, can be defined with B as the origin such that $\hat{x}$ is always aligned with both primaries, $\hat{y}$ is perpendicular to $\hat{x}$ and in the plane of primary motion, and $\hat{z} = \hat{Z}$. This frame R is rotating at a rate θ' relative to the inertial frame. (Prime indicates

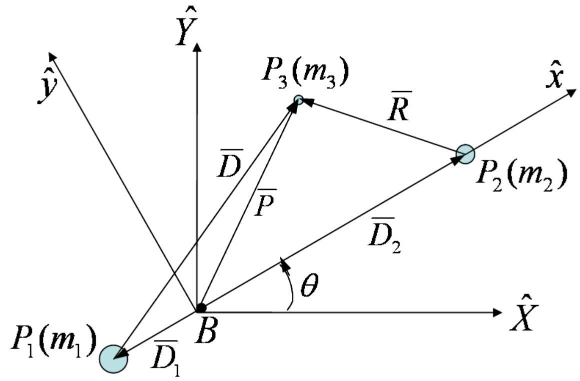

Figure 2.2. Definitions of reference frames and position vectors in the CR3BP.

differentiation with respect to dimensional time.) In the rotating frame, the locations of P_1 and P_2 are at fixed distances, D_1 and D_2, from B on the $\hat{x}$-axis, while P_3 can move freely through three-dimensional space. Equation 2.3 becomes

$$\bar{P}'' = -\frac{Gm_1}{D^3}\bar{D} - \frac{Gm_2}{R^3}\bar{R} \tag{2.4}$$

using the notation defined above.

2.1.2 Nondimensionalization

Prior to any attempt to analyze Equation 2.4, it is useful to nondimensionalize the scalar equations. Characteristic quantities are defined including length, l^*, mass, m^*, and time, t^*, as follows

$$\begin{aligned} l^* &= D_1 + D_2 \\ m^* &= m_1 + m_2 \\ t^* &= \sqrt{\frac{(D_1 + D_2)^3}{G(m_1 + m_2)}} \end{aligned} \tag{2.5}$$

Note that t^* is defined such that the nondimensional value of the gravitational constant, G, will be equal to one [2]. Dividing by the characteristic quantities in Equation 2.5, leads to the following nondimensional vectors

$$\bar{d} = \frac{\bar{D}}{l^*}$$
$$\bar{r} = \frac{\bar{R}}{l^*} \tag{2.6}$$
$$\bar{\rho} = \frac{\bar{P}}{/} l^*$$

$$\tag{2.7}$$

and nondimensional time, τ, such that

$$\tau = \frac{t}{t^*}$$

Next, define a nondimensional mass parameter μ such that

$$\frac{m_2}{m^*} = \mu \tag{2.8}$$
$$\frac{m_1}{m^*} = 1 - \mu$$

From Equation 2.8 and the definition of the barycenter as the center of mass, the nondimensional distances d_1 and d_2 between B and each of the primaries can be evaluated as

$$d_1 = \frac{D_1}{l^*} = \mu \tag{2.9}$$
$$d_2 = \frac{D_2}{l^*} = 1 - \mu$$

Finally, the angular velocity of the rotating frame with respect to the inertial frame, that is, θ', is equal to the mean motion, N, because the orbits of the primaries are circular. From the definition of mean motion, it is clear that N, and thus θ', are equal to the inverse of the characteristic time as follows [20]

$$\theta' = N = \sqrt{\frac{G(M_1 + M_2)}{(D_1 + D_2)^3}} = \frac{1}{t^*} \tag{2.10}$$

Therefore, the nondimensional mean motion is obviously equal to 1

$$n = Nt^* = \frac{t^*}{t^*} = 1 \tag{2.11}$$

Equation 2.11 implies that the angle between the rotating and inertial frame is equal to the nondimensional time, τ.

2.1.3 Derivation of the Equations of Motion

Now that the characteristic quantities have been defined, the equations of motion are derived in a nondimensional form that is conducive to further study. With the characteristic quantities used to nondimensionalize Equation 2.4, the inertial acceleration vector for P_3 is rewritten

$$\ddot{\bar{\rho}} = -\frac{(1-\mu)}{d^3}\bar{d} - \frac{\mu}{r^3}\bar{r} \tag{2.12}$$

where the vector $\bar{\rho}$ is expressed in terms of rotating components, $\bar{\rho} = x\hat{x} + y\hat{y} + z\hat{z}$, and dots indicate a derivative with respect to nondimensional time, τ, relative to an inertial observer [2]. The position vectors $\bar{r}$ and $\bar{d}$ in Equation 2.12 are evaluated in terms of unit vectors defined in the rotating frame, that is,

$$\begin{aligned} \bar{r} &= (x + \mu - 1)\hat{x} + y\hat{y} + z\hat{z} \\ \bar{d} &= (x + \mu)\hat{x} + y\hat{y} + z\hat{z} \end{aligned} \tag{2.13}$$

Note that $\bar{r}$ and $\bar{d}$ are modeled in three dimensions.

The scalar equations of motion are obtained only after the appropriate kinematic expansion is available for the left side of Equation 2.12. Differentiating the position vector $\bar{\rho}$ with respect to τ, using the basic kinematic equation twice, yields the following expansion of the inertial acceleration of P_3 expressed in terms of rotating coordinates, x, y, and z, and their first and second derivatives [2]

$$\ddot{\bar{\rho}} = (\ddot{x} - 2\dot{y} - x)\hat{x} + (\ddot{y} + 2\dot{x} - y)\hat{y} + \ddot{z}\hat{z} \tag{2.14}$$

Substituting Equations 2.13 and 2.14 into Equation 2.12 yields the following three scalar equations of motion for the CR3BP [2]

$$\begin{aligned}
&\ddot{x} - 2\dot{y} - x = -\frac{(1-\mu)(x+\mu)}{d^3} - \frac{\mu(x+\mu-1)}{r^3} \\
&\ddot{y} + 2\dot{x} - y = -\frac{(1-\mu)y}{d^3} - \frac{\mu y}{r^3} \\
&\ddot{z} = -\frac{(1-\mu)z}{d^3} - \frac{\mu z}{r^3}
\end{aligned} \tag{2.15}$$

where

$$\begin{aligned}
d &= \left|\bar{d}\right| = \sqrt{(x+\mu)^2 + y^2 + z^2} \\
r &= |\bar{r}| = \sqrt{(x+\mu-1)^2 + y^2 + z^2}
\end{aligned}$$

The equations of motion may be expressed in terms of the partial derivatives of the pseudo-potential function

$$U = \frac{(1-\mu)}{d} + \frac{\mu}{r} + \frac{1}{2}(x^2 + y^2) \tag{2.16}$$

The equations of motion from Equation 2.15 are written as [18]

$$\begin{aligned}
&\ddot{x} - 2\dot{y} = \frac{\partial U}{\partial x} \\
&\ddot{y} + 2\dot{x} = \frac{\partial U}{\partial y} \\
&\ddot{z} = \frac{\partial U}{\partial z}
\end{aligned} \tag{2.17}$$

The scalar equations of motion (Equation 2.15 or 2.17) are nonlinear, coupled, second-order differential equations with no closed-form analytical solution; however, insight into the CR3BP can still be gained by analyzing the problem further.

2.1.4 Jacobi's Integral

The set of scalar second-order differential equations in Equation 2.15 or 2.17 does admit a constant. The integral of the motion in the CR3BP was first recognized by Jacobi in 1836; thus, it is known as Jacobi's Integral, and the resulting constant of integration is denoted Jacobi's Constant [2]. Consistent with a process to seek an energy-like constant, the dot product between the vector equations of motion in Equation 2.17 and the velocity of P_3 with respect to the rotating frame, ${}^{R}\bar{v}^{P_3}$ [18] yields

$$\dot{x}\ddot{x} + \dot{y}\ddot{y} + \dot{z}\ddot{z} = \frac{\partial U}{\partial x}\dot{x} + \frac{\partial U}{\partial y}\dot{y} + \frac{\partial U}{\partial z}\dot{z} \tag{2.18}$$

Since U is a function only of position, Equation 2.18 can be easily integrated resulting in Jacobi's Integral

$$v^2 = 2U - C \tag{2.19}$$

where $v^2 = \left|{}^{R}\bar{v}^{P_3}\right|^2 = \dot{x}^2 + \dot{y}^2 + \dot{z}^2$, and C is Jacobi's Constant of integration [18].

2.2 Equilibrium Solutions

In the CR3BP, there exist five equilibrium solutions: three collinear points determined by Euler in 1765 plus, after continued investigation by both Euler and Lagrange, two triangular points identified by Lagrange in 1772 [2,4]. These solutions, labeled libration points or Lagrange points, are solutions to Equation 2.17 under the condition that both velocity and acceleration relative to the rotating frame are equal to zero, that is, $\frac{\partial U}{\partial x} = \frac{\partial U}{\partial y} = \frac{\partial U}{\partial z} = 0$. Thus, it is apparent that [2]

$$\frac{\partial U}{\partial x} = -\frac{(1-\mu)(x+\mu)}{\left[(x+\mu)^2 + y^2 + z^2\right]^{3/2}} - \frac{\mu(x-1+\mu)}{\left[(x-1+\mu)^2 + y^2 + z^2\right]^{3/2}} + x = 0 \tag{2.20}$$

$$\frac{\partial U}{\partial y} = \left\{-\frac{(1-\mu)}{\left[(x+\mu)^2 + y^2 + z^2\right]^{3/2}} - \frac{\mu}{\left[(x-1+\mu)^2 + y^2 + z^2\right]^{3/2}} + 1\right\} y = 0 \tag{2.21}$$

$$\frac{\partial U}{\partial z} = -\frac{(1-\mu)z}{\left[(x+\mu)^2 + y^2 + z^2\right]^{3/2}} - \frac{\mu z}{\left[(x-1+\mu)^2 + y^2 + z^2\right]^{3/2}} = 0 \tag{2.22}$$

For equilibrium points in the primary plane of motion, Equation 2.22 reduces to $z = 0$. Equation 2.21 has two possible solutions. The first occurs when the expression in brackets equals zero. This results in $r = d = 1$, thus, two of the points, L_4 and L_5, lie at the vertices of equilateral triangles above and below the $\hat{x}$-axis as illustrated in Figure 2.3. The other solution to Equation 2.21 requires a value of y equal to zero. Hence, the remaining three points lie along the $\hat{x}$-axis. Finally, Equation 2.20 can be reformulated into the following three scalar equations, each associated with one of the three collinear equilibrium points

$$\begin{aligned}\frac{(1-\mu)}{(1-\gamma_1)^2} - \frac{\mu}{\gamma_1^2} &= 1-\mu-\gamma_1 \\ \frac{(1-\mu)}{(\gamma_2+1)^2} + \frac{\mu}{\gamma_2^2} &= 1-\mu+\gamma_2 \\ \frac{(1-\mu)}{\gamma_3^2} + \frac{\mu}{(\gamma_3+1)^2} &= \mu+\gamma_3\end{aligned} \tag{2.23}$$

Equations 2.23 are numerically solved for the positions along the $\hat{x}$-axis, relative to the nearest primary, (γ_1, γ_2, and γ_3) of the three equilibrium points. These positions appear in Figure 2.3. The exact solutions to these equations vary depending on the system. Labeling of these points varies in literature. For this analysis, L_1 is located between the two primaries, L_2 is on the far side of the smaller primary, P_2, and L_3 is found on the far side of the larger primary, P_1.

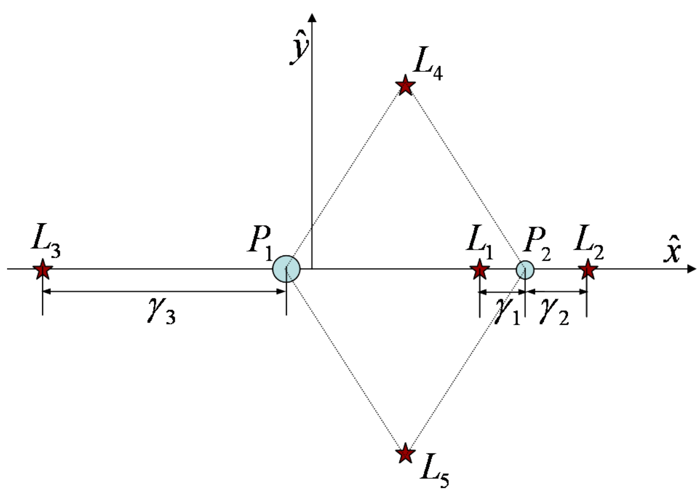

Figure 2.3. Locations of the five equilibrium solutions, or libration points, in the CR3BP; identified in the rotating frame.

2.3 Periodic Orbits near the Collinear Libration Points

Infinitely many periodic orbits exist in the vicinity of the three collinear libration points. Because the CR3BP possesses no known closed-form analytical solution, these orbits are usually exposed through numerical integration. The computation of a periodic orbit is very difficult, however, unless a reasonably close approximation for the corresponding initial conditions are available. Then, an iterative differential corrections process must still be successfully implemented to determine the desired orbit. If the equations of motion are linearized relative to the libration points, approximate analytical solutions to the variational equations yield initial conditions for some periodic orbits close to the libration points [21]. These trajectories in the vicinity of the libration points lead to many other solutions and families of periodic orbits.

2.3.1 In-Plane Periodic Trajectories and Three-Dimensional Halo Orbits

There are various types of families of periodic orbits that can be generated through a differential corrections process, but only two families are of particular interest here. The families that serve as the basis for this analysis include the planar Lyapunov trajectories and the three-dimensional halo orbits. Portions of the Lyapunov families emanating from the vicinity of the Earth-Moon L_1 and L_2 libration points appear in Figure 2.4. The Lyapunov families in the vicinity of each of the collinear libration points all possess similar characteristics. Lyapunov orbits are planar, that is, in the xy-plane, as well as symmetric across the $\hat{x}$-axis. Each of the three families extends outwards from its libration point toward the nearest primary [6].

Unlike the planar Lyapunov families, the halo families of orbits are three-dimensional. Sections of the L_1 and L_2 halo families are plotted in Figure 2.5. These halo families result from a bifurcation in the corresponding L_1 or L_2 Lyapunov family [6]. The halo orbit family also extends from the vicinity of the libration point toward the nearest primary; however, unlike the planar Lyapunov orbits, every periodic halo orbit includes an out-of-plane component, i.e., an amplitude component in the z-direction, Az. Along the L_1 halo family, the Az-amplitude increases as the orbit moves toward P_2. For L_2 halos, the Az-amplitude first increases and then collapses back into the xy-plane as the orbits approach the primary [6]. By definition, the halo orbits are symmetric across the xz-plane. Because the halo family results from a pitchfork bifurcation in the planar family, the bifurcation introduces two new branches that extend both above and below the xy-plane. A halo family with a maximum out-of-plane excursion in the positive z-direction is labeled a northern halo family, while the family with a maximum Az amplitude in the negative z-direction is termed southern [22]. In general, if the position and velocity states for the CR3BP, in the six-element state vector, $\bar{y} = \begin{bmatrix} x & y & z & \dot{x} & \dot{y} & \dot{z} \end{bmatrix}^T$, satisfy the equations of motion (Equation 2.17), then so do the states in the associated state vector, $\bar{y} = \begin{bmatrix} x & y & -z & \dot{x} & \dot{y} & \dot{-z} \end{bmatrix}^T$ [22]. A sample northern orbit (black) with the corresponding southern halo (red) is plotted in Figure 2.6. Note that the direction of motion for both northern and southern orbits about L_1 is clockwise when viewed in an xy-projection. However, when viewed from

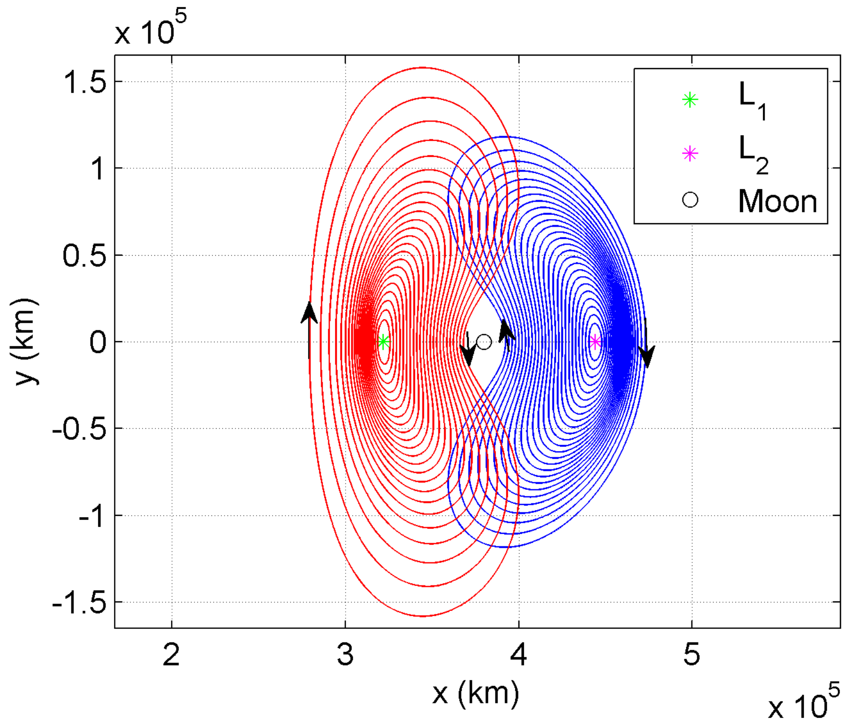

Figure 2.4. Lyapunov families of orbits in the vicinity of L_1 and L_2; Earth-Moon system.

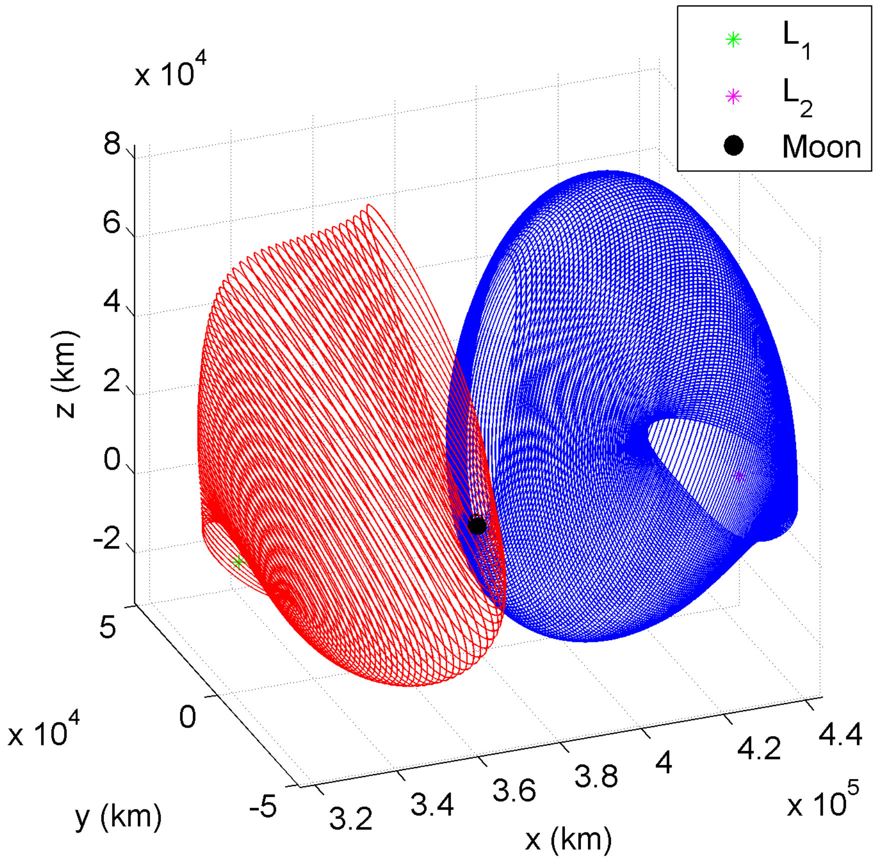

Figure 2.5. Halo families of orbits in the vicinity of L_1 and L_2; Earth-Moon system.

a yz-projection, the direction along the northern orbit is clockwise, but the direction of motion along the southern orbit is counter-clockwise.

2.3.2 State Transition Matrix

Recall that Equations 2.17 model motion in the CR3BP. As noted previously, there is no known closed-form analytical solution to these equations. Some particular solutions (e.g., equilibrium points) can be identified and used as a basis for investigation of the flow in their vicinity. Alternatively, any set of initial conditions can be propagated forward numerically. Sensitivities of the flow to changes in those initial

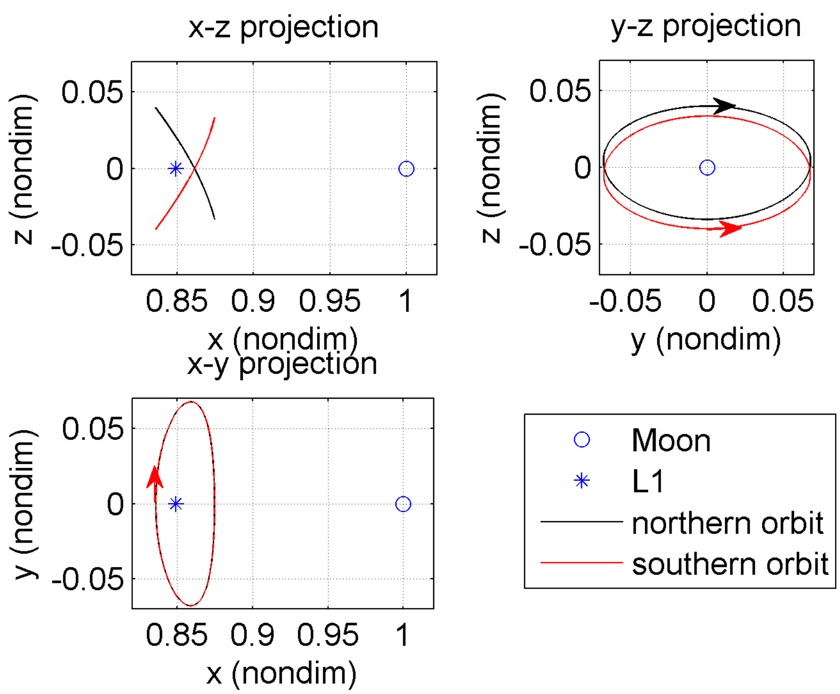

Figure 2.6. Symmetry between northern and southern halo orbits.

conditions can be significant. To gain insight into the sensitivities, it is useful to examine the evolution of a state vector in the vicinity of a reference solution.

Assume that the system can be represented by nonlinear equations of motion in the general form

$$\dot{\bar{y}} = \bar{f}(\bar{y}, t) \tag{2.24}$$

It is necessary to first identify a particular solution to the nonlinear differential equations. Label this solution as the reference trajectory, $\bar{y}_0(t)$. Note that the reference solution is not necessarily constant. Define the relationship between the reference trajectory, $\bar{y}_0(t)$, and a nearby trajectory, $\bar{y}(t)$, as

$$\bar{y}(t) = \bar{y}_0(t) + \delta\bar{y}(t) \tag{2.25}$$

This relationship is also illustrated in Figure 2.7. Given the nonlinear system in

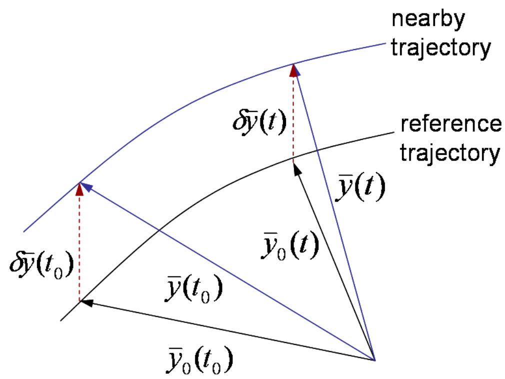

Figure 2.7. Relationship between reference and nearby trajectories.

Equation 2.24, expand about the reference solution in a Taylor series to generate a set of linear variational equations, that is

$$\delta\dot{\bar{y}} = A(t)\delta\bar{y} \tag{2.26}$$

where $A(t) = \frac{\partial \bar{f}}{\partial \bar{y}}\Big|_{\bar{y}_0}$ is time-varying. Of course, $A(t)$ is evaluated along the reference, $\bar{y}_0$. The general solution to Equation 2.26 is

$$\delta\bar{y}(t) = \phi(t, t_0)\delta\bar{y}(t_0) \tag{2.27}$$

Because the solution (Equation 2.27) to Equation 2.26 is a transformation of the initial condition, the matrix $\phi(t, t_0)$ is termed the state transition matrix or STM [23]. In general, $\phi(t_2, t_1)$ relates a state vector at time t_2 to a state at time t_1. The STM, $\phi(t, t_0)$, satisfies the following differential equation [23]

$$\dot{\phi}(t, t_0) = A(t)\phi(t, t_0) \tag{2.28}$$
$$\phi(t_0, t_0) = I$$

If $A(t)$ is not solvable analytically, Equation 2.28 is numerically integrated simultaneously with the system equations of motion, Equation 2.24, to determine the STM as a function of time.

In the CR3BP, there are three position and three velocity states. For numerical simulation, the scalar equations of motion in Equation 2.17 must be rewritten as the following set of six first-order differential equations

$$\begin{aligned}
\dot{r}_x &= v_x \\
\dot{r}_y &= v_y \\
\dot{r}_z &= v_z \\
\dot{v}_x &= 2\dot{r}_y + \frac{\partial U}{\partial x} \\
\dot{v}_y &= -2\dot{r}_x + \frac{\partial U}{\partial y} \\
\dot{v}_z &= \frac{\partial U}{\partial z}
\end{aligned} \tag{2.29}$$

Note that, in application to the CR3BP, the independent variable is nondimensional time, τ. Thus, the six-element state vector, $\bar{y}$, in Equation 2.24 is

$$\bar{y} = \begin{Bmatrix} r_x \\ r_y \\ r_z \\ v_x \\ v_y \\ v_z \end{Bmatrix} = \begin{Bmatrix} \bar{r} \\ \bar{v} \end{Bmatrix} \tag{2.30}$$

The Taylor series expansion about a reference solution, $\bar{y}_0 = \begin{Bmatrix} \bar{r}_0 \\ \bar{v}_0 \end{Bmatrix}$, yields linear variational equations of the form of Equation 2.26 as follows

$$\begin{Bmatrix} \delta\dot{\bar{r}} \\ \delta\dot{\bar{v}} \end{Bmatrix} = A(\tau) \begin{Bmatrix} \delta\bar{r} \\ \delta\bar{v} \end{Bmatrix} \tag{2.31}$$

where the matrix, A, is a function of nondimensional time, τ, for the application of interest, and

$$A(\tau) = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ U_{xx} & U_{xy} & U_{xz} & 0 & 2 & 0 \\ U_{yx} & U_{yy} & U_{yz} & -2 & 0 & 0 \\ U_{zx} & U_{zy} & U_{zz} & 0 & 0 & 0 \end{bmatrix} \tag{2.32}$$

and

$$\begin{aligned}
U_{xx} &= \frac{\partial^2 U}{\partial x^2} = 1 - \frac{(1-\mu)}{d^3} - \frac{\mu}{r^3} + \frac{3(1-\mu)(x+\mu)^2}{d^5} + \frac{3\mu(x-1+\mu)^2}{r^5} \\
U_{yy} &= \frac{\partial^2 U}{\partial y^2} = 1 - \frac{(1-\mu)}{d^3} - \frac{\mu}{r^3} + \frac{3(1-\mu)y^2}{d^5} + \frac{3\mu y^2}{r^5} \\
U_{yy} &= \frac{\partial^2 U}{\partial y^2} = \frac{(1-\mu)}{d^3} - \frac{\mu}{r^3} + \frac{3(1-\mu)z^2}{d^5} + \frac{3\mu z^2}{r^5} \\
U_{xy} = U_{yx} &= \frac{\partial^2 U}{\partial xy} = \frac{3(1-\mu)(x+\mu)y}{d^5} + \frac{3\mu(x-1+\mu)y}{r^5} \\
U_{xz} = U_{zx} &= \frac{\partial^2 U}{\partial xz} = \frac{3(1-\mu)(x+\mu)z}{d^5} + \frac{3\mu(x-1+\mu)z}{r^5} \\
U_{yz} = U_{zy} &= \frac{\partial^2 U}{\partial yz} = \frac{3(1-\mu)yz}{d^5} + \frac{3\mu yz}{r^5}
\end{aligned}$$

The solution to these variational equations in the CR3BP (Equation 2.31) is

$$\begin{Bmatrix} \delta r_{xf} \\ \delta r_{yf} \\ \delta r_{zf} \\ \delta v_{xf} \\ \delta v_{yf} \\ \delta v_{zf} \end{Bmatrix} = \begin{bmatrix} \phi_{11} & \phi_{12} & \phi_{13} & \phi_{14} & \phi_{15} & \phi_{16} \\ \phi_{21} & \phi_{22} & \phi_{23} & \phi_{24} & \phi_{25} & \phi_{26} \\ \phi_{31} & \phi_{32} & \phi_{33} & \phi_{34} & \phi_{35} & \phi_{36} \\ \phi_{41} & \phi_{42} & \phi_{43} & \phi_{44} & \phi_{45} & \phi_{46} \\ \phi_{51} & \phi_{52} & \phi_{53} & \phi_{54} & \phi_{55} & \phi_{56} \\ \phi_{61} & \phi_{62} & \phi_{63} & \phi_{64} & \phi_{65} & \phi_{66} \end{bmatrix} \begin{Bmatrix} \delta r_{x0} \\ \delta r_{y0} \\ \delta r_{z0} \\ \delta v_{x0} \\ \delta v_{y0} \\ \delta v_{z0} \end{Bmatrix} \tag{2.33}$$

This 36-element STM in Equation 2.33 may be more succinctly expressed using 3×3 submatricies as follows

$$\begin{Bmatrix} \delta \bar{r}_f \\ \delta \bar{v}_f \end{Bmatrix} = \begin{bmatrix} \phi_{rr} & \phi_{rv} \\ \phi_{vr} & \phi_{vv} \end{bmatrix} \begin{Bmatrix} \delta \bar{r}_0 \\ \delta \bar{v}_0 \end{Bmatrix} \tag{2.34}$$

where ϕ_{rr} is a submatrix of the STM that relates change in final position to change in initial position, ϕ_{rv} transfers a variation in initial velocity into a change in final position, ϕ_{vr} relates change in final velocity to change in initial position, and ϕ_{vv} reflects a change in final velocity due to a variation in initial velocity. The STM for the CR3BP in Equation 2.34, satisfies the differential equation

$$\begin{bmatrix} \dot{\phi}_{rr} & \dot{\phi}_{rv} \\ \dot{\phi}_{vr} & \dot{\phi}_{vv} \end{bmatrix} = A(\tau) \begin{bmatrix} \phi_{rr} & \phi_{rv} \\ \phi_{vr} & \phi_{vv} \end{bmatrix} \tag{2.35}$$

where the matrix, $A(\tau)$, is equal to that in Equation 2.32. The differential equation for the STM in Equation 2.35 is integrated simultaneously with the CR3BP equations of motion in Equation 2.17. Thus, sensitivities concerning trajectories nearby the reference trajectory are available.

The validity of Equation 2.34 is based on the reference solution and nearby trajectories that are evaluated over the same time period. It is potentially necessary to compare the reference path and nearby trajectories that are propagated for different times. To incorporate variable time, Equation 2.34 is modified as follows

$$\begin{Bmatrix} \delta\bar{r}_f \\ \delta\bar{v}_f \end{Bmatrix} = \begin{bmatrix} \phi_{rr} & \phi_{rv} \\ \phi_{vr} & \phi_{vv} \end{bmatrix} \begin{Bmatrix} \delta\bar{r}_0 \\ \delta\bar{v}_0 \end{Bmatrix} + \begin{bmatrix} \frac{\partial\bar{r}}{\partial\tau} \\ \frac{\partial\bar{v}}{\partial\tau} \end{bmatrix} \delta\tau \tag{2.36}$$

Combining the previous relationship into one state transition matrix results in the form

$$\begin{Bmatrix} \delta\bar{r}_f \\ \delta\bar{v}_f \end{Bmatrix} = \begin{bmatrix} \phi_{rr} & \phi_{rv} & \dot{\bar{r}}(\tau) \\ \phi_{vr} & \phi_{vv} & \dot{\bar{v}}(\tau) \end{bmatrix} \begin{Bmatrix} \delta\bar{r}_0 \\ \delta\bar{v}_0 \\ \delta\tau \end{Bmatrix} \tag{2.37}$$

Equation 2.37 represents sensitivities of the final position and velocity to changes, not only in initial position and velocity, but also in nondimensional time.

2.3.3 Differential Corrections Process to Determine Periodic Orbits

Computing a periodic orbit is equivalent to solving a two-point boundary value problem when the initial and final states are identical. However, any periodic orbit possesses characteristics that can be exploited during the search process. For example, a corollary to the mirror theorem states that if, at two different times, a mirror configuration occurs along a trajectory, then that trajectory is periodic [24]. So, for a trajectory crossing the xz-plane to be continuous and satisfy the mirror theorem, two perpendicular xz-plane crossings must occur. Thus, it is not necessary to propagate a full orbit. Instead, the starting point is selected as one of the perpendicular crossings; the target point is then the second perpendicular crossing. Because this approach allows for a nondimensional final time that is variable, the STM in Equation 2.37 is used to approximate an adjustment in the initial conditions, including $\delta\tau$, to produce a desired change in the final state. Depending on the type of orbit desired, varying constraints and target conditions apply. For example, the initial variations for a three-dimensional halo orbit are represented as elements of the vector $\delta\bar{y}_0 = \begin{bmatrix} \delta r_{x0} & \delta r_{y0} & \delta r_{z0} & \delta v_{x0} & \delta v_{y0} & \delta v_{z0} & \delta\tau \end{bmatrix}^T$ and the final variations are $\delta\bar{y}_f = \begin{bmatrix} \delta r_{xf} & \delta r_{yf} & \delta r_{zf} & \delta v_{xf} & \delta v_{yf} & \delta v_{zf} \end{bmatrix}^T$. A periodic halo orbit is symmetric across the xz-plane; therefore, the initial state is a perpendicular crossing of the xz-plane and, to determine a periodic orbit, a second perpendicular crossing of this plane is sought. So, a corrections process to determine a three-dimensional halo orbit only allows changes in the initial velocity, v_{y0}, the initial position, r_{x0}, and nondimensional time, τ. All other initial variations must be zero. Since the trajectory is integrated until a second xz-plane crossing, the targeted condition $r_{yf} = 0$ is always satisfied, therefore, $\delta r_{yf} = 0$. The other target conditions of interest are $v_{xf} = 0$ and $v_{zf} = 0$ if determining a three-dimensional halo orbit, since these conditions will constitute a perpendicular xz-plane crossing. However, for a corrections process used to compute a planar Lyapunov orbit, the z-components of the initial and final variations are zero; therefore, $\delta\bar{y}_0 = \begin{bmatrix} \delta r_{x0} & \delta r_{y0} & 0 & \delta v_{x0} & \delta v_{y0} & 0 & \delta\tau \end{bmatrix}^T$ and $\delta\bar{y}_f = \begin{bmatrix} \delta r_{xf} & \delta r_{yf} & 0 & \delta v_{xf} & \delta v_{yf} & 0 \end{bmatrix}^T$. Only changes in v_{y0} and τ are allowed when calculating a planar Lyapunov orbit. Consistent with the three-dimensional halo orbits, $\delta r_{yf} = 0$, but now only $v_{xf} = 0$ is required to satisfy the perpendicular crossing requirement. Using the appropriate constraints and targets, the matrix Equation 2.37 may be reduced to

$$\left\{\begin{array}{c} 0 \\ \delta v_{xf} \\ \delta v_{zf} \end{array}\right\} = \begin{bmatrix} \phi_{21} & \phi_{25} & \dot{r}_{yf} \\ \phi_{41} & \phi_{45} & \dot{v}_{xf} \\ \phi_{61} & \phi_{65} & \dot{v}_{zf} \end{bmatrix} \left\{\begin{array}{c} \delta r_{x0} \\ \delta v_{y0} \\ \delta \tau \end{array}\right\} \tag{2.38}$$

for a three-dimensional halo orbit or

$$\left\{\begin{array}{c} 0 \\ \delta v_{xf} \end{array}\right\} = \begin{bmatrix} \phi_{25} & \dot{r}_{yf} \\ \phi_{45} & \dot{v}_{xf} \end{bmatrix} \left\{\begin{array}{c} \delta v_{y0} \\ \delta \tau \end{array}\right\} \tag{2.39}$$

for a two-dimensional Lyapunov orbit. Equations 2.38 or 2.39 may then be solved for the desired changes in the final state. Of course, iteration is required to reach the desired final state to within some specified tolerance.

The basic differential corrections process can be summarized in terms of the following steps:

1. Assume an initial guess at the first perpendicular crossing. This guess may be available from some linear approximation or various other options.

2. Integrate the equations of motion in Equation 2.17 and the differential equations for the STM in Equation 2.28. Terminate the integration at the crossing of the xz-plane.

3. Check the targeted states; for a three-dimensional periodic halo orbit, the *desired* perpendicular crossing requires $v_{xf} = 0$ and $v_{zf} = 0$. If either $|v_{xf}| < \epsilon$, or $|v_{zf}| < \epsilon$, where ϵ is some acceptable error, a solution has been reached. If not, let $\delta v_{xf} = -v_{xf}$ and $\delta v_{zf} = -v_{zf}$. For a planar periodic Lyapunov orbit, only the condition $v_{xf} = 0$ is necessary. If $|v_{xf}| < \epsilon$ the process has reached a solution, if it is not, then let $\delta v_{xf} = -v_{xf}$ and continue to step 4.

4. Derive a reduced STM, appropriate to the dimension of the target periodic orbit. For example, Equation 2.38 is appropriate for a three-dimensional halo orbit while Equation 2.39 is appropriate for a planar Lyapunov orbit. This reduced STM is then used to solve for the estimated adjustments in the initial conditions (for a

halo orbit δr_{x0} and δv_{y0}, for a Lyapunov orbit just δv_{y0}) to reach the target. Update the initial conditions to incorporate the appropriate calculated changes and return to step 2.

A sequence of iterations for a planar differential corrections process is plotted in Figure 2.8. The successive iterations determine the required initial conditions to define an L_2

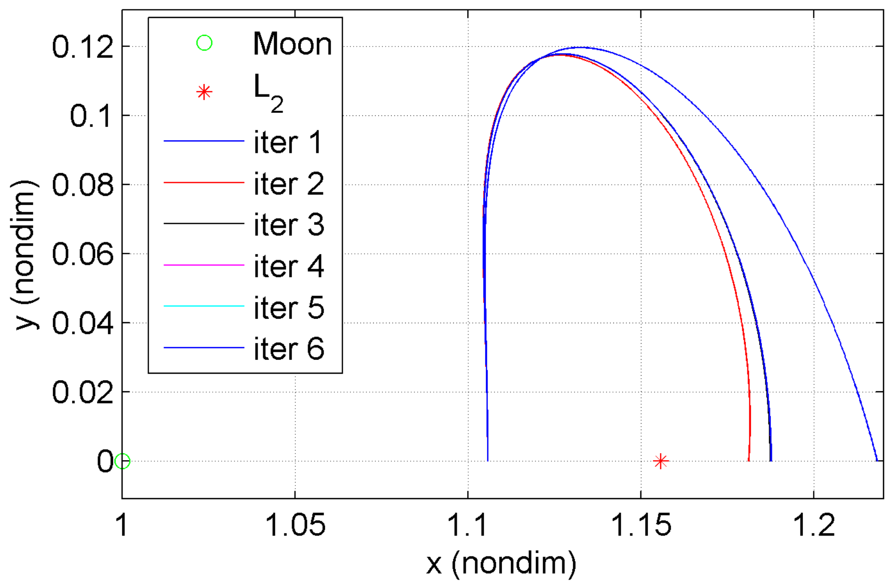

Figure 2.8. Progressive iterations from a differential corrections scheme to compute an L_2 Lyapunov orbit.

Lyapunov orbit. For this particular case, the corrections process is visually successful in three iterations and requires six iterations to meet a tolerance of 1×10^{-12}.

2.4 Mondromy Matrix

For periodic orbits, there is a significant STM, that is, the monodromy matrix, evaluated after exactly one period, T, of the orbit. The monodromy matrix can be determined using a number of different approaches. In some rare instances (for example, the two-body problem), an analytical solution is available for the elements of the STM. Alternatively, in the CR3BP, given the initial conditions that correspond to a periodic orbit, the state equations as well as the vector differential equation for the STM can be integrated for exactly one period. However, it is also possible to integrate for only one half-period and use the resulting STM at the half-period to compute the monodromy matrix. If T is the time required to complete one period of the orbit, then

$$\phi(T,0) = G \begin{bmatrix} 0 & -I \\ I & -2\Omega \end{bmatrix} \phi^T(T/2,0) \begin{bmatrix} -2\Omega & I \\ -I & 0 \end{bmatrix} G\phi(T/2,0) \tag{2.40}$$

where

$$G = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}$$

and

$$\Omega = \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

This result is valid because the STM is symplectic. It is well known that the STM also possesses two other very useful properties, that is [20],

$$\phi(t_2,t_0) = \phi(t_2,t_1)\phi(t_1,t_0) \tag{2.41}$$

$$\phi(t_0,t_1) = \phi^{-1}(t_1,t_0) \tag{2.42}$$

The monodromy matrix is significant for numerous reasons. One observation in particular, is very useful in the transfer problem. The monodromy matrix contains linear stability information for motion in the neighborhood of the periodic orbit. The information can be employed to determine transfers, i.e., trajectories that approach or depart the periodic orbit [25].

2.5 Stability of a Periodic Orbit

The stability of an orbit that is periodic relative to the rotating frame can be studied using a combination of Floquet theory and Poincaré sections [2]. A Poincaré section effectively reduces the dimension of the phase space by one. For example, define a hyperplane, Σ, that is transverse to the flow in n-dimensional space. For a three-dimensional system, Σ is a plane. From some set of initial conditions in Σ, let the system evolve. At the time that the path crosses this plane again, proceeding in the same direction, mark the intersecting point. This point reflects a second crossing of the hyperplane and, thus, the point in Σ is denoted a first-return map. As time increases, a series of points appears in Σ as seen in Figure 2.9. Note that a periodic

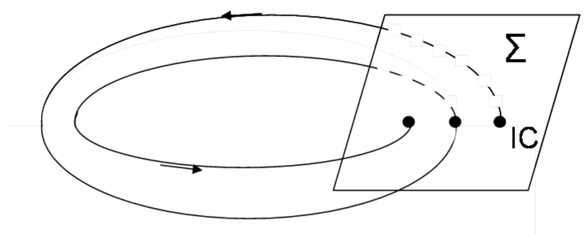

Figure 2.9. Multiple intersections of the hyperplane, Σ, by a single trajectory; resulting plot on Σ is a Poincaré section.

orbit would be represented in this plane by a single point, denoted as a fixed point, $\bar{x}^*$, since, on every pass, the orbit intersects the same location in the plane [2]. In general, the plane Σ can be sampled in terms of a state, for example, every crossing of the $\hat{x}$-axis. Alternately, Σ can be sampled in time, e.g., every period. From Equation 2.27, it is clear that $\delta\bar{y}(T) = \phi(T,0)\delta\bar{y}(0)$. Thus, for this linear system, the monodromy matrix maps the state forward by exactly one period. Therefore, the monodromy matrix is a linear stroboscopic map for the fixed point in the vicinity of the reference trajectory [15].

Stability information associated with the orbit is contained within the monodromy matrix. Recall that linearizing the equations of motion (Equation 2.17) relative to the periodic orbit results in Equation 2.31, where $A(t)$ is a continuous, periodic matrix; therefore, Floquet theory can be applied to the STM, resulting in the following form

$$\phi(t,0) = F(t)e^{Jt}F^{-1}(0) \tag{2.43}$$

where $F(t)$ is a time-varying, periodic matrix and J is a constant diagonal matrix of Poincaré exponents, ω_i [20]. After one period, where $t = T$, $F(T) = F(0)$; the monodromy matrix is evaluated as the STM at $t = T$ and Equation 2.43 can be rewritten in the form

$$e^{JT} = F^{-1}(0)\phi(T,0)F(0) \tag{2.44}$$

Thus, $F(0)$ is a matrix containing the eigenvectors of the monodromy matrix. The eigenvalues of the monodromy matrix, λ_i, are termed the characteristic multipliers and are related to the Poincaré exponents, ω_i, as follows

$$\lambda_i = e^{\omega_i T} \text{ or } \omega_i = \frac{1}{T}ln(\lambda_i) \tag{2.45}$$

The eigenvalues of the monodromy matrix offer information about the phase space in the vicinity of the periodic orbit because λ_i (and the Poincaré exponents, ω_i) reflect the linear stability of the fixed point in the map. Similar to the eigenvalues of a constant coefficient system, the sign of the real part of the Poincaré exponents determines the stability of the fixed point, $\bar{x}^*$. If $Re(\omega_i) < 0$, then the fixed point, and by implication the periodic orbit, is stable, while $Re(\omega_i) > 0$ indicates instability [26]. The Poincaré exponents are functions only of the eigenvalues of the monodromy matrix and the period; thus, the linear stability information of the orbit is completely defined by the eigenvalues, which span the solution space of the linear system [25,26]. Furthermore, the solution space may be decomposed into, at most, three subspaces, that is, the stable, unstable, and center subspaces. Specifically, an eigenvalue with $|(\lambda_i)| < 1$ is considered stable and the corresponding eigenvector resides in the stable subspace, E^s, of the linear solution space. An eigenvalue with a magnitude $|(\lambda_i)| > 1$ is unstable and its corresponding eigenvector lies in the unstable subspace, E^u, corresponding to the linear system. Finally, an eigenvalue with $|(\lambda_i)| = 1$ is neither stable nor unstable and the corresponding eigenvector reflects the center subspace, E^c, in terms of the linear variational equations [26].

According to Lyapunov's Theorem, since the determinant of the monodromy matrix is equal to one, the eigenvalues of the monodromy matrix must occur in reciprocal pairs. Also, the monodromy matrix is always a real matrix; therefore, any complex eigenvalues appear only in complex conjugate pairs as well. [22]. Furthermore, because the orbit is periodic, at least one eigenvalue must be equal to one. Since all eigenvalues are reciprocal pairs, at least two eigenvalues are equal to one. For a halo orbit, there is typically one pair of eigenvalues equal to one, another pair of complex conjugate eigenvalues located on the unit circle, and a real reciprocal pair corresponding to one stable and one unstable eigenvalue [6].

2.6 Invariant Manifolds

The eigenvectors of the monodromy matrix completely span the space of the linear solution and can be decomposed into the three independent subspaces, E^c, E^s, and E^u. Any trajectory originating in one of these subspaces will remain within that subspace for all time. Thus, trajectories originating in the stable subspace will approach the orbit asymptotically as $t \to \infty$, while trajectories originating in the unstable subspace will asymptotically approach the orbit as $t \to -\infty$. In the center subspace, trajectories will neither approach nor depart the orbit as $t \to \pm\infty$, that is, motion relative to the orbit is bounded, perhaps periodic [26]. The directions defined by the eigenvectors associated with the stable/unstable subspace of the linear system are used to approximate the the direction of the local stable and unstable manifolds [26]. The local stable/unstable manifolds are then propagated forward/backward in time to compute approximations to the global manifolds in the nonlinear system.

For the majority of halo orbits, four eigenvectors span the center subspace and one each spans the stable and unstable subspaces. So, for a fixed point, $\bar{x}^*$, on a halo orbit, there is a four-dimensional center subspace, a one-dimensional stable subspace and a one-dimensional unstable subspace. The trajectory that exists in the stable subspace for the nonlinear system is known as the one-dimensional stable global manifold, W^s. Similarly, the unstable nonlinear subspace trajectory is the one-dimensional unstable global manifold, W^u. The hyperplane, Σ, and therefore, the fixed point, $\bar{x}^*$, may theoretically be placed at any point along the orbit. At each fixed point, the eigenvalues of the monodromy matrix are the same; however, the associated eigenvectors vary. Thus, the subspaces, E^k, and the manifolds, W^k, differ at each point reflecting the fact that the flow arrives and departs in different directions at various points along the orbit. When a one-dimensional manifold is computed for every fixed point around the orbit, a two-dimensional manifold surface results [26].

2.6.1 Generating Stable and Unstable Manifolds

The determination of transfers toward and away from a periodic orbit benefits greatly from the availability of the stable and unstable manifolds. To generate the stable or unstable manifold associated with a periodic orbit, the eigenvector spanning the corresponding subspace yields approximate initial conditions to begin the process. The six-element eigenvector, $\bar{\xi}(\bar{x}*)$, corresponding to the fixed point, $\bar{x}*$, is calculated from the monodromy matrix and then normalized with respect to its position only, x, y, and z, such that

$$\bar{\xi}_n = \frac{\bar{\xi}}{\sqrt{x^2 + y^2 + z^2}} \tag{2.46}$$

The eigenvector is oriented in the six-dimensional direction defined in the corresponding linear subspace. Because the local manifold, W^s_{loc} or W^u_{loc}, in the nonlinear system is tangent to the subspaces E^s and E^u defined in the linear system, a small shift in the direction of the normalized eigenvector can reasonably approximate the global manifolds [26]. A simple illustration of the manifold, locally tangent to the linear eigenvector directions, $\bar{\xi}_n$, appears in Figure 2.10. Because the eigenvector is directed in either a positive or negative sense, the shift, d, in the direction of the eigenvector

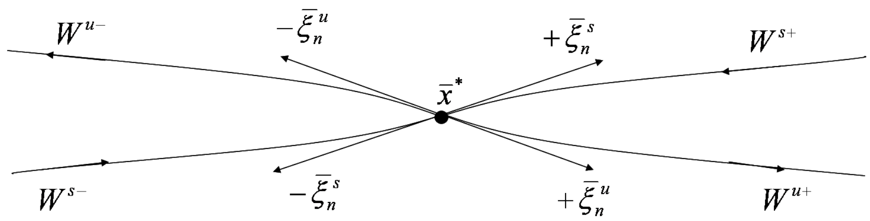

Figure 2.10. Illustration of tangency between eigenvector directions, $\hat{V}$, and manifolds.

occurs as either positive or negative. The six-element initial condition vector used to propagate the global manifold is calculated as follows

$$\bar{y}_0 = \bar{x}^* \pm d\bar{\xi}_n \tag{2.47}$$

A shift in the $+\bar{\xi}_n$ direction results in manifolds W_{loc}^{s+} or W_{loc}^{u+}, while the shift in $-\bar{\xi}_n$ direction results in the manifolds W_{loc}^{s-} or W_{loc}^{u-} [26]. This new shifted initial condition, $\bar{y}_0$, is then used to propagate the CR3BP equations of motion (Equation 2.17) forward in time if the initial condition corresponds to the unstable manifold or backward in time if it corresponds to the stable manifold. This propagation creates the global manifolds, W^{s+}, W^{s-}, W^{u+}, or W^{u-}. If a global manifold is computed for each fixed point along the orbit, the manifold surface is generated [26]. For this analysis in the Earth-Moon system, a shift distance of $d = 50$ km is used for all manifold calculations. Stable (blue) and unstable (red) manifolds, generated from an L_1 halo orbit with out-of-plane amplitude, Az, equal to 20,000 km, appear in Figure 2.11.

The stable and unstable manifolds in Figure 2.11 illustrate a second type of symmetry in the CR3BP, that is, the symmetry of the stable and unstable manifolds across the xz-plane due to time-invariance. If the state vector, $\bar{y} = \begin{bmatrix} x & y & z & \dot{x} & \dot{y} & \dot{z} \end{bmatrix}^T$, satisfies the equations of motion when propagated forward in time ($\Delta t > 0$), then the state vector, $\bar{y} = \begin{bmatrix} x & -y & z & -\dot{x} & \dot{y} & -\dot{z} \end{bmatrix}^T$, satisfies the equations of motion when propagated backwards in time ($\Delta t < 0$) [22]. This symmetry is particularly obvious in the xz-projection; it is clear that the stable and unstable manifolds overlap.

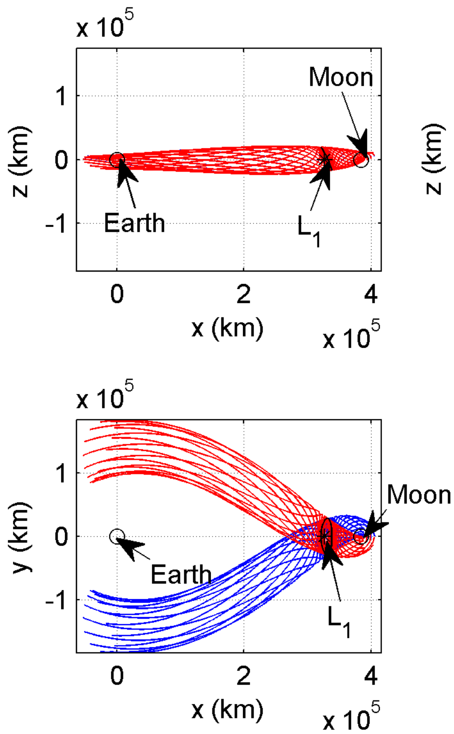

Figure 2.11. Stable (blue) and unstable (red) manifolds for a 20,000 km L_1 halo orbit.

3. Transfers to L_2 Planar Lyapunov Orbits

The set of trajectories connecting low Earth orbits (LEO) and the manifolds associated with the L_2 planar, Lyapunov orbits is the focus of this chapter. A numerical differential corrections process is used to compute the desired transfers. Various design variables, including the altitude of the low Earth orbit, the size of the Lyapunov orbit, the point along the Lyapunov orbit that serves as a basis to propagate the targeted manifold, as well as the location of the manifold insertion point are varied to compute a variety of transfers with manifold insertion maneuvers at varying altitudes and orientations relative to the Moon. The maneuver costs, that is, the required velocity discontinuities or ΔV's, are calculated and compared to determine the effect of lunar proximity as well as any design conditions favorable to lower costs.

3.1 Differential Corrections Process

Computation of these transfers is based on a numerical differential corrections process as part of a targeting scheme. This process is very sensitive to changes in conditions in the vicinity of the Earth, and targeting any point in the vicinity of the Moon by varying the conditions at the Earth orbit is very difficult. The problem is more easily approached by targeting a state backwards in time, that is, targeting the conditions at the Earth orbit by varying the conditions at the manifold insertion point and integrating the trajectory in negative time from the Moon to the Earth. Because integration proceeds backwards in time, the term "initial conditions" always refers to the state at the manifold insertion point and the term "final conditions" implies the state at insertion onto the transfer path from the Earth orbit.

To develop a targeter for this problem, it is critical to define every element of the initial state vector as a constraint or a control. The constraints will be fixed and not allowed to vary. The controls are adjusted to meet the target conditions. For this scenario, the initial position, $\bar{r}_i$, must remain constant, since the trajectory is initially positioned on the manifold at a specified point by definition. However, the initial velocity, $\bar{v}_i$, is the control and is adjusted to meet the target. For these planar cases, only transfers tangent to the manifold at the initial intersection point are considered to minimize the maneuver cost. Therefore, only the initial velocity magnitude, $|\bar{v}_i|$, varies, and the initial velocity direction, $\hat{v}_i$, is constrained to be tangent to the velocity, $\hat{v}_m$, along the manifold at the insertion point.

The target conditions at the final time must also be specified. The departure from the Earth, the target in the backwards targeting scheme, is defined as tangent to a low Earth parking orbit, assumed to be circular. A tangential final state is accomplished by targeting the final flight path angle, γ_f, relative to the Earth. The desired flight path angle is zero, that is, $\gamma_d = 0$. To specify the size of the Earth parking orbit, the final altitude, h_f, above the Earth is also a target variable. The desired final altitude is denoted h_d. Thus, the final flight path angle and final altitude are evaluated as

$$\begin{aligned} \sin(\gamma_f) &= -\frac{{}^e\bar{r}_f^s \cdot \bar{v}_f}{\left|{}^e\bar{r}_f^s\right| |\bar{v}_f|} \\ h_f &= \left|{}^e\bar{r}_f^s\right| - R_\oplus \end{aligned} \tag{3.1}$$

where ${}^e\bar{r}_f^s$ is the final position of the spacecraft relative to the Earth and the symbol $R_\oplus$ represents the radius of the Earth. These quantities are also defined in Figure 3.1.

Given the target values of the flight path angle and the altitude, the error between the desired and actual values, at the final time, is calculated. This error is summarized in vector form as follows

$$\bar{E} = \begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \begin{bmatrix} \left|{}^e\bar{r}_f^s\right| - R_\oplus - h_d \\ -\left({}^e\bar{r}_f^s \cdot \bar{v}_f\right) - \left|{}^e\bar{r}_f^s\right| |\bar{v}_f| \sin(\gamma_d) \end{bmatrix} \tag{3.2}$$

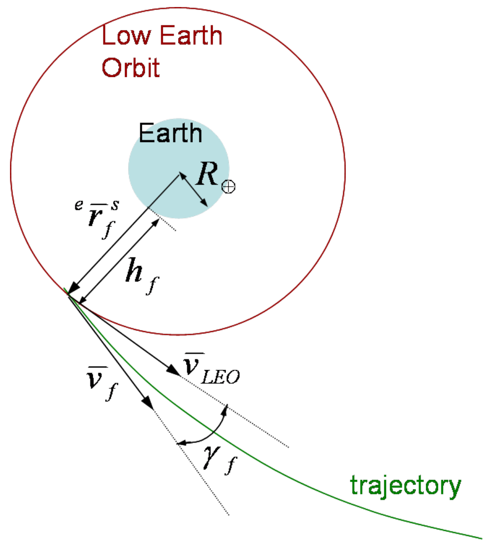

Figure 3.1. Definition of the target conditions: flight path angle, γ_f, and altitude, h_f.

Express the position and velocity vectors in Equation 3.2 in terms of components defined relative to the rotating frame as

$$
\begin{aligned}
{}^{e}\bar{r}_f^{s} &= (x_f + \mu)\hat{x} + y_f\hat{y} + z_f\hat{z} \qquad (3.3)\\
\bar{v}_f &= \dot{x}_f\hat{x} + \dot{y}_f\hat{y} + \dot{z}_f\hat{z}
\end{aligned}
$$

Note, that the $\hat{z}$-components in Equation 3.3 are equal to zero for this planar case; however, they have been included as variables so that these equations are valid when later applied to a three-dimensional corrections process. This is true for all of the following complete derivation. The differential corrections process includes a number of iterations until the components of $\bar{E}$, E_1 and E_2, are both within some specified tolerance. If the error is not sufficiently small, the value of the error, that is, $\delta\bar{E}$, in terms of a change in the initial state, $\delta\bar{y}_i$, is required to estimate the updated initial conditions for the next iteration. To develop $\delta\bar{E}$ as a function of $\delta\bar{y}_i$, express $\delta\bar{E}$ in terms of the variation in the final state, $\delta\bar{y}_f$, via the STM that predicts $\delta\bar{y}_f$ as a result of the initial variation, i.e., $\delta\bar{y}_i$. Recall that the state vector, $\bar{y}$, is defined as

$$\bar{y} = \begin{Bmatrix} x \\ y \\ z \\ \dot{x} \\ \dot{y} \\ \dot{z} \end{Bmatrix} \tag{3.4}$$

Note that $\delta\bar{E}$ may be written for convenience in the following form

$$\delta\bar{E} = \bar{E}_d - \bar{E} = M\delta\bar{y}_f = M\phi(\tau_f, \tau_i)\delta\bar{y}_i \tag{3.5}$$

where τ is nondimensional time and M is a 2×6 matrix

$$M = \frac{\partial\bar{E}}{\partial\bar{y}_f} = \begin{bmatrix} \frac{(x_f+\mu)}{\left|{}^e\bar{r}^s_f\right|} & \frac{y_f}{\left|{}^e\bar{r}^s_f\right|} & \frac{z_f}{\left|{}^e\bar{r}^s_f\right|} & 0 & 0 & 0 \\ -\dot{x}_f - \frac{(x_f+\mu)\left|\bar{v}_f\right|\sin(\gamma_d)}{\left|{}^e\bar{r}^s_f\right|} & -\dot{y}_f - \frac{y_f\left|\bar{v}_f\right|\sin(\gamma_d)}{\left|{}^e\bar{r}^s_f\right|} & -\dot{z}_f - \frac{z_f\left|\bar{v}_f\right|\sin(\gamma_d)}{\left|{}^e\bar{r}^s_f\right|} & -(x_f+\mu) - \frac{\dot{x}_f\left|{}^e\bar{r}^s_f\right|\sin(\gamma_d)}{\left|\bar{v}_f\right|} & -y_f - \frac{\dot{y}_f\left|{}^e\bar{r}^s_f\right|\sin(\gamma_d)}{\left|\bar{v}_f\right|} & -z_f - \frac{\dot{z}_f\left|{}^e\bar{r}^s_f\right|\sin(\gamma_d)}{\left|\bar{v}_f\right|} \end{bmatrix} \tag{3.6}$$

Assuming that the desired error is zero and, incorporating a variation in nondimensional time, τ, Equation 3.5 becomes

$$\delta\bar{E} = -\bar{E} = M\left[\phi(\tau_f, \tau_i)\delta\bar{y}_i + \frac{\partial\bar{y}_f}{\partial\tau}\delta\tau)\right] \tag{3.7}$$

The targeter is designed to stop the integration when the trajectory is closest to Earth; this stopping requirement automatically satisfies the tangency condition. Therefore, the second component in the error vector, E_2, will always be forced to equal zero.

Recall the constraints on the initial conditions. The initial position is fixed; therefore, all variations in the elements in the initial position vector are zero and may be removed from $\delta\bar{y}_i$. The associated terms in the STM are also removed. The updated error vector is now written only in terms of the variation in the initial velocity components and nondimensional time, that is

$$\begin{bmatrix} \delta E_1 \\ 0 \end{bmatrix} = - \begin{bmatrix} E_1 \\ 0 \end{bmatrix} = M \begin{bmatrix} \phi_{14} & \phi_{15} & \phi_{16} & \dot{x}_f \\ \phi_{24} & \phi_{25} & \phi_{26} & \dot{y}_f \\ \phi_{34} & \phi_{35} & \phi_{36} & \dot{z}_f \\ \phi_{44} & \phi_{45} & \phi_{46} & \ddot{x}_f \\ \phi_{54} & \phi_{55} & \phi_{56} & \ddot{y}_f \\ \phi_{64} & \phi_{65} & \phi_{66} & \ddot{z}_f \end{bmatrix} \begin{Bmatrix} \delta\dot{x}_i \\ \delta\dot{y}_i \\ \delta\dot{z}_i \\ \delta\tau \end{Bmatrix} \tag{3.8}$$

The direction of the initial velocity vector is also constrained; therefore, $\delta\dot{x}_i$, $\delta\dot{y}_i$, and $\delta\dot{z}_i$ are not independent. Adjusting one velocity component implies a corresponding adjustment to the other. For example, given a change in $\dot{x}_i$, the velocity adjustments in $\dot{y}_i$ and $\dot{z}_i$ are computed in terms of $\delta\dot{x}_i$ and estimated as

$$\begin{aligned} \delta\dot{y}_i &= \delta\dot{x}_i \frac{\dot{y}_i}{\dot{x}_i} \\ \delta\dot{z}_i &= \delta\dot{x}_i \frac{\dot{z}_i}{\dot{x}_i} \end{aligned} \tag{3.9}$$

Notice that there is a singularity in Equations 3.9 when $\dot{x}_i$ is equal to zero. To avoid this singularity, the targeter always determines the velocity updates in terms of the largest initial velocity component. Equations 3.8 and 3.9 result in a set of four independent equations with four unknowns and, thus, only one solution exists.

The overall differential corrections scheme is iterative. The steps in the targeting process are summarized:

1. An initial ΔV for the transfer is estimated using one of two methods. If no transfers to nearby manifold insertion points have been calculated, a rough grid search of the solution space is used to determine an appropriate maneuver estimate. If nearby transfers exist, then the ΔV magnitude of the nearby solution, added to an appropriate weighting term and multiplied by the direction of the velocity of the current manifold insertion point, is used as an initial guess for the corrections process.

2. The equations of motion (Equation 2.17) in the CR3BP as well as the differential equations for the STM (Equation 2.28) are propagated backwards until the trajectory reaches its closest approach to Earth. This is the reference trajectory.

3. The error is calculated using Equation 3.2. If $|E_1| > 1 \times 10^{-12}$, Equations 3.8 and 3.9 are employed to compute a value for the update to the initial velocity components. The velocity variation is merely an estimate for what is required to eliminate the error and reach the desired altitude at Earth closest approach.

4. This variation is added to the initial velocity vector along the reference path, creating a new set of initial conditions.

5. The new initial conditions initiate a new iteration. The process is repeated until the error, $|E_1|$, is below the tolerance value of 1×10^{-12}.

Figure 3.2 includes a plot of the iterations necessary to target an 800-km Earth altitude. (Recall that the process targets backwards in time.) This particular example

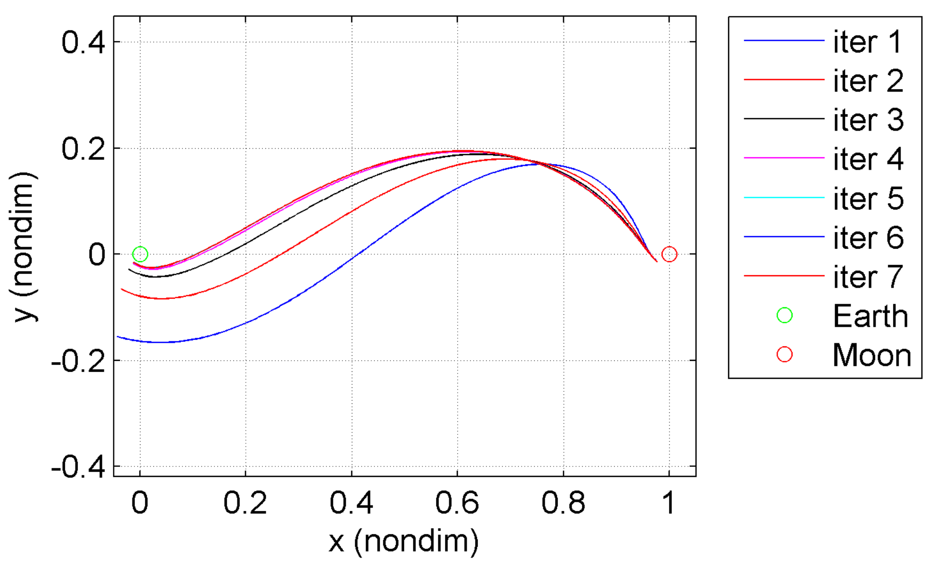

Figure 3.2. Iterations required in the differential corrections process to target an 800-km Earth departure; CR3BP rotating frame.

is successful within seven iterations, the first of which has an Earth departure altitude of 61,720 km. The resulting transfer from an 800-km low Earth orbit to the manifold insertion point appears in blue in Figure 3.3 along with the connecting manifold (black) and Lyapunov orbit (orange).

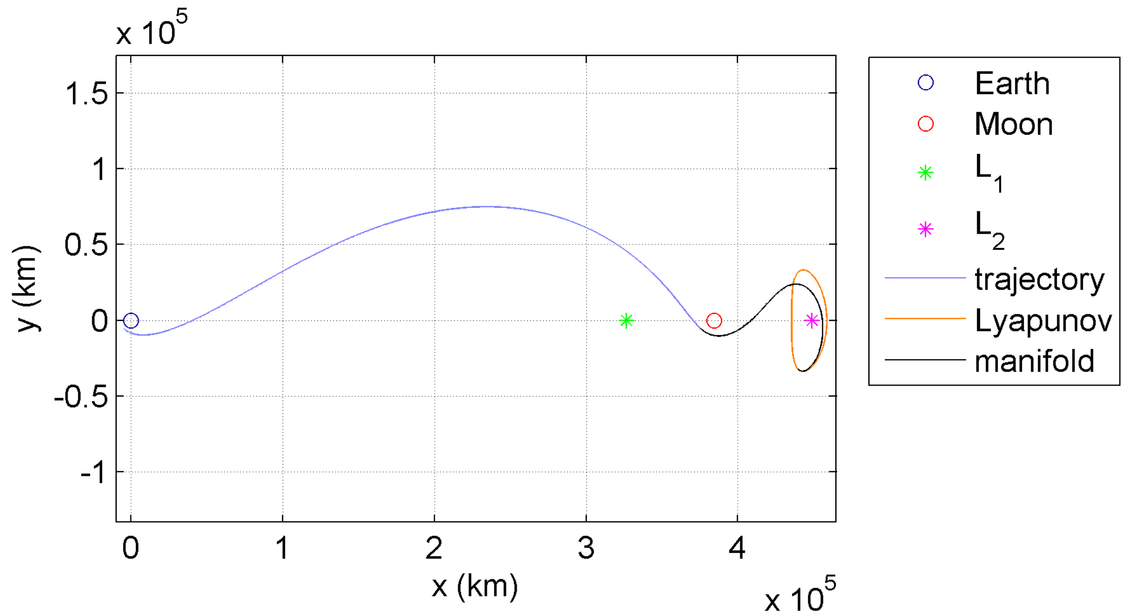

Figure 3.3. Transfer trajectory (blue), from an 800-km low Earth orbit to the manifold insertion point near the Moon; resulting from differential corrections process; CR3BP rotating frame.

3.2 Characteristics of Selected Transfers to Lyapunov Orbits

Using the differential corrections process, several transfers from an 800-km low Earth orbit (LEO) to selected Lyapunov orbits are computed. Transfers to the particular Lyapunov orbit that is located at a bifurcation point are calculated for several different design parameters. (This family of Lyapunov orbits bifurcates to the three-dimensional family of halo orbits and, thus, the target Lyapunov orbit is a member of both the two-dimensional and three-dimensional families.) The transfer trajectory characteristics are identified and those parameters that result in lower insertion costs are used to calculate transfers to additional Lyapunov orbits.

Three design parameters are varied during this analysis. Because manifolds originating from different fixed points around the libration point orbit pass the Moon at differing altitudes, the location along the orbit of these fixed points is varied. Also, the manifold insertion maneuver is allowed to occur at different locations along the manifold. This location is identified by the manifold insertion angle, ϕ, between the negative $\hat{x}$-axis and the radial line, in the xy-plane, connecting the Moon with the manifold insertion point. An illustration of this angle appears in Figure 3.4. Finally,

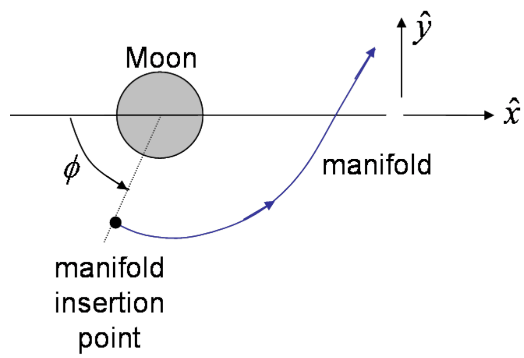

Figure 3.4. Definition of angle, ϕ, between the negative $\hat{x}$-axis and the radial line connecting the Moon and the manifold insertion point.

the size of the Lyapunov orbit itself is varied. For the purpose of this study, Lyapunov orbits are characterized by their y-amplitude, y_a, that is, the distance from the $\hat{x}$-axis to the maximum y value along the orbit.

The bifurcating orbit in the L_2 Lyapunov family corresponds to an orbit of size $y_a = 33,297$ km. As plotted in Figure 3.5, ten stable manifolds originating from fixed points spaced equally in time along the entire two-dimensional orbit are computed. Trajectories to each of these ten manifolds are calculated for manifold insertion angles of $\phi = 0\,°$, $30\,°$, $45\,°$, $60\,°$, and $90\,°$. Note, that trajectories with negative lunar altitudes, that is, below the lunar surface, at any point during the transfer between the Earth orbit and the Lyapunov orbit are considered invalid and are not included

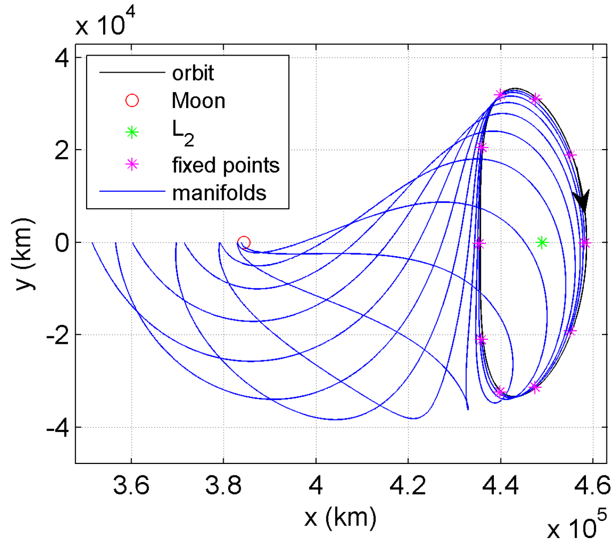

Figure 3.5. Lyapunov orbit, $y_a = 33,297$ km, and the manifolds originating from fixed points spaced equally in time about the orbit.

in the analysis. The resulting feasible transfers to each of the manifolds appear in Figure 3.6. Each trajectory is targeted to the point along the manifold when $\phi = 45\,°$. The insertion ΔV value for each trajectory is printed in the legend. From the plot in Figure 3.6, it is obvious that the choice of manifold greatly affects the insertion cost. For example, trajectories 2 (pink) and 9 (green) both incorporate manifold insertion points at similar lunar altitudes; however, the ΔV for insertion from trajectory 9 is 0.422 km/s lower than arrival from trajectory 2. It is also apparent that the lunar altitude affects the ΔV. Trajectories 4 (cyan) and 8 (light blue), which pass the Moon at the lowest altitudes, also possess the lowest ΔV. The impact of the arrival angle at the Moon, that is, ϕ, on the maneuver magnitude is also significant. Costs for the manifold insertion maneuver appear in Table 3.1. The data in the table includes the ΔV, in km/s, at manifold insertion along each trajectory at the corresponding value of ϕ. The smallest ΔV values for the lowest lunar altitude trajectories, that is, trajectories 4 and 8, both occur at $\phi = 45\,°$.

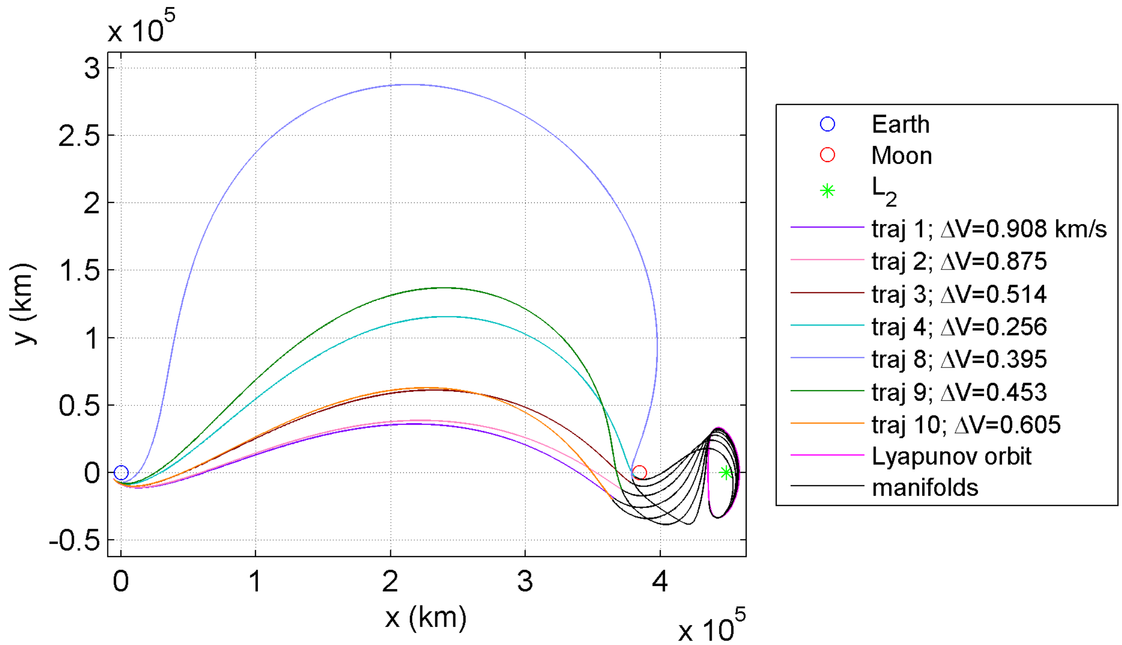

Figure 3.6. Transfers from an 800-km altitude LEO to a Lyapunov orbit of amplitude $y_a = 33,297$ km using various manifolds; $\phi = 45^\circ$.

Table 3.1 ΔV (km/s) at manifold insertion for various insertion angles, ϕ.

Trajectory	$\phi = 0^\circ$	$\phi = 30^\circ$	$\phi = 45^\circ$	$\phi = 60^\circ$	$\phi = 90^\circ$
1	0.544	0.672	0.908	1.515	no convergence
2	0.524	0.654	0.875	1.429	no convergence
3	0.412	0.442	0.514	0.707	4.121
4	0.278	0.257	0.255	0.261	0.305
8	no convergence	0.400	0.395	0.397	0.431
9	no convergence	0.453	0.453	0.476	0.850
10	0.508	0.522	0.605	0.833	5.586

The specific region of interest for this analysis includes trajectories with manifold insertion points near the Moon. The two manifolds in Figure 3.5 that pass closest to the Moon, with a pass distance above the lunar surface, originate from two distinct regions along the Lyapunov path. The two regions that result in the lowest insertion maneuver magnitudes are located in the upper left and center right of the Lyapunov orbit. To further investigate these two areas along the orbit, additional manifolds are numerically computed in these regions. Figure 3.7 includes representative manifolds that originate from these two regions. Because a manifold insertion angle, ϕ, equal

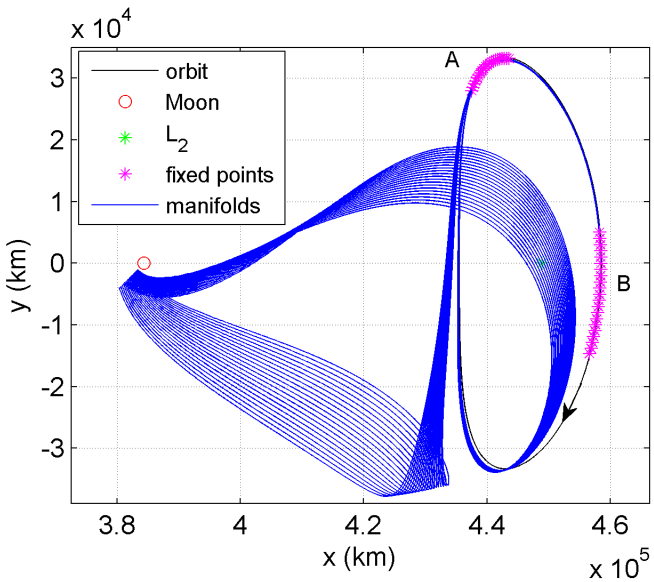

Figure 3.7. Lyapunov orbit, $y_a = 33,297$km, and manifolds originating from fixed points along the upper left (region A) and center right (region B) of the orbit.

to 45° results in the lowest ΔV values for trajectories 4 and 8, the two trajectories in this region of interest, the angle $\phi = 45°$ is selected for all subsequent transfers to Lyapunov orbits. This value of ϕ may or may not yield the minimum ΔV for other transfers; it is a reasonable selection, based on current data, to further investigate the transfers.

The trajectories computed for the region of interest, those that intersect manifolds in close lunar proximity, may be divided into two categories, short and long times of flight (TOF). The short TOF transfers intersect manifolds originating from region A, while the long TOF transfers are associated with manifolds defined in terms of fixed points located within region B. The transfer times from LEO to the manifold insertion point near the Moon vary between 4.0 and 5.8 days for the short transfers and between 8.6 and 14.1 days for the long transfers. A plot of the manifold insertion cost (ΔV) versus the lunar altitude at the time of insertion for both short and long TOF transfers appears in Figure 3.8. For both types of transfers, the ΔV decreases

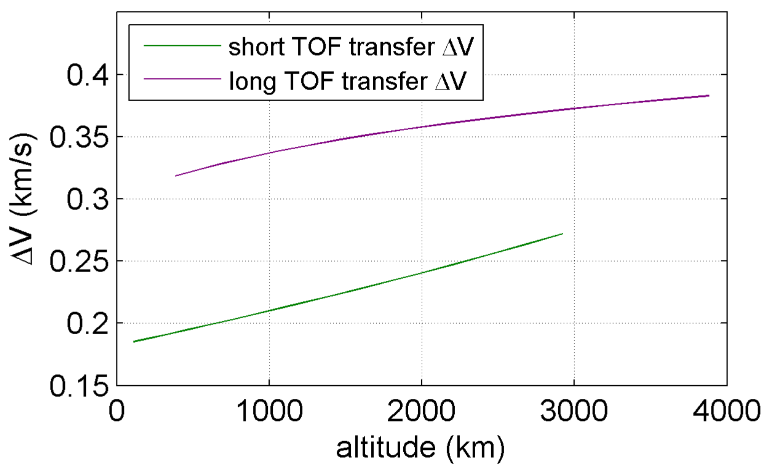

Figure 3.8. Manifold insertion ΔV as a function of lunar flyby altitude for short and long TOF transfers.

as the lunar altitude decreases; however, a short transfer requires a ΔV at least 0.1 km/s lower than a long transfer with similar lunar altitude. The short transfer (green) as well as the long transfer (purple) resulting in the lowest ΔV for each family, are plotted in Figure 3.9. The minimum ΔV among the short transfers is 0.185 km/s, a value that is nearly half the lowest cost, that is, $\Delta V = 0.318$ km/s, from the family of long TOF transfers.

The insertion maneuver cost is also a function of the size of the target Lyapunov orbit. Transfers to three additional Lyapunov orbits (of various sizes) are also deter-

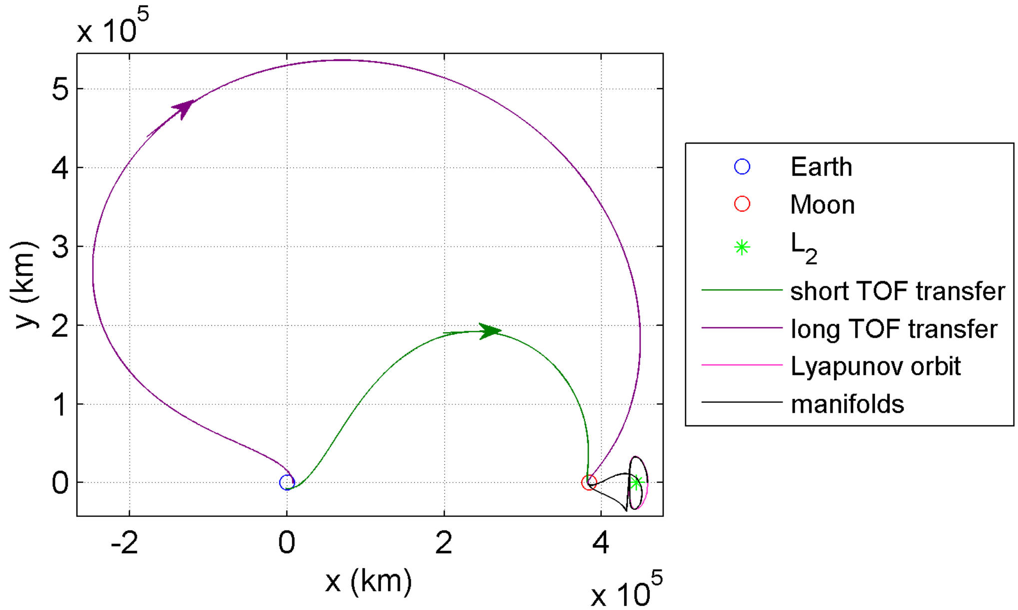

Figure 3.9. Short and long TOF transfers; lowest ΔV in each respective family. Short transfer: ΔV=0.185 km/s, TOF=5.75 days. Long transfer: ΔV=0.318 km/s, TOF=14.10 days.

mined. The corresponding orbits are defined in terms of the y-amplitudes $y_a = 10,627$ km, $y_a = 49,012$ km, and $y_a = 66,808$ km. These orbits appear in Figure 3.10 along with the previous orbit of size $y_a = 33,297$ km. Since the long transfers possess a higher insertion ΔV, as well as a longer time of flight, only the short transfers are computed for these additional Lyapunov orbits. Recall that all insertion maneuvers occur at $\phi = 45\,°$. The ΔV insertion cost versus lunar altitude at insertion for transfers to all four orbits appears in Figure 3.11. The manifold tube extending from orbit 1, the smallest of the four orbits, does not pass very close to the Moon. This fact is illustrated in Figure 3.11, where the curve of transfers to the smallest Lyapunov orbit (orbit 1) is the very short green line to the right in the figure. The lowest lunar altitude for a manifold from orbit 1 is 3,700 km. Although a lower ΔV may be achieved by using a larger Lyapunov orbit and a lower lunar flyby altitude, orbit 1 is associated with the lowest ΔV for transfers that pass the Moon at altitudes between 3,700 and 3,900 km. Also apparent in Figure 3.11, a correlation exists between the size of the

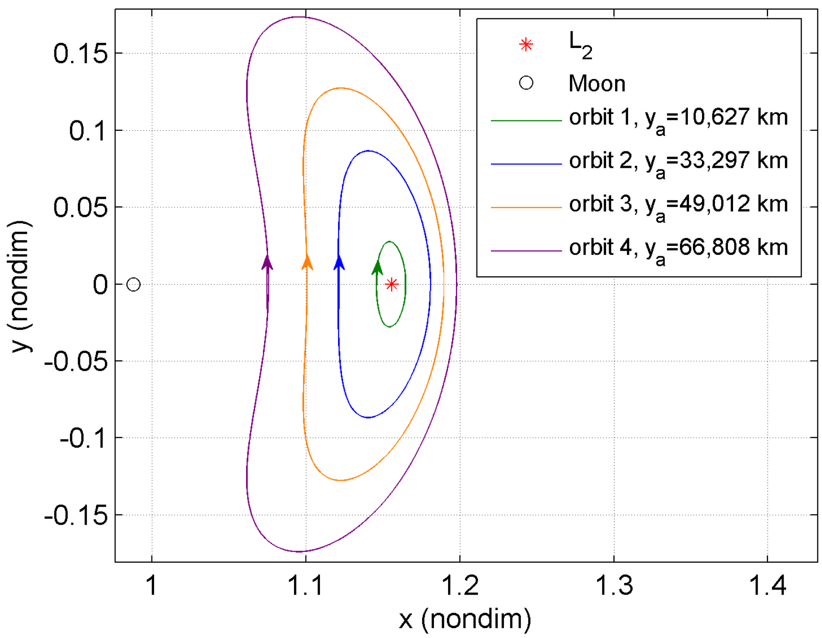

Figure 3.10. Lyapunov orbits of various sizes.

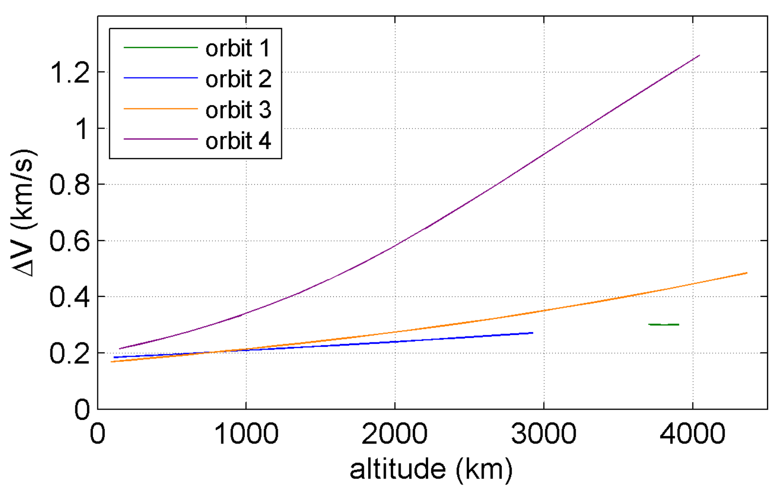

Figure 3.11. Manifold insertion ΔV as a function of lunar flyby altitude; short TOF transfers; four different target Lyapunov orbits.

Lyapunov orbit and the rate of change of the insertion cost. Clearly, a lunar altitude as low as possible is advantageous for a Lyapunov orbit of any size; however, if a certain lunar altitude is desired, then an optimal size of libration point orbit can be determined. The "optimal" orbit size will vary depending on the specified altitude. From among all of the transfers plotted in Figure 3.11, the lowest cost transfer, i.e., ΔV=0.169 km/s, is a transfer to Lyapunov orbit 3, for which the manifold insertion maneuver occurs at a lunar altitude of 89 km.

4. Transfers to L_2 Halo Orbits

The analysis of transfers from low Earth orbit to planar Lyapunov orbits can be expanded into three dimensions. Specifically, transfers to halo orbits of low out-of-plane (Az) amplitudes are of interest. Recall that the halo family of orbits results from a bifurcation in the Lyapunov family and that each orbit includes an amplitude component in the z-direction, Az. Transfers to halo orbits require lower ΔV's when the manifold insertion maneuver occurs in close proximity to the Moon, consistent with the work of Parker and Born [17]; however, the analysis of Parker and Born in this region of transfers to low Az-amplitude orbits was not exhaustive. Also, because tangent solutions are typically optimal, only trajectories that arrived at the manifold insertion point tangentially were considered in this previous work [17]. During early analysis in this current effort, the tangency constraint resulted in convergence difficulty for several transfers; therefore, the constraint was removed from the differential corrections process to allow for a greater number of control parameters as well as an expansion of the possible solution space. Using this modified corrector, trajectories from various low Earth orbits to selected low-Az halo orbit manifolds are successfully computed.

4.1 Modified Differential Corrections Process

The differential corrections process in the three-dimensional problem is based on the corrector used to develop planar transfers to Lyapunov orbits. However, to add flexibility, the constraint that the trajectory must be tangent to the manifold at the insertion point is removed. Once again, the trajectory is propagated in reverse time and "initial conditions" actually constitute the state at the manifold insertion point, while the term "final conditions" identifies the transfer insertion state from low

Earth orbit. The constrained initial condition for this process is position, $\bar{r}_0$, only; the velocity, $\bar{v}_0$, as well as nondimensional time of flight, may vary. The targeted final conditions are the same as for the previous planar transfers; the trajectory must depart tangentially from the low Earth orbit at a specified altitude. This translates into a desired flight path angle, γ_d, that is equal to zero and a final Earth altitude, h_f, that is specified to be a desired final altitude, h_d. Note that these target conditions do not constrain the inclination of the low Earth orbit. Since this is a three-dimensional problem using reverse propagation, the transfers will depart from Earth orbits of various inclinations. Ultimately, this would affect any total cost.

Since the targeted conditions have not changed from those used for the planar transfers, much of the former derivation associated with the corrections process is applicable. The error vector, $\bar{E}$, remains as derived previously, that is

$$\bar{E} = \begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \begin{bmatrix} \left|{}^e\bar{r}_f^s\right| - R_\oplus - h_d \\ -\left({}^e\bar{r}_f^s \cdot \bar{v}_f\right) - \left|{}^e\bar{r}_f^s\right| \left|\bar{v}_f\right| \sin(\gamma_d) \end{bmatrix} \tag{4.1}$$

and the resulting change in the error vector, $\delta\bar{E}$, in terms of the change in the initial state, $\delta\bar{y}_i$, remains as

$$\delta\bar{E} = -\bar{E} = M(\phi(\tau_f, \tau_i)\delta\bar{y}_i + \frac{\partial \bar{y}_f}{\partial \tau}\delta\tau) \tag{4.2}$$

Recall that the state vector, $\bar{y}$, is defined as

$$\bar{y} = \begin{Bmatrix} x \\ y \\ z \\ \dot{x} \\ \dot{y} \\ \dot{z} \end{Bmatrix} \tag{4.3}$$

The targeter terminates the integration when the trajectory reaches the closest approach distance relative to the Earth, which automatically satisfies the tangency condition. Therefore, the second term in the error matrix, E_2, is forced to equal zero as before. Initial position, $\bar{r}_0$, once again remains fixed; therefore, in the corrector equations the changes in the position components of the initial state vector are zero and are removed from $\delta\bar{y}_i$. The resulting change in the error matrix is again formulated as

$$\begin{bmatrix} \delta E_1 \\ 0 \end{bmatrix} = - \begin{bmatrix} E_1 \\ 0 \end{bmatrix} = M \begin{bmatrix} \phi_{14} & \phi_{15} & \phi_{16} & \dot{x}_f \\ \phi_{24} & \phi_{25} & \phi_{26} & \dot{y}_f \\ \phi_{34} & \phi_{35} & \phi_{36} & \dot{z}_f \\ \phi_{44} & \phi_{45} & \phi_{46} & \ddot{x}_f \\ \phi_{54} & \phi_{55} & \phi_{56} & \ddot{y}_f \\ \phi_{64} & \phi_{65} & \phi_{66} & \ddot{z}_f \end{bmatrix} \begin{Bmatrix} \delta\dot{x}_i \\ \delta\dot{y}_i \\ \delta\dot{z}_i \\ \delta\tau \end{Bmatrix} \tag{4.4}$$

Recall that M is a 2×6 matrix such that

$$M = \frac{\partial \bar{E}}{\partial \bar{y}_f}$$

All of the initial constraints and targeted final conditions are incorporated.

The matrix equation, Equation 4.4, is a system of two equations and four unknowns and therefore, infinitely many solutions. The minimum norm solution to a general system of equations of the form $\bar{a} = B\bar{c}$ where B is a known $m \times n$ matrix and $m < n$ is

$$\bar{c} = B^T(BB^T)^{-1}\bar{a} \tag{4.5}$$

where $B^T(BB^T)^{-1}$ is denoted the pseudoinverse of the matrix B. This solution can be easily proven by substituting Equation 4.5 into the original system as follows

$$\bar{a} = BB^T(BB^T)^{-1}\bar{a} \tag{4.6}$$

The minimum norm solution from the pseudoinverse approach is applied to the system of equations in Equation 3.8. The targeting process remains similar to that for the planar case and is summarized as follows:

1. Propagate the manifolds from regions on the orbit that result in near-lunar flybys and obtain the manifold state at a specified insertion point. The initial focus is a manifold that passes furthest from the Moon; assume a tangential arrival and generate

a first guess for the ΔV. Experience with the planar problem and a fundamental understanding of the affect of the ΔV magnitude on the flow of the planar transfer trajectories aids considerably in the determination of ΔV magnitudes for these three-dimensional trajectories. A range of potential ΔV magnitudes is generated; a gross grid search over this range yields a satisfactory first guess.

2. The differential equations governing the CR3BP (Equation 2.17) and the STM (Equation 2.28) are integrated in negative (nondimensional) time, using this initial guess for the ΔV. The integration continues until the trajectory reaches its closest approach to the Earth, creating a reference trajectory.

3. The error is calculated from Equation 4.1. An acceptable error tolerance is $|E_1| < 1 \times 10^{-12}$. (Recall that E_2 is forced to equal zero.) If the error does not meet this requirement, an adjustment to the insertion maneuver is computed using the pseudoinverse approach in Equation 4.4.

4. The resulting updates to the initial velocity components are added creating a new set of initial conditions; this new initial state may or may not be tangential to the velocity at the manifold insertion point. The integration process is repeated to generate a new reference trajectory. Iterations continue until the error meets the tolerance requirement of 1×10^{-12} nondimensional units in position.

5. Recall that this process results in a transfer to one specified manifold. A new manifold is selected, one that passes closer to the Moon; therefore, an initial guess is required for the insertion ΔV to initiate a new corrections process to determine a transfer to this new manifold. Again, for the first guess, a tangential arrival is assumed. A guess for the ΔV magnitude is obtained from the previous solution. This ΔV magnitude is added to an appropriate weighting term and applied tangent to the new manifold insertion point. Then the corrections process is repeated.

Using this basic procedure, the differential corrector is able to obtain transfers to several points around the manifold tube associated with an L_2 halo orbit of interest.

4.2 Characteristics of Transfers to L_2 Halo Orbits

Trajectories between low Earth orbits and L_2 halo orbit manifolds are computed using various design parameters. These parameters include the altitude of the LEO orbit, the Az-amplitude of the three-dimensional L_2 halo orbit, the location along the halo orbit that is associated with the origin of the manifold, and the insertion angle, ϕ, defined as the angle in the xy-plane, between the negative $\hat{x}$-axis and the line radially connecting the Moon and the *xy-projection* of the manifold insertion point. A halo family is continuous with an infinite number of orbits, which are typically identified by their out-of-plane amplitude, Az. To produce representative orbits, halo orbits are selected at 1,000 km intervals in Az. Thus, Az ranges between 1,000 km and 10,000 km. This range of low Az-amplitude orbits appears in Figure 4.1. For this

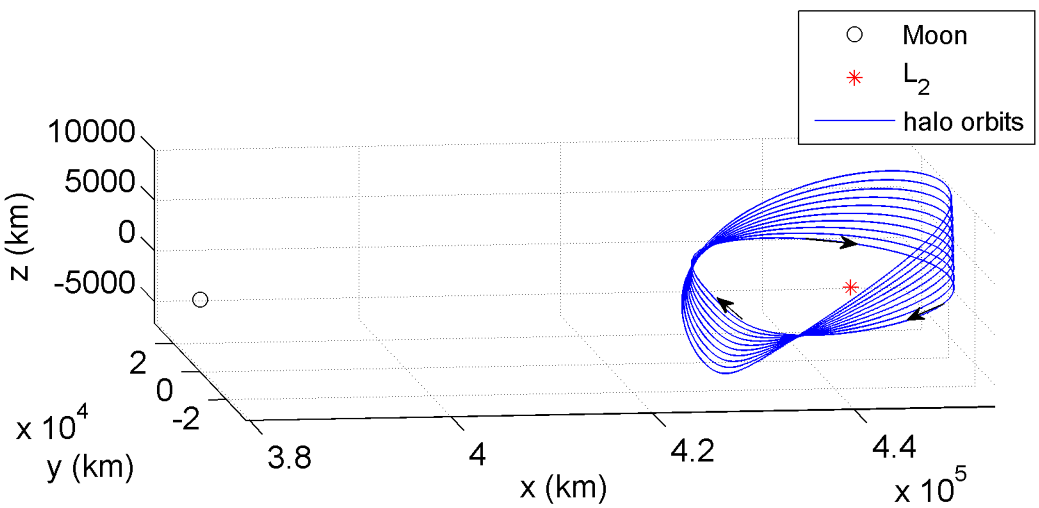

Figure 4.1. Representative low Az-amplitude L_2 halo orbits.

analysis, halo orbits in a northern family are selected, but the results are applicable to southern orbits as well.

Based on the previous planar analysis, manifolds that originate from two areas along the halo orbit pass close to the Moon. One set of manifolds leads to short time of flight transfers and the other to transfers with long times of flight. Initially, consider the effect of Earth altitude on both types of transfers. Several manifolds are propagated from both regions for a selected halo orbit. For a given orbit, transfer trajectories are computed from circular Earth orbits with altitudes over a range from 200 to 2,000 km; the transfers insert into various manifolds at manifold insertion angles of $\phi = 0\,°$, $30\,°$, $45\,°$, $60\,°$, and $90\,°$. Such transfers are computed for a variety of halo orbits. The ΔV magnitude at the manifold insertion point is then compared for the various trajectories. Recall that the altitude of the low Earth orbit is varied between 200 km and 2,000 km. Over this range, the magnitude of the manifold insertion maneuver does vary on the order of 1×10^2 m/s. However, the total ΔV, that is, the manifold insertion ΔV plus the Earth orbit departure maneuver, is significantly influenced by the altitude of the low Earth orbit. In general, the total ΔV varies on the order of 1×10^3 m/s, an order of magnitude greater than the variation solely in the manifold insertion ΔV. A transfer to a halo orbit such that $Az = 6,000$ km with $\phi = 60\,°$ illustrates this difference in magnitudes in Figure 4.2. The higher the LEO

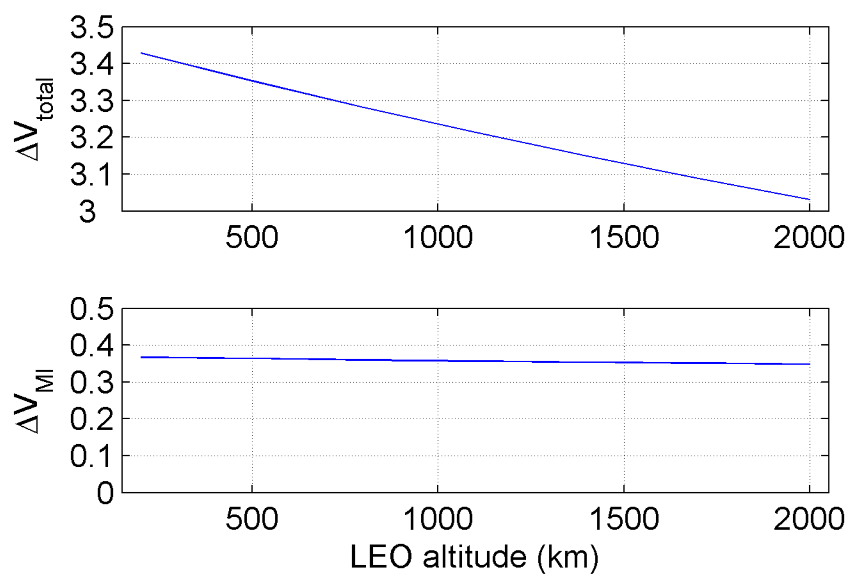

Figure 4.2. A comparison of the effect of Earth orbit altitude on the manifold insertion maneuver and total ΔV. Minimum ΔV values for transfers to a halo orbit of $Az = 6,000$ km; $\phi = 60\,°$.

altitude, the lower the total ΔV; this is consistent for all selected halo orbits and insertion angles near the Moon. In this particular case, the manifold insertion ΔV also decreased as the LEO altitude increased, but the decease is slight. Any increase or decrease in the manifold insertion ΔV due to changes in LEO altitude become insignificant when added to the total ΔV. In addition, this behavior in the Earth departure maneuver is well known and expected. Therefore, it is more beneficial to compare transfers using a single LEO altitude. In this case, an altitude of 500 km for the Earth departure orbit is selected.

The general impact of lunar proximity on the manifold insertion ΔV is apparent in a plot of lunar altitude versus the ΔV value. Figures 4.3, 4.5, 4.7, 4.9, and 4.11 each include such a plot for a different manifold insertion angle, ϕ. For $\phi = 0\,^\circ$ (Figure 4.3), only the short time of flight transfers are displayed; the differential corrections process did not converge on a reasonable solution for any of the long transfers. The remaining plots include both short and long transfers to all ten halo orbits. The solid lines represent the short transfers, while the dashed lines indicate long transfers. Consistent with the planar transfer analysis, if, at any point, the trajectory passes below the lunar surface, it is considered invalid and is not included.

The ΔV at manifold insertion for short TOF transfers to all ten different halo orbits that incorporate a manifold insertion angle of $0\,^\circ$ appear in Figure 4.3. The minimum ΔV for the short transfers does not correspond to the minimum lunar altitude at insertion. For a 1,000-km Az halo orbit, the minimum ΔV, equal to 0.282 km/s, occurs at a lunar altitude of 2,240 km. As the Az-amplitude of the halo orbit increases, the manifold corresponding to the minimum insertion ΔV passes the Moon at higher altitudes. Thus, for a 10,000 km-Az halo (the largest halo orbit included in the analysis), the minimum ΔV value of 0.489 km/s occurs at a lunar altitude of 5,670 km. It is also observed that the value of the minimum ΔV increases as the Az-amplitude increases. The ΔV for the 10,000-km Az halo orbit is nearly twice the value for the transfer to the 1,000 km Az halo orbit. Recall that these are the lowest insertion costs available to the given halo orbit. In Figure 4.3, the lowest point on each curve represents the transfer to each particular halo orbit that possesses the minimum insertion cost. Each of these ten minimum ΔV transfers are plotted in Figure 4.4. The transfers to each halo orbit are plotted in various colors, consistent with the legend in Figure 4.3; the colors correspond to the Az value. The transfer arcs insert onto manifolds; the manifold trajectory arcs appear in black and the orbits are plotted in red. The point where the transfer changes to black corresponds with the location of the manifold insertion ΔV. In the zoomed view, it is clear that the trajectory is nearly tangent to the manifold at the insertion point for all of the transfers. Also, the transfers to the higher-Az orbits proceed further out-of-plane than the transfers to lower-Az halo orbits.

The manifold insertion angle is increased to $\phi = 30\,°$ and a new set of transfers is computed. The insertion ΔV for both short and long TOF transfers is plotted against lunar altitude at the time of insertion in Figure 4.5. Again, each curve in the figure corresponds to a set of short of long TOF transfers to the specified halo orbit.

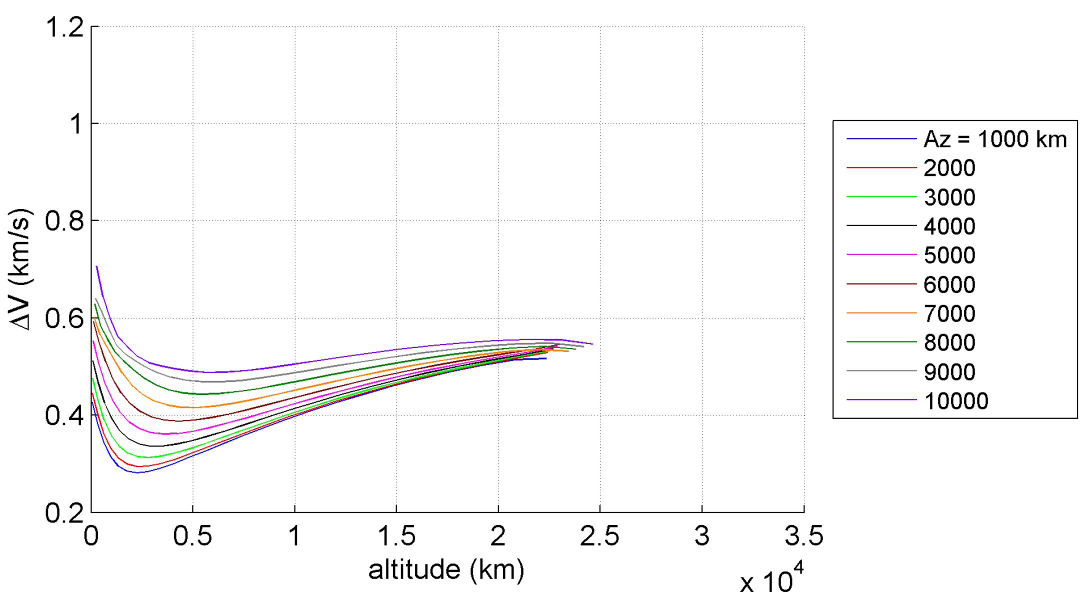

Figure 4.3. Manifold insertion ΔV for short TOF transfers to halo orbits between $Az = 1,000$ and $Az = 10,000$ km; $\phi = 0\,°$.

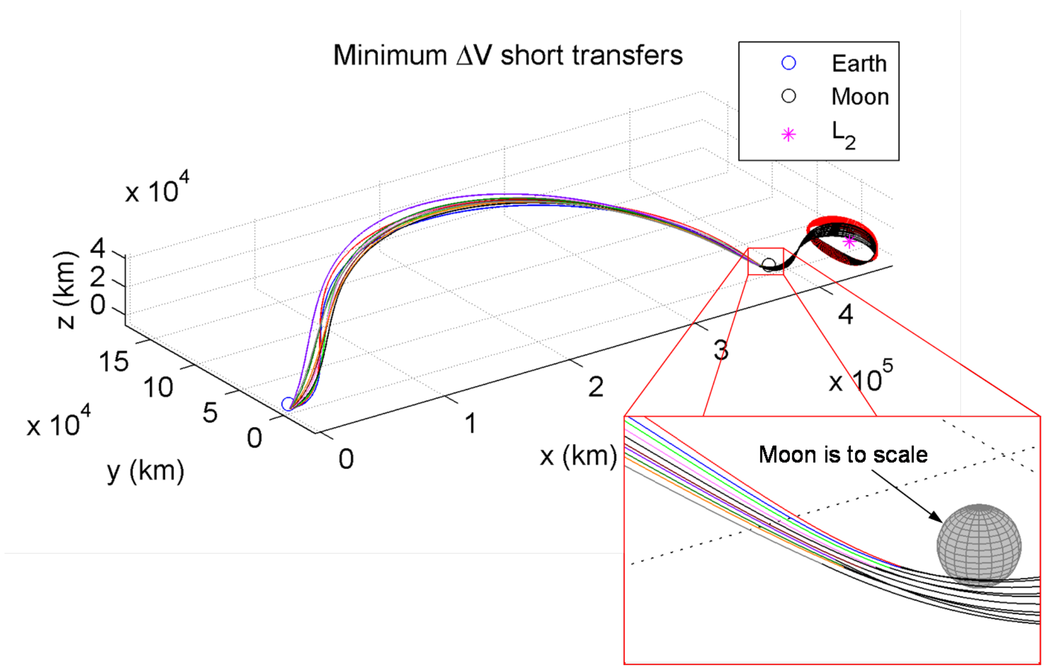

Figure 4.4. Minimum ΔV short TOF transfers to each of ten halo orbits between $Az = 1,000$ and $Az = 10,000$ km; $\phi = 0\,°$.

The ΔV histories for the short transfers possess the same general characteristics as seen in the previous case when $\phi = 0°$. The minimum ΔV ranges between values of 0.269 km/s to reach a 1,000-km Az halo orbit and 0.456 km/s for delivery into a 10,000-km Az halo orbit. For both the short and long TOF transfers, the minimum ΔV increases as the value of Az increases. However, in contrast to the short transfers, the curves representing the long TOF transfers to a specified halo orbit, all indicate that the minimum ΔV transfer is also the trajectory arc passing the Moon at the lowest altitude. For the majority of the halo orbits, the short TOF transfers are lower cost, that is, the arc with the overall minimum ΔV for delivery to the given halo orbit exploits a short TOF transfer. However, the exceptions include transfers to the 7,000-km, 8,000-km, and 9,000-km Az orbits; for halo orbits within this size range, the overall minimum ΔV transfer is from the long TOF class. For each halo orbit, the short or long transfer with the minimum insertion cost can be identified. These ten minimum ΔV short and long TOF transfers to each specified halo orbit

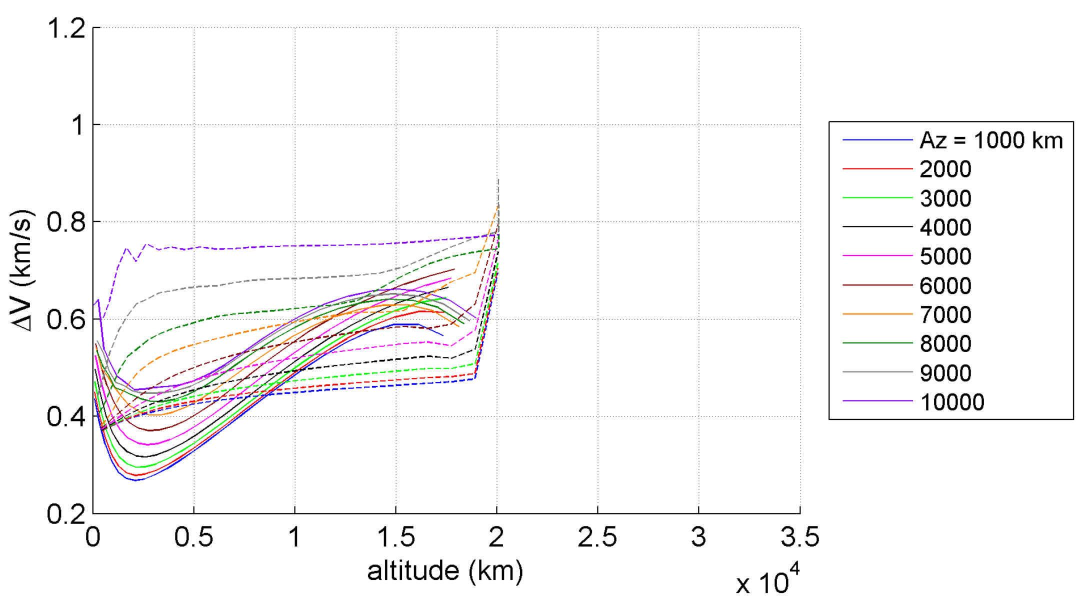

Figure 4.5. Manifold insertion ΔV for short (solid) and long (dashed) transfers to halo orbits between $Az = 1,000$ and 10,000 km; $\phi = 30°$.

are plotted in Figure 4.6. From the figure, it is clear that the short transfers grow increasingly out-of-plane as the out-of-plane Az-amplitude of the halo orbit increases; this is also visible in the close-up view near the manifold insertion point. Also from this close-up view, it is clear that the transfer trajectory, at the manifold insertion point, possesses an increasing $\hat{z}$-component as the Az-amplitude increases. To reach the halo orbits with higher Az values, for example 9,000 km (gray) and 10,000 km (purple), the required ΔV is not tangent to the manifold direction. The trajectories in Figure 4.6 also indicate another difference between the two categories of transfers. Short TOF arcs are above the fundamental Earth-Moon plane; arcs with long times of flight spend a significant interval below the Earth-Moon plane. There is also a change in the characteristics of the long TOF transfer arcs when the halo orbit amplitudes exceed 7,000 km (orange). The transfers begin expanding outward in the x- and y-directions rather than further in the z-direction. This shift in the characteristics of the transfer path coincides with the emergence of long transfers to halo orbits of higher Az-amplitudes that possess lower ΔV insertion values than the short transfers.

The manifold insertion ΔV for transfers with $\phi = 45\,^\circ$ are plotted in Figure 4.7. One of the more noticeable features of the plot is the two distinct sets of curves for the short transfers. This split occurs for all of the insertion angles, but it is most prominent for this instance where $\phi = 45\,^\circ$ as well as for $\phi = 60\,^\circ$. The initial estimate of the ΔV magnitude that is used to generate transfers to the lower Az-amplitude halo orbits is not sufficient to generate transfers to the higher Az-amplitude halo orbits. These halo orbits with a larger out-of-plane amplitude required a different initial estimate, resulting in the difference in curvature. This is true for all insertion angles. Note that many of the features near the minimum ΔV value along the transfer arcs that are present in the curves for lower ϕ angles also appear here for both short and long TOF transfers. However, for halos with an Az-amplitude equal to 8,000 km and higher, the solutions that pass the Moon and reach $\phi = 45\,^\circ$ at the lower lunar altitudes tend to be less predictable. For long TOF transfers to 9,000-km and 10,000-km Az halo orbits, the corrections process did not converge for arcs with low lunar pass

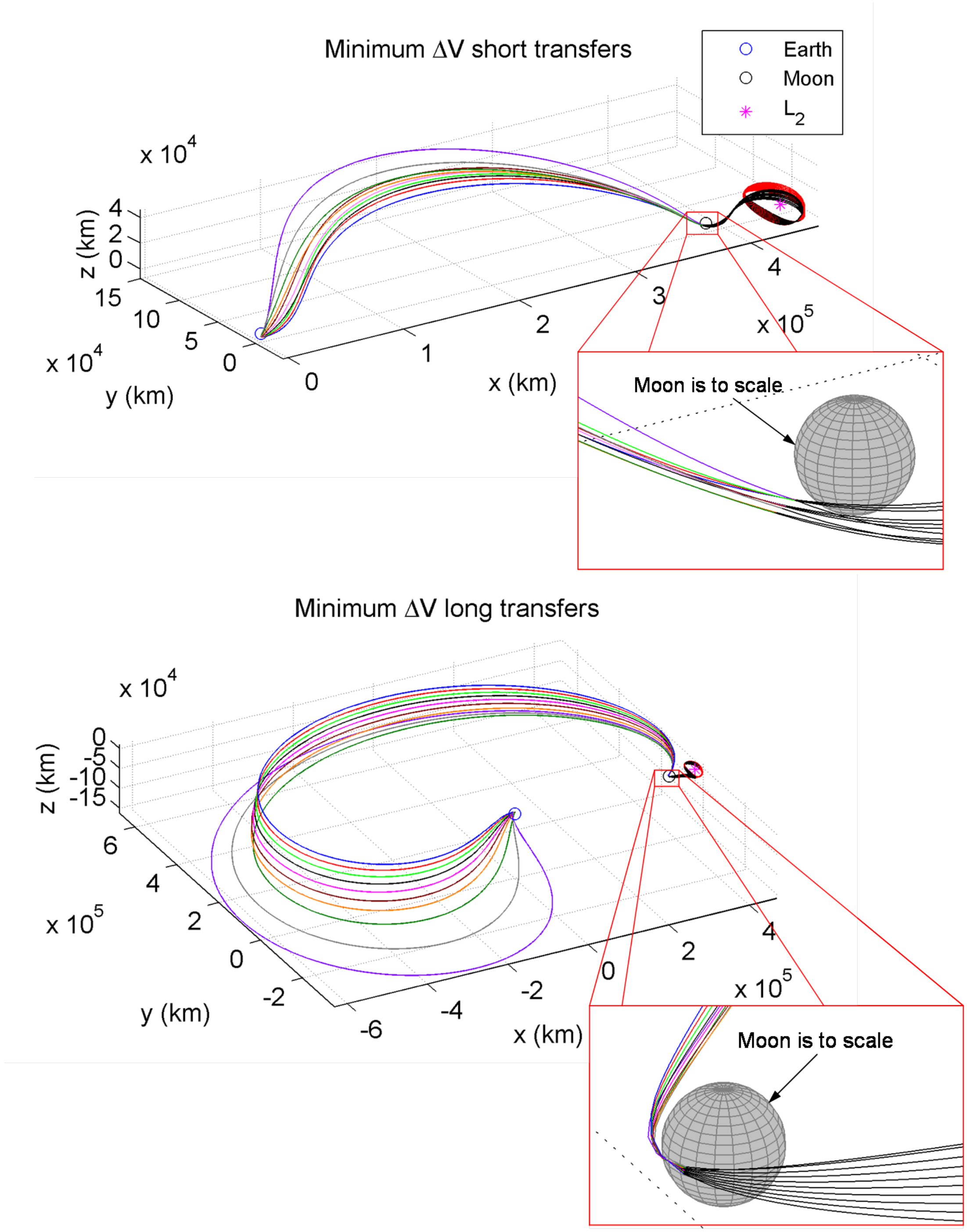

Figure 4.6. Short (top) and long (bottom) transfers corresponding to minimum ΔV for delivery to each of ten halo orbits between $Az =$ 1,000 and 10,000 km; $\phi = 30°$.

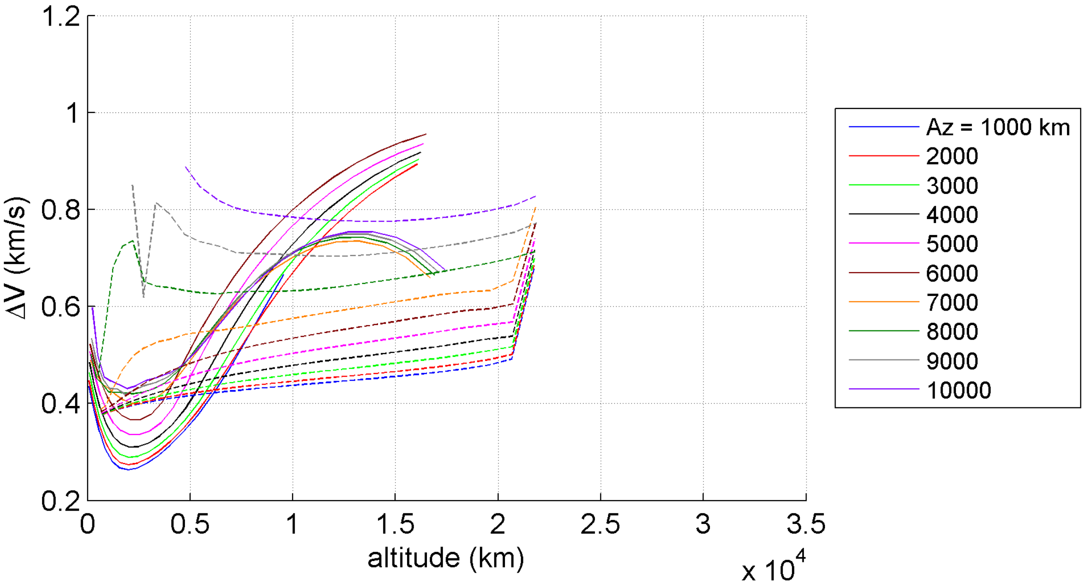

Figure 4.7. Manifold insertion ΔV for short (solid) and long (dashed) transfers to halo orbits between $Az = 1,000$ and 10,000 km; $\phi = 45\,°$.

altitudes. A solution may exist with a lower ΔV, but a more sophisticated differential corrections process or a more accurate initial estimate is required. When $\phi = 45\,°$, the minimum ΔV value ranges between 0.264 and 0.431 km/s. These minimums occur on a short TOF transfer to all halo orbits except the transfer to a halo of amplitude $Az = 7,000$ km. This result is evident in Figure 4.7. The lowest point on each curve in Figure 4.7 represents the long or short transfer arc with the minimum insertion cost to each halo orbit. Transfers corresponding to these minimums for both the short and long TOF transfers are plotted in Figure 4.8. The short transfer arcs possess the same general characteristics; however, the nature of the long TOF transfers changes significantly when the halo amplitude exceeds 6,000 km (dark red). Beyond this Az-amplitude, the solutions are clearly not tangent at the manifold insertion point as seen in the zoomed-in view. Recall that, for the long transfers to halo orbits of amplitude 9,000 km (gray) and 10,000 km (purple), the insertion point occurs at an unusually high lunar altitude. Given the insertion condition, these transfers

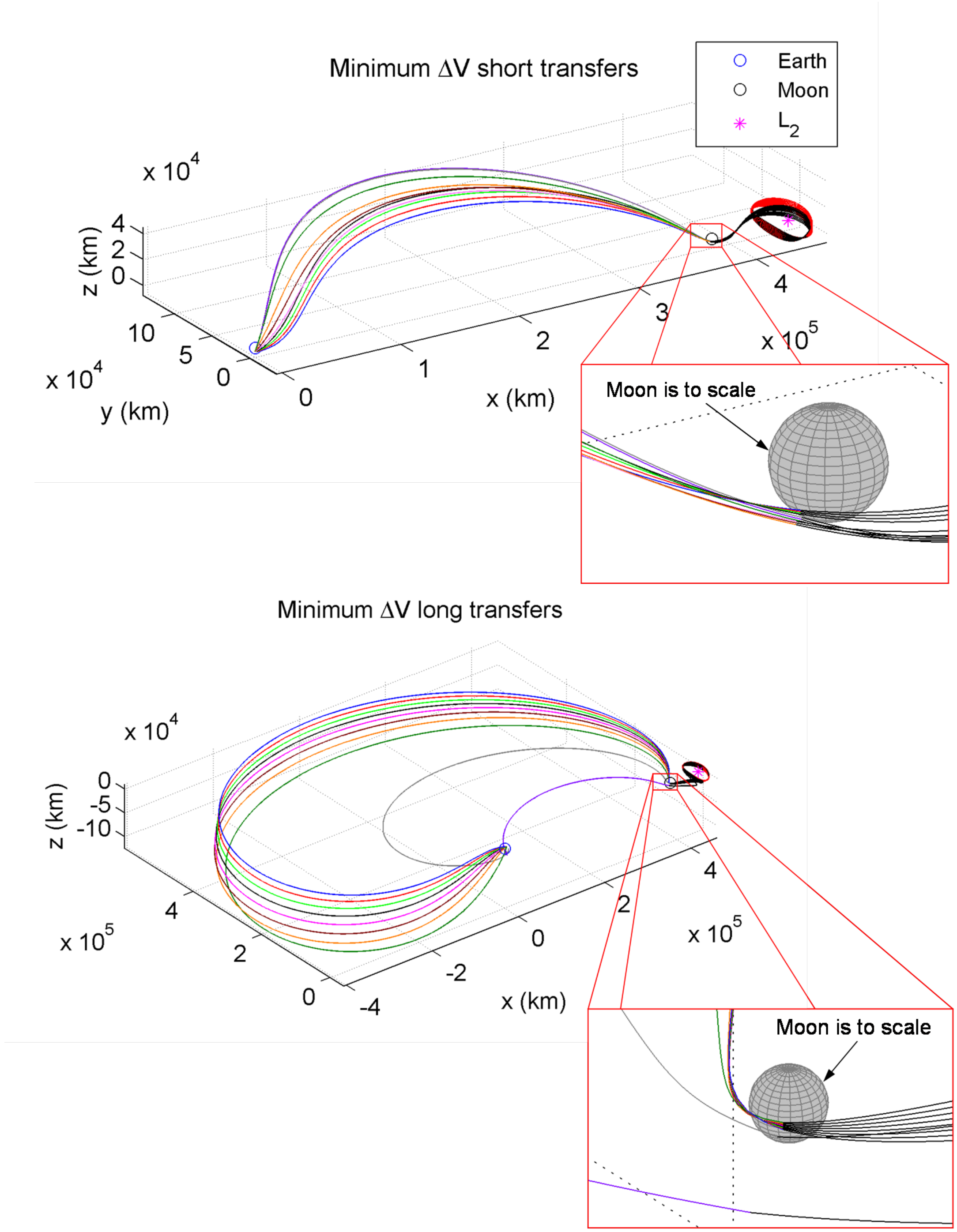

Figure 4.8. Short (top) and long (bottom) transfers corresponding to minimum ΔV for delivery to each halo orbit between $Az = 1,000$ and 10,000 km; $\phi = 45°$.

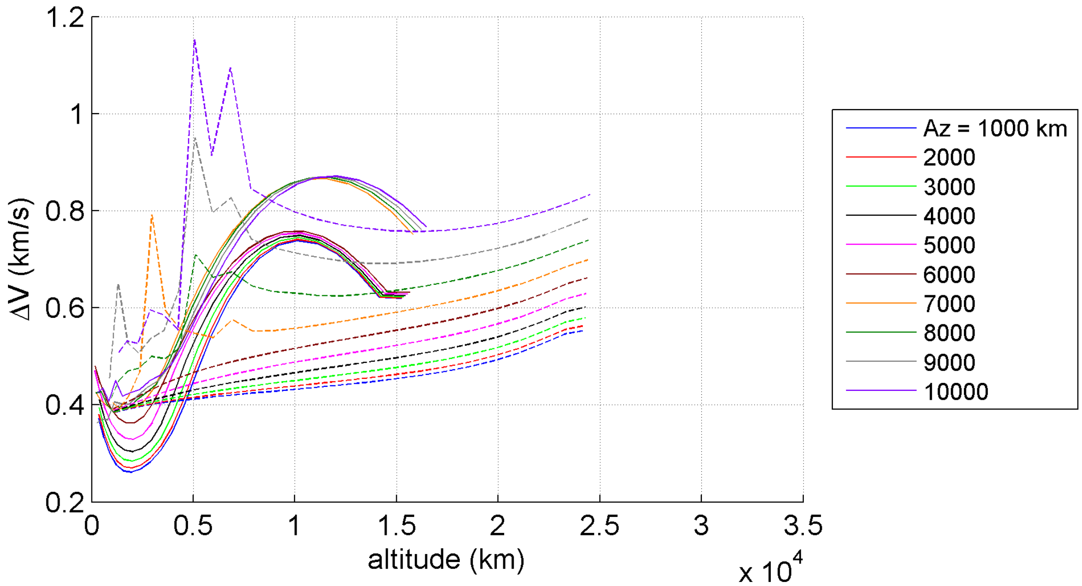

Figure 4.9. Manifold insertion ΔV for short (solid) and long (dashed) transfers to halo orbits between $Az = 1,000$ and 10,000 km; $\phi = 60\,°$.

are not as cost efficient as the transfers to other orbits, i.e., those that include a manifold insertion point in closer lunar proximity. From the figure, it is also apparent that these transfers to halos with greater out-of-plane components possess different characteristics because the manifold insertion point occurs farther from the Moon. Not only are the ΔV vectors less tangent to the manifold velocity at insertion, but the times of flight are shorter than the more typical "long" transfers, which have times of flight from LEO to the manifold insertion maneuver ranging between 15.89 and 16.66 days. The transfer to a halo orbit of amplitude $Az = 10,000$ km (purple), in particular, with a ΔV that occurs at the highest lunar altitude for this entire set of transfers, is actually quite short; the time of flight to the insertion maneuver is only 5.08 days.

Efficient transfers still remain available when $\phi = 60\,°$. A summary of such transfer arcs are plotted in Figure 4.9 where the ΔV is plotted as a function of lunar altitude for an insertion angle of $\phi = 60\,°$. Similar to the curves in Figure 4.7 for transfers with an insertion angle of 45°, two distinct sets of curves in Figure 4.9 appear for the short TOF transfers. For this set of parameters the curve clearly shifts up for transfers to larger-amplitude halo orbits. Much of the same general behavior reappears here, consistent with the previous results for other ϕ angles. Again, the trajectories to the higher-Az halos follow a much less predictable curve. For the short TOF transfers, the minimum costs in Figure 4.9 occur at or near the lowest lunar altitude. For the short transfers to higher-amplitude halo orbits ($Az = 9,000$ km and $Az = 10,000$ km), the usual increase in cost as the lunar altitude continues to decrease beyond the minimum ΔV location is not present. Overall, the minimum values for ΔV ranged from 0.262 to 0.407 km/s and always occurred on a short TOF transfer. The short and long TOF transfers corresponding to the minimum ΔV along each curve appear in Figure 4.10. It is evident that both the short and long TOF transfers to halo orbits of amplitude $Az = 7,000$ km (orange) and higher are not tangent to the velocity along the manifold at the insertion point. This results in a visible difference in the characteristics representative of both types of transfers. For the short TOF transfers, all those transfer arcs to halo orbits below $Az = 6,000$ km (dark red) are growing increasingly out-of-plane at a fairly regular rate. As the out-of-plane amplitude of the halo orbit becomes larger than 6,000 km, a large gap appears in the transfer arcs and the remaining transfers progress out-of-plane in a less predictable manner. For the long TOF transfers, there are characteristic changes similar to those seen at previous values of ϕ. Long transfers to halo orbits smaller than $Az = 6,000$ km shift further below the fundamental plane as the size of the halo orbit increases. As the size of the halo orbit increases beyond $Az = 6,000$ km, the transfers no longer change noticeably in the z-direction; instead, the transfers are generally smaller and progress outwards in the x- and y-directions with a further increase in Az.

The insertion cost for transfers from an Earth parking orbit such that the manifold insertion maneuver occurs at $\phi = 90^\circ$, are plotted in Figure 4.11 as a function of lunar altitude at insertion. For the short TOF transfers to halo orbits such that $Az = 5,000$ km and lower, the behavior is similar to that for lower values of ϕ. For halo orbits

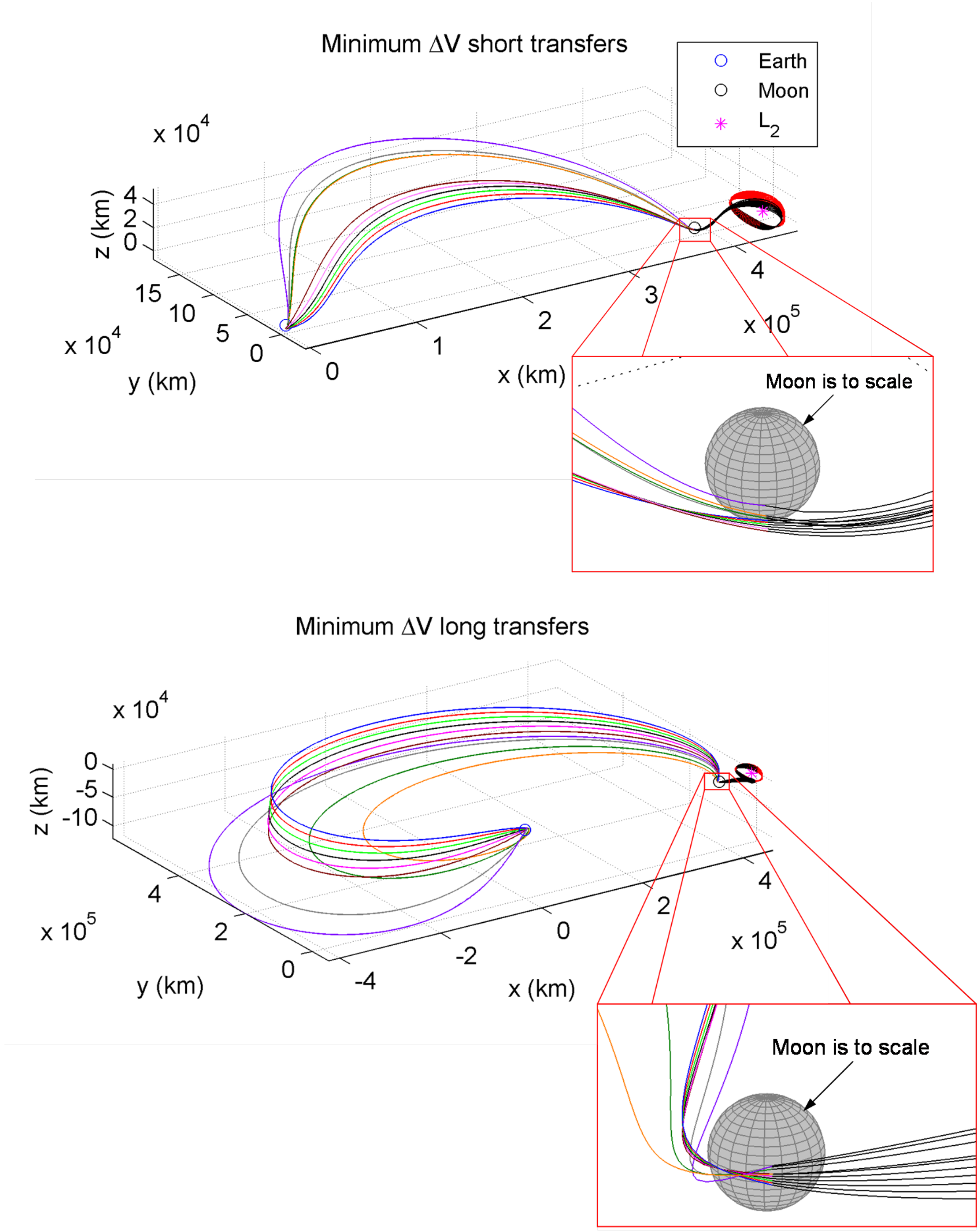

Figure 4.10. Short (top) and long (bottom) transfers corresponding to minimum ΔV for delivery to each halo orbit between $Az = 1,000$ and 10,000 km; $\phi = 60\,°$.

larger than this Az-amplitude, the ΔV maneuver value still falls to a minimum value as the distance to the Moon decreases and is followed by a sharp increase as the lunar altitude continues to decrease; however, the minimums for the various halo orbits are spread over a much larger range. The long transfers for halo orbits with $Az = 8,000$ km and lower also exhibit behavior similar to that seen for lower ϕ values. However, for transfers to halos with larger amplitudes, the characteristics differ. Proceeding from the highest lunar altitude to the lowest for a halo orbit of amplitude $Az = 8,000$ km, the maneuver cost associated with the transfers suddenly decreases at around 11,000 km altitude. After this sharp decrease in the ΔV value, the cost continues to decrease with decreasing lunar altitude. For long TOF transfers to a halo orbit of $Az = 9,000$ km, again consider the curve in Figure 4.11 as lunar altitude decreases. A decrease in cost is apparent when the insertion point occurs closer than 11,000 km lunar altitude; however, the decrease is more severe. The ΔV then increases slightly as the lunar altitude continues to decrease. The ΔV value

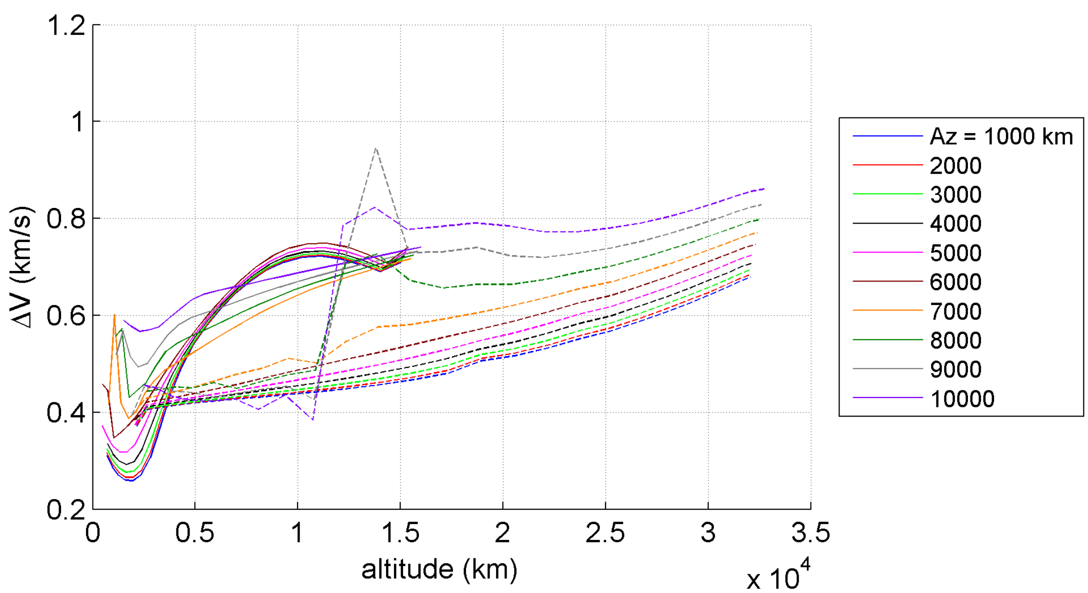

Figure 4.11. Manifold insertion ΔV for short (solid) and long (dashed) transfers to halo orbits between $Az = 1,000$ and 10,000 km; $\phi = 90°$.

decreases again to the minimum value at the lowest lunar altitude. For transfers to the $Az = 10,0000$ km halo orbit, the curves of insertion ΔV as a function of lunar altitude behave similarly, but the minimum value occurs at the first sharp drop near 11,000 km lunar altitude. Note that, near the lowest lunar altitudes, the curves appear to be cut off. However, these solutions actually pass below the lunar surface and are, therefore, not valid. It is likely that a ΔV curve with more typical behavior could be determined for the transfer to a halo orbit of $Az = 10,000$ km, but additional halo orbits along the family and more manifolds are required. For halo orbits with Az values of 9,000 km and 10,000 km, the minimum ΔV transfer occurs on a long TOF trajectory. For all other halo orbits, the minimum ΔV solution occurs on a short transfer. Transfers to each halo orbit, corresponding to these minimum ΔV short and long TOF transfers, appear in Figure 4.12. These transfers, both short and long, possess no clear pattern unlike those at previous ϕ values; however, they do appear to be bounded within their respective regions. Also, for this insertion location ($\phi = 90\,°$), the long TOF transfers actually approach the manifold insertion point with a velocity that is closer to tangential. The exception is the long TOF transfer to a halo obit of amplitude $Az = 10,000$ km (purple). This is the transfer corresponding to the sharp decrease in ΔV that appears in Figure 4.11. Similar to the transfer to the same halo orbit ($Az = 10,000$ km) for $\phi = 45\,°$, appearing in Figure 4.8, this transfer also incorporates a manifold insertion point much farther from the Moon than the transfers to halo orbits of other sizes. Also, the transfer to the $Az = 10,000$ km halo orbit is not tangent at the insertion point and requires an abbreviated time of flight to the manifold insertion location equal to only 5.56 days; both of these characteristics are also reflected in the transfer using $\phi = 45\,°$.

Results from Figures 4.3-4.12 are collected in Figures 4.13 and 4.14. For each insertion angle, ϕ, the short and long TOF transfers that result in the minimum insertion ΔV are summarized in terms of cost and lunar altitude at insertion. In Figure 4.13, the short TOF transfer cost (ΔV) and its corresponding lunar altitude are plotted as a function of halo orbit amplitude (Az) for each of the manifold insertion

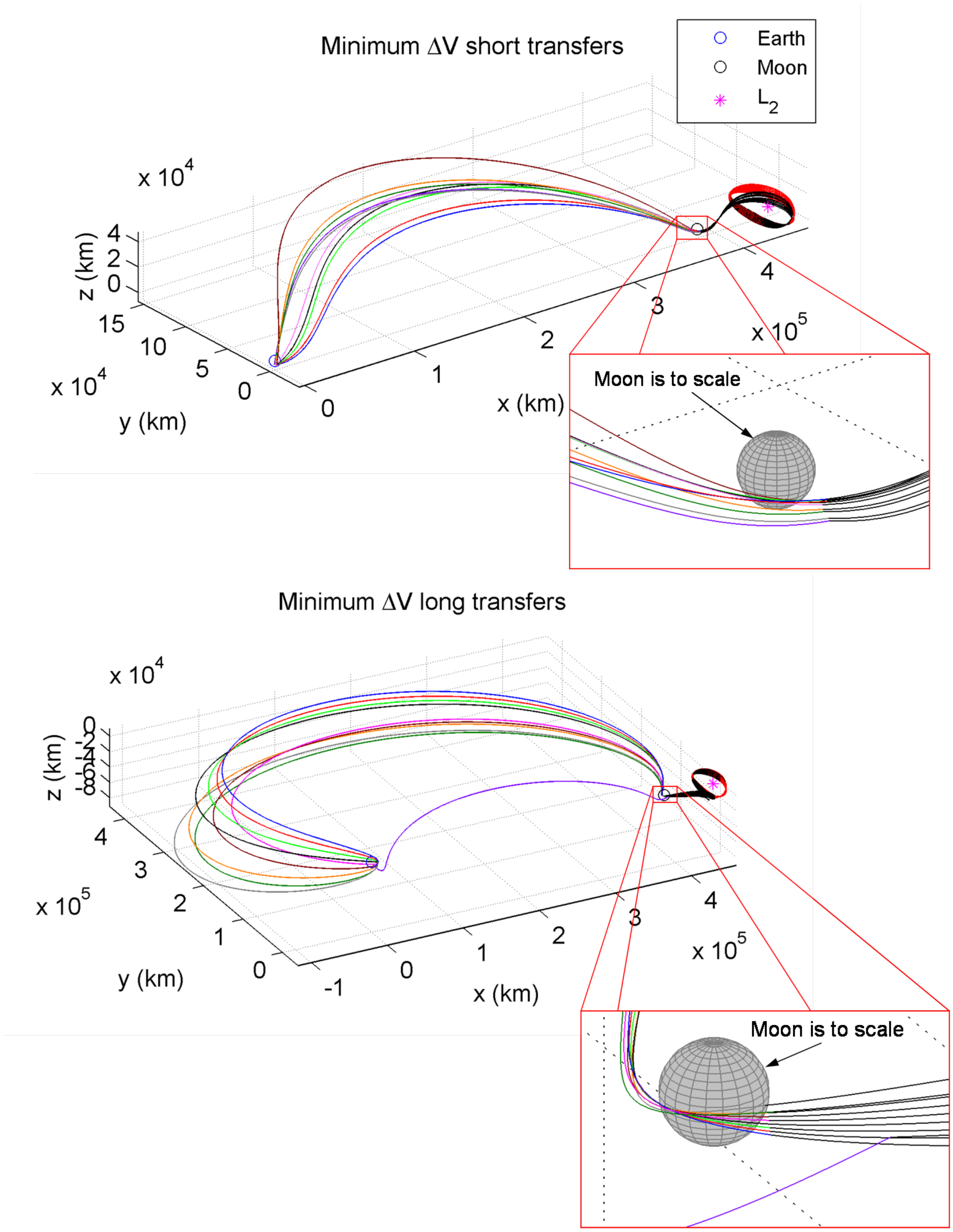

Figure 4.12. Short (top) and long (bottom) transfers corresponding to minimum calculated ΔV for each halo orbit between $Az = 1,000$ and 10,000 km; $\phi = 90\,^{\circ}$.

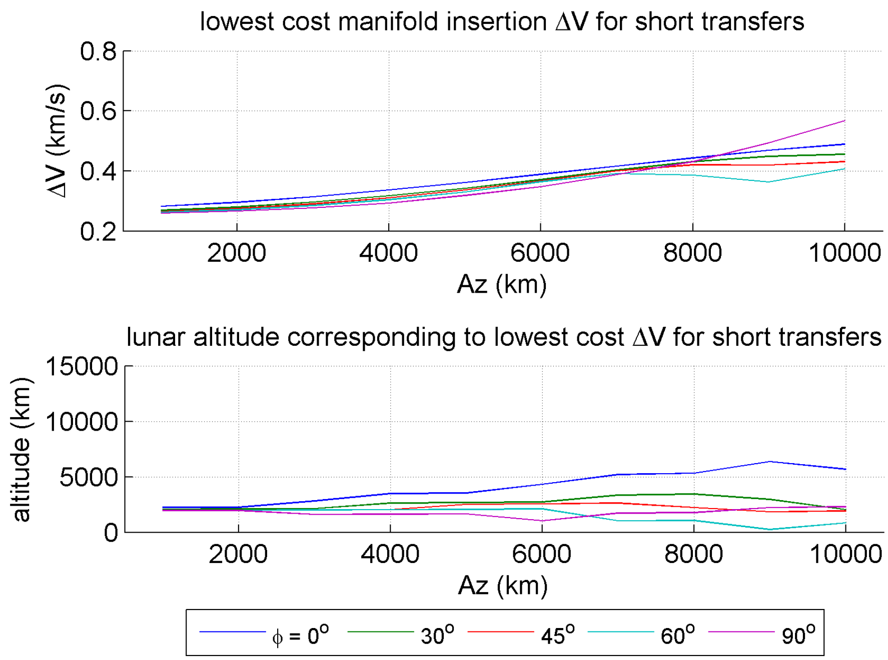

Figure 4.13. Upper plot includes minimum short transfer manifold insertion cost (ΔV) versus halo orbit Az-amplitude for various insertion angles, ϕ. Lower plot includes the corresponding lunar altitude at which the minimum ΔV occurs.

angles, ϕ. Figure 4.14 contains the same information for the long TOF transfers. In general, the minimum ΔV corresponding to each type of transfer increases with Az; this increase is more evident in the short TOF transfers. For halo orbits with lower Az values, that is, less than 7,000 km, the short TOF transfers possess lower minimum ΔV for all insertion angles. Also, the insertion cost decreases as ϕ increases. So, a $90\,^\circ$ insertion angle in combination with a short TOF transfer yields the lowest cost for any trajectory that inserts into a halo orbit with an Az value less than 7,000 km. For Az-amplitude values of 7,000 km and higher, either the short or long TOF transfer may possess a lower ΔV depending on the insertion angle and Az value. For example, for $\phi = 90\,^\circ$, the ΔV for a short TOF transfer is only slightly lower than that for a long TOF transfer to a 7,000-km Az halo orbit. But, above an amplitude of $Az = 7,000$ km, the long TOF transfer to the halo orbit has an increasingly lower

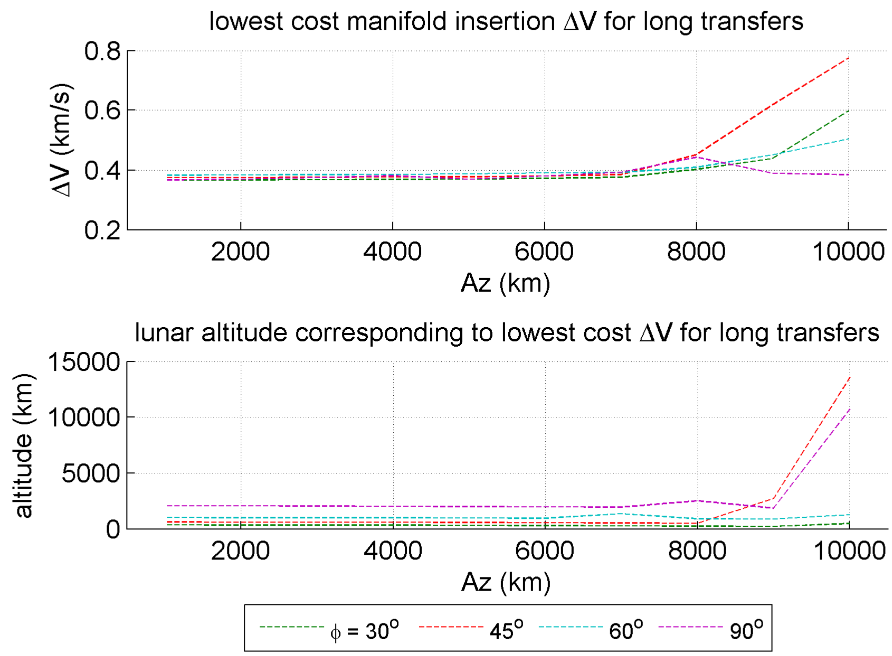

Figure 4.14. Upper plot includes minimum long transfer manifold insertion cost (ΔV) versus halo orbit Az-amplitude for various insertion angles, ϕ. Lower plot includes the corresponding lunar altitude at which the minimum ΔV occurs.

ΔV than the short transfer. However, for $\phi = 60\,^\circ$, the cost of the short TOF transfer is lower for transfers to halos with all Az values.

The lunar altitude at which the long TOF transfer with minimum cost occurs remains fairly consistent, with two exceptions, as the size of the halo orbit changes. For the long TOF transfers, the lunar altitude remains nearly constant as Az-amplitude increases and is often between 200 and 2,000 km depending on the insertion angle. For the majority of the transfers in this study, a lower insertion angle corresponds to a lower lunar altitude. The two exceptions occur for insertion angles of $\phi = 45\,^\circ$ and $\phi = 90\,^\circ$. Recall that when $\phi = 45\,^\circ$, the corrections process did not converge for trajectories with very low lunar altitudes at halo amplitudes of 9,000 and 10,000 km; therefore, the minimum ΔV transfer is not in the same region as the other cases. Also, when $\phi = 90\,^\circ$, a sharp change in the ΔV cost for the transfer to a 10,000-km Az-amplitude halo (seen in Figure 4.11) is noted. This fact results in a minimum ΔV

at a much higher altitude than previously observed. For the short TOF transfers, the lunar altitude at which the minimum ΔV occurs is less consistent across all sizes, Az, of halo orbits. The lunar altitudes corresponding to the minimum ΔV for the various insertion angles initially have similar values at an Az-amplitude of 1,000 km. As the amplitude of the halo orbit increases, the values of the lunar altitudes corresponding to the minimum ΔV for the various ϕ angles differ. When the insertion angle $\phi = 0\,^{\circ}$, the curve of ΔV versus halo size (Az) possesses a fairly consistent positive slope as Az increases. When $\phi = 90\,^{\circ}$, there is a downward trend as Az increases to 6,000 km, then the altitude begins to increase again. When $\phi = 60\,^{\circ}$; there is initially little change in altitude as Az increases. Then, after the Az reaches 6,000 km, the lunar altitude tends to decrease as Az continues to increase. The other two ϕ angles of $30\,^{\circ}$ and $45\,^{\circ}$ both increase and decrease intermittently as the size of the halo orbit increases.

5. Summary and Recommendations

The focus of this investigation is transfer trajectories departing from low Earth orbit and arriving at orbits in the vicinity of L_2 that incorporate manifold insertion maneuvers in close proximity to the Moon. Of particular interest is the impact of the manifold insertion maneuver location on ΔV costs, specifically the effects of lunar altitude and the angle with respect to the Earth-Moon line. The analysis is conducted for transfers to two types of orbits. Transfers to selected planar Lyapunov orbits are examined, then the analysis is extended to include transfers to selected low-amplitude three-dimensional halo orbits.

Planar transfers to selected Lyapunov orbits are considered initially. A differential corrections process is formulated to compute the section of the transfer between the Earth orbit and the manifold insertion point. The transfer is constrained to depart tangentially from a circular low Earth orbit and arrive tangent to the manifold at the insertion point. Various parameters, including the location of the point along the Lyapunov orbit from which the manifold originates, the manifold insertion angle, and the size of the libration point orbit, are varied to explore the solution space. Two distinct types of transfers result corresponding to two sections of the Lyapunov orbit; transfers with short times of flight and those with long transfer times. For the planar transfers, the short time of flight trajectories always result in lower ΔV when compared to the longer transfers. Other characteristics also result in lower ΔV costs. Transfers with manifold insertion angles of $45\,^\circ$ relative to the Earth-Moon line generally possess lower ΔV compared to transfers with various other insertion angles. Furthermore, the ΔV decreases as the lunar altitude corresponding to the manifold insertion point decreases. The size of the Lyapunov orbit also affects the manifold insertion cost. A larger orbit may result in a smaller ΔV for transfers with insertion points at very low lunar altitudes; however, the increase in ΔV over a specified increase in lunar altitude is much larger compared to that for transfers to smaller orbits. So, as the lunar altitude increases, transfers to smaller orbits result in lower costs.

The analysis is then extended to three-dimensional transfers for delivery to selected low-amplitude three-dimensional halo orbits. Much of the same methodology that applies to the planar transfers is incorporated into the three-dimensional analysis; however, one important difference emerges. To further expand the solution space, the transfer trajectories are no longer constrained to arrive tangentially at the manifold insertion point. Consistent with the planar cases, these three-dimensional transfers also fall into the two general categories of short and long times of flight, depending on the origin of the connecting manifolds along the halo orbit. Although the solutions for these transfers are less predictable since both the halo orbits and transfers proceed out-of-plane, there are still some general features of the behavior. Of note, is that the long time of flight transfer with the lowest computed ΔV to a particular halo orbit tends to occur at the lowest lunar altitude; however, the cost corresponding to a short time of flight transfer decreases with lunar altitude until a certain altitude is reached, then increases again as lunar altitude continues to decrease. Also, the required ΔV for any particular transfer tends to increase as the out-of-plane amplitude of the halo orbit increases. For transfers to halo orbits with Az-amplitudes below 7,000 km, short transfers with a manifold insertion angle of 90 degrees tend to possess lower ΔV costs. Lower maneuver costs for transfers to halo orbits with Az-amplitudes at or above 7,000 km occur for either short or long transfers depending on the specific parameters associated with the transfer.

From the basic structure of the solutions in this study, additional development could be very beneficial. For instance, rough grid searches are used to generate initial ΔV estimates for the transfers; then, the solution is determined using a basic differential corrector. It may be useful to implement a more sophisticated differential corrections process incorporating the solutions calculated in this study as a first estimate. Now that there is a better understanding of the surface these solutions create, it may also be possible to identify different families of solutions. Furthermore, there is no attempt to determine an *optimal* solution. The goal for this study is the generation of initial guesses for processes such as optimization. Using the results of this analysis in an optimization scheme is a reasonable ‘next step’ in further development of the methodology. For applications, a higher fidelity ephemeris model is also necessary. Thus, from this initial analysis, transfers from low Earth orbit to L_1 and L_2 libration point orbits can be designed with explicit exploitation of lunar proximity.

APPENDICES

A. Constants

The following constants and characteristic values are used for computation throughout the analysis:

Radius of the Earth: $R_{Earth} = R_{\oplus} = R_{P_1} = 6378.14$ km

Radius of the Moon: $R_{Moon} = R_{P_2} = 1738.2$ km

(assumed minimum safe altitude for lunar pass is 10 km)

3-body Earth-Moon system nondimensional mass parameter: $\mu = 0.01215057143$

Earth-Moon system characteristic length: $l^* = 384388$ km

Earth-Moon system characteristic time: $t^* = 377239.8364$ sec $= 4.36620181$ days

Earth-Moon system characteristic mass: $m^* = 6.0468 \times 10^{15}$ kg

Manifold offset distance: $d = 50$ km

B. Initial Conditions for Short Transfers

In the following tables of initial conditions, manifolds are identified by the point on the orbit from which they were propagated using an offset distance of $d = 50$ km in the direction of the corresponding eigenvector. There are 5,000 points spaced equally in time about each orbit. Point 1 occurs at the xz-plane crossing in the negative y-direction and the points proceed in a clockwise manner about the orbit. Also, all initial conditions are given in dimensional Earth-centered rotating frame coordinates.

Table B.1 Initial conditions for short transfers to a 1000 km Az halo orbit

$Az = 1000$ km

$\phi = 0^\circ$

manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	355648.87898650	0.00000001	461.09852782	0.44512913	-0.86370122	-0.01088452	3.64168008
2551	357170.54040733	0.00000000	434.20987584	0.48516403	-0.87131137	-0.01407307	3.58417201
2601	358705.40955297	0.00000001	405.60321617	0.49895730	-0.88571344	-0.01597024	3.60307404
2651	360232.99263462	0.00000001	375.99279638	0.50848797	-0.90276522	-0.01752421	3.63849773
2701	361735.11302522	0.00000001	346.02717844	0.51708600	-0.92203180	-0.01901451	3.68195809
2751	363196.21433001	0.00000001	316.26926511	0.52535951	-0.94366232	-0.02050954	3.73237503
2801	364603.50644044	0.00000001	287.18656693	0.53348612	-0.96794533	-0.02203991	3.78992702
2851	365946.96394228	0.00000001	259.14993747	0.54157006	-0.99523473	-0.02363237	3.85507844
2901	367219.19858470	0.00000001	232.43860055	0.54968881	-1.02593698	-0.02531544	3.92844086
2951	368415.23578041	0.00000000	207.24929138	0.55788867	-1.06050825	-0.02712006	4.01077628
3001	369532.22818831	0.00000002	183.70760061	0.56617094	-1.09945309	-0.02907929	4.10303276
3051	370569.13796453	0.00000000	161.88001155	0.57447584	-1.14332322	-0.03122789	4.20639804
3101	371526.41439766	0.00000000	141.78555626	0.58266528	-1.19271675	-0.03360195	4.32237305
3151	372405.68711035	0.00000002	123.40641412	0.59050431	-1.24827775	-0.03623890	4.45287333
3201	373209.48816984	0.00000000	106.69710133	0.59764056	-1.31069619	-0.03917756	4.60037073
3251	373941.01033527	0.00000002	91.59213924	0.60358063	-1.38070757	-0.04245831	4.76809398
3301	374603.90378765	0.00000003	78.01224985	0.60766387	-1.45909023	-0.04612290	4.96031243
3351	375202.11019602	0.00000002	65.86922123	0.60903733	-1.54665619	-0.05021356	5.18273180
3401	375739.73077480	0.00000001	55.06963094	0.60664395	-1.64422758	-0.05477083	5.44302505
3451	376220.92381680	0.00000000	45.51762715	0.59925178	-1.75258613	-0.05982906	5.75148589
3501	376649.82680261	0.00000000	37.11695853	0.58557724	-1.87237912	-0.06540767	6.12168335
3551	377030.49830705	0.00000000	29.77242287	0.56457611	-2.00397194	-0.07149591	6.57076245
3601	377366.87535947	0.00000004	23.39087990	0.53594393	-2.14726960	-0.07803095	7.11870765
3651	377662.74249983	0.00000000	17.88194712	0.50071452	-2.30159014	-0.08487394	7.78571726
3701	377921.70940488	0.00000000	13.15847388	0.46168570	-2.46567995	-0.09179383	8.58674350

$Az = 1000$ km continued

$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	363201.11432888	-9535.72016946	253.24890420	0.73831931	-0.83178939	-0.01374470	3.20439775
2551	364263.21841954	-8922.51408681	226.63599531	0.82760183	-0.82813472	-0.01785654	3.05042577
2601	365318.15630633	-8313.44541389	200.97026993	0.87154103	-0.83126374	-0.02128327	3.00818135
2651	366355.90278825	-7714.30220322	176.51094126	0.89480382	-0.83763638	-0.02387363	3.01548234
2701	367367.62788499	-7130.18244627	153.46091446	0.90755318	-0.84661287	-0.02578662	3.05138949
2751	368345.81895045	-6565.42357129	131.96731456	0.91492634	-0.85829219	-0.02723530	3.10703610
2801	369284.34104364	-6023.56758814	112.12453531	0.91988896	-0.87306544	-0.02840817	3.17820808
2851	370178.43469600	-5507.36237728	93.97927744	0.92436209	-0.89146586	-0.02946116	3.26267509
2901	371024.65688516	-5018.79576859	77.53693407	0.92969136	-0.91408916	-0.03052691	3.35908652
2951	371820.77624127	-4559.15604403	62.76866088	0.93681375	-0.94154491	-0.03171926	3.46658248
3001	372565.63635105	-4129.11085914	49.61853519	0.94629510	-0.97444131	-0.03312985	3.58478926
3051	373259.00153367	-3728.79628428	38.01032986	0.95834765	-1.01339933	-0.03482459	3.71395630
3101	373901.39799464	-3357.90851464	27.85357710	0.97287639	-1.05907478	-0.03684690	3.85505949
3151	374493.96063769	-3015.79231314	19.04874218	0.98954346	-1.11217100	-0.03922697	4.00984348
3201	375038.29272751	-2701.52203458	11.49144950	1.00781814	-1.17344402	-0.04199086	4.18088777
3251	375536.34263290	-2413.97278760	5.07579450	1.02699608	-1.24370948	-0.04516541	4.37178165
3301	375990.29938459	-2151.88073482	-0.30316643	1.04619293	-1.32385073	-0.04877873	4.58744257
3351	376402.50690030	-1913.89261468	-4.74762525	1.06433229	-1.41481325	-0.05285775	4.83457659
3401	376775.39547825	-1698.60529383	-8.35579877	1.08016414	-1.51755624	-0.05742310	5.12223732
3451	377111.42842677	-1504.59658050	-11.22114474	1.09237753	-1.63292029	-0.06247954	5.46232433
3501	377413.06138999	-1330.44870803	-13.43190374	1.09989790	-1.76137432	-0.06799989	5.86961810
3551	377682.71190058	-1174.76591310	-15.07087002	1.10241418	-1.90267089	-0.07390421	6.36068927
3601	377922.73685392	-1036.18744173	-16.21531241	1.10096108	-2.05559456	-0.08004366	6.95125048
3651	378135.41585584	-913.39716272	-16.93698382	1.09813469	-2.21805472	-0.08620053	7.65239337

$Az = 1000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2801	371735.10241390	-7982.36373526	36.91007500	1.23886052	-0.79495040	-0.04453950	2.63714401
2851	372403.16855084	-7314.29759830	23.64072242	1.20833864	-0.80087602	-0.04184091	2.76297589
2901	373035.91721304	-6681.54893613	12.01638154	1.18190400	-0.81208392	-0.03944679	2.90613343
2951	373631.94894144	-6085.51720770	1.95982796	1.16154537	-0.83021500	-0.03749892	3.06574709
3001	374190.55517999	-5526.91096914	-6.62183167	1.14971592	-0.85624752	-0.03635398	3.23658457
3051	374711.62583691	-5005.84031226	-13.83213078	1.14785175	-0.89007988	-0.03629288	3.41187723
3101	375195.55140924	-4521.91473989	-19.78084125	1.15533020	-0.93131251	-0.03727373	3.58890954
3151	375643.12665316	-4074.33949600	-24.58031055	1.17017016	-0.98015605	-0.03905911	3.77038551
3201	376055.46091809	-3662.00523103	-28.34255804	1.19027381	-1.03738295	-0.04145292	3.96154049
3251	376433.89836812	-3283.56778101	-31.17708502	1.21391096	-1.10393620	-0.04436124	4.16809330
3301	376779.94964331	-2937.51650586	-33.18931077	1.23962645	-1.18076767	-0.04775214	4.39621837
3351	377095.23521071	-2622.23093846	-34.47952716	1.26605469	-1.26883403	-0.05161637	4.65329755
3401	377381.43974543	-2336.02640373	-35.14226040	1.29183619	-1.36906560	-0.05594536	4.94866240
3451	377640.27631725	-2077.18983186	-35.26593528	1.31569509	-1.48220785	-0.06071484	5.29401444
3501	377873.45888318	-1844.00726589	-34.93275019	1.33672677	-1.60850556	-0.06586659	5.70314023
3551	378082.68150867	-1634.78464049	-34.21868681	1.35487148	-1.74731871	-0.07129058	6.19044734
3601	378269.60280264	-1447.86334646	-33.19359377	1.37131183	-1.89695064	-0.07681851	6.76845884
3651	378435.83419231	-1281.63195685	-31.92129815	1.38840148	-2.05493637	-0.08223476	7.44536244

$Az = 1000$ km	continued						
$\phi = 60^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	371230.82392823	-14699.29551229	54.26876403	0.61987821	-0.85345151	-0.01500501	4.11599053
2551	371769.17245989	-13766.84850331	35.46285673	0.91986688	-0.77377374	-0.01180202	3.13547654
2601	372298.81798273	-12849.47554771	18.37860711	1.06768863	-0.76275588	-0.01393256	2.84626899
2651	372816.39503711	-11953.00579270	3.04558620	1.17568054	-0.75722910	-0.01651348	2.68492669
2701	373318.88746006	-11082.66338575	-10.53553882	1.25772491	-0.75238820	-0.01947229	2.58818225
2751	373803.68334937	-10242.97227418	-22.39142773	1.31929261	-0.74718190	-0.02283016	2.53424214
2801	374268.61315139	-9437.69023508	-32.57341539	1.36334409	-0.74145716	-0.02660337	2.51389662
2851	374711.96713404	-8669.77861139	-41.15398728	1.39174952	-0.73545522	-0.03075243	2.52384817
2901	375132.49165988	-7941.40876685	-48.22269232	1.40579712	-0.72979217	-0.03510040	2.56483314
2951	375529.36644880	-7254.00146816	-53.88184250	1.40650598	-0.72571562	-0.03919069	2.64147008
3001	375902.16690379	-6608.29213903	-58.24232359	1.39520173	-0.72575766	-0.04211965	2.76262516
3051	376250.81647960	-6004.41335968	-61.41977396	1.37512365	-0.73482240	-0.04270785	2.93936530
3101	376575.53405174	-5441.98602667	-63.53129907	1.35437980	-0.75973097	-0.04093072	3.17231512
3151	376876.78058968	-4920.21171735	-64.69280127	1.34495846	-0.80257022	-0.03938225	3.43298996
3201	377155.20843440	-4437.96054399	-65.01692996	1.35224451	-0.85762825	-0.04000550	3.68792120
3251	377411.61538994	-3993.85066965	-64.61160352	1.37264719	-0.92096815	-0.04218424	3.93391198
3301	377646.90483639	-3586.31739384	-63.57902190	1.40100403	-0.99305326	-0.04516917	4.18458765
3351	377862.05225930	-3213.67112632	-62.01507444	1.43370015	-1.07551878	-0.04868199	4.45420017
3401	378058.07799672	-2874.14458951	-60.00904610	1.46842832	-1.16966304	-0.05262583	4.75515223
3451	378236.02561906	-2565.93026646	-57.64353340	1.50363553	-1.27622948	-0.05693421	5.09956967
3501	378396.94514146	-2287.20947772	-54.99449335	1.53840040	-1.39526405	-0.06152085	5.50000820
3551	378541.88018260	-2036.17462276	-52.13136284	1.57262838	-1.52586627	-0.06626040	5.96856617
3601	378671.85818736	-1811.04611465	-49.11719977	1.60721282	-1.66614816	-0.07098654	6.51518432

$Az = 1000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614915	-16752.98856993	-131.14850974	0.77746050	-0.73196607	-0.01502034	4.23568768
2551	379717.46614915	-15746.31467057	-139.72123729	0.96161934	-0.66006177	-0.01042009	3.41009686
2601	379717.46614917	-14758.11837011	-146.68078048	1.06295225	-0.64510739	-0.01052361	3.14759193
2651	379717.46614915	-13792.83035130	-152.07099588	1.14451144	-0.63465766	-0.01103935	2.98780328
2701	379717.46614917	-12854.60834620	-155.95138837	1.21391726	-0.62426833	-0.01174678	2.87964609
2751	379717.46614917	-11947.21514918	-158.39642038	1.27413853	-0.61275817	-0.01261374	2.80486896
2801	379717.46614915	-11073.91882934	-159.49388820	1.32712175	-0.59976124	-0.01364892	2.75415898
2851	379717.46614917	-10237.42376013	-159.34257058	1.37458098	-0.58520773	-0.01488052	2.72166970
2901	379717.46614915	-9439.83606826	-158.04942657	1.41812806	-0.56915077	-0.01635365	2.70332658
2951	379717.46614917	-8682.66231423	-155.72663607	1.45915253	-0.55169055	-0.01813310	2.69638849
3001	379717.46614917	-7966.83659146	-152.48874376	1.49856569	-0.53294761	-0.02030776	2.69967416
3051	379717.46614917	-7292.76904609	-148.45010360	1.53643078	-0.51309900	-0.02299111	2.71441301
3101	379717.46614914	-6660.40816627	-143.72274494	1.57142789	-0.49256105	-0.02629677	2.74612283
3151	379717.46614917	-6069.30967540	-138.41470888	1.60008884	-0.47263040	-0.03022122	2.80872579
3201	379717.46614917	-5518.70609897	-132.62884530	1.61647151	-0.45772857	-0.03424706	2.93270443
3251	379717.46614917	-5007.57262642	-126.46202004	1.61732767	-0.46137266	-0.03662917	3.16764230
3301	379717.46614914	-4534.68645108	-120.00465894	1.61765957	-0.50299891	-0.03671331	3.51922692
3351	379717.46614917	-4098.67813863	-113.34054674	1.63667244	-0.57515461	-0.03825316	3.90004853
3401	379717.46614917	-3698.07464435	-106.54680083	1.67307093	-0.65784342	-0.04123568	4.26355326
3451	379717.46614913	-3331.33437796	-99.69394764	1.72050109	-0.74483265	-0.04443746	4.62003277
3501	379717.46614913	-2996.87520984	-92.84604111	1.77455583	-0.83758890	-0.04759307	4.99368587
3551	379717.46614917	-2693.09659794	-86.06077437	1.83303908	-0.93731622	-0.05063918	5.40294682
3601	379717.46614913	-2418.39713501	-79.38954737	1.89528635	-1.04326015	-0.05347701	5.85791088

Table B.2 Initial conditions for short transfers to a 2000 km Az halo orbit

$Az = 2000$ km

$\phi = 0^\circ$

manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	355594.29313093	0.00000001	924.49213028	0.48315827	-0.85609027	-0.02635009	3.53584262
2551	357117.22437836	0.00000001	870.76482961	0.49090889	-0.87014127	-0.02908011	3.56603106
2601	358653.70857493	0.00000000	813.56295977	0.49981765	-0.88560072	-0.03202843	3.59783201
2651	360183.19594074	0.00000000	754.31989195	0.50858752	-0.90286550	-0.03498568	3.63501319
2701	361687.45408363	0.00000001	694.33819592	0.51707228	-0.92218215	-0.03794098	3.67842037
2751	363150.87299019	0.00000000	634.74917400	0.52532800	-0.94381030	-0.04092489	3.72846411
2801	364560.61265986	0.00000001	576.49302519	0.53344582	-0.96805352	-0.04398050	3.78555657
2851	365906.60263833	0.00000000	520.31609058	0.54151738	-0.99526508	-0.04715812	3.85019434
2901	367181.41514206	0.00000001	466.78080235	0.54962009	-1.02584854	-0.05051406	3.92298749
2951	368380.04175140	0.00000002	416.28395020	0.55780350	-1.06025694	-0.05410992	4.00468804
3001	369499.60684484	0.00000000	369.07941110	0.56607428	-1.09899152	-0.05801169	4.09622867
3051	370539.04943516	0.00000002	325.30229793	0.57438010	-1.14260043	-0.06228881	4.19877594
3101	371498.80025018	0.00000000	284.99235855	0.58259255	-1.19167779	-0.06701346	4.31380247
3151	372380.47431628	0.00000000	248.11526012	0.59048905	-1.24686325	-0.07226031	4.44318571
3201	373186.59245744	0.00000004	214.58104763	0.59773288	-1.30884196	-0.07810679	4.58934541
3251	373920.33897450	0.00000002	184.25954946	0.60385038	-1.37834436	-0.08463335	4.75543754
3301	374585.35787530	0.00000000	156.99282514	0.60820559	-1.45614397	-0.09192314	4.94562876
3351	375185.58651751	0.00000002	132.60494146	0.60997538	-1.54304927	-0.10006037	5.16548011
3401	375725.12331606	0.00000001	110.90945418	0.60813609	-1.63988251	-0.10912628	5.42246519
3451	376208.12499536	0.00000000	91.71499660	0.60148676	-1.74743363	-0.11919065	5.72661781
3501	376638.72847569	0.00000000	74.82935765	0.58875841	-1.86637322	-0.13029537	6.09120750
3551	377020.99260672	0.00000000	60.06239153	0.56888031	-1.99711366	-0.14242532	6.53312655
3601	377358.85539305	0.00000004	47.22804960	0.54145147	-2.13963506	-0.15546541	7.07235198
3651	377656.10294700	0.00000000	36.14577352	0.50732979	-2.29335035	-0.16915187	7.72964011
3701	377916.34703527	0.00000000	26.64143954	0.46907735	-2.45710265	-0.18303667	8.52156169

$Az = 2000$ km continued

$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	363163.89525757	-9557.20861031	508.43681879	0.82594741	-0.82145437	-0.03439389	3.00206254
2551	364226.98830908	-8943.43155084	455.12011549	0.86713402	-0.82515071	-0.04060034	2.96278583
2601	365283.13616879	-8333.66429974	403.68604509	0.89074411	-0.83104045	-0.04547222	2.96431594
2651	366322.27434677	-7733.71759296	354.65645579	0.90477396	-0.83871462	-0.04927877	2.99057584
2701	367335.53433625	-7148.71166526	308.44029187	0.91333173	-0.84830460	-0.05231147	3.03471302
2751	368315.36710483	-6583.00495257	265.33456061	0.91884364	-0.86018835	-0.05481150	3.09359246
2801	369255.60448447	-6040.15864833	225.53038642	0.92296644	-0.87489347	-0.05698014	3.16568786
2851	370151.45757835	-5522.93762343	189.12308250	0.92698820	-0.89304242	-0.05900711	3.25011249
2901	370999.45803121	-5033.34433370	156.12494495	0.93197535	-0.91529956	-0.06108875	3.34616817
2951	371797.35322542	-4572.67932851	126.47943617	0.93877477	-0.94232352	-0.06342421	3.45324694
3001	372543.96936485	-4141.62029943	100.07555512	0.94795241	-0.97474693	-0.06619249	3.57099854
3051	373239.05687632	-3740.31133760	76.76144032	0.95974834	-1.01319263	-0.06952956	3.69960010
3101	373883.13111799	-3368.45490076	56.35654984	0.97409232	-1.05830603	-0.07352516	3.83994660
3151	374477.31872364	-3025.40052672	38.66205522	0.99066250	-1.11077758	-0.07823905	3.99371974
3201	375023.21681646	-2710.22611585	23.46933281	1.00894110	-1.17135169	-0.08372114	4.16343999
3251	375522.76934536	-2421.80932881	10.56661906	1.02823957	-1.24083330	-0.09002299	4.35261777
3301	375978.16228990	-2158.88808973	-0.25598570	1.04769478	-1.32009576	-0.09719950	4.56605382
3351	376391.73759139	-1920.11027808	-9.20291858	1.06625540	-1.41007801	-0.10530424	4.81028994
3401	376765.92440687	-1704.07341944	-16.47069569	1.08269310	-1.51174386	-0.11437984	5.09417246
3451	377103.18555039	-1509.35560744	-22.24633808	1.09569876	-1.62596328	-0.12443986	5.42938939
3501	377405.97667260	-1334.53907152	-26.70645368	1.10415256	-1.75327610	-0.13543785	5.83061349
3551	377676.71570490	-1178.22781834	-30.01678105	1.10762675	-1.89355323	-0.14722567	6.31460128
3601	377917.76025283	-1039.06068371	-32.33203691	1.10698468	-2.04571655	-0.15951781	6.89771707
3651	378131.39088763	-915.72097915	-33.79594412	1.10466287	-2.20777989	-0.17188643	7.59222447

$Az = 2000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	367136.91411644	-12580.55203271	305.72229041	1.24061170	-0.80005836	-0.05893393	2.39059064
2551	367943.21288934	-11774.25325982	259.16429790	1.24357111	-0.79959838	-0.06198988	2.41490669
2601	368739.68845869	-10977.77769046	215.58664148	1.24328535	-0.79927913	-0.06512640	2.44710583
2651	369520.12538708	-10197.34076206	175.23086039	1.23958313	-0.79924982	-0.06819930	2.48864453
2701	370279.02074806	-9438.44540110	138.25535972	1.23246544	-0.79974711	-0.07102565	2.54124482
2751	371011.66581857	-8705.80033058	104.73908488	1.22211299	-0.80115271	-0.07337717	2.60702486
2801	371714.19426094	-8003.27188822	74.68809780	1.20893690	-0.80409293	-0.07498993	2.68858154
2851	372383.59302913	-7333.87312004	48.04448455	1.19370820	-0.80958581	-0.07561513	2.78887567
2901	373017.67718900	-6699.78896014	24.69679270	1.17780516	-0.81918189	-0.07515455	2.91055825
2951	373615.03397001	-6102.43217912	4.49111788	1.16351760	-0.83487682	-0.07390361	3.05423910
3001	374174.94399883	-5542.52215034	-12.75797815	1.15398015	-0.85844841	-0.07273346	3.21618858
3051	374697.28861214	-5020.17753702	-27.25736937	1.15204593	-0.89051602	-0.07275910	3.38882196
3101	375182.45168957	-4535.01445956	-39.22652618	1.15866844	-0.93068281	-0.07455506	3.56617804
3151	375631.22301754	-4086.24313159	-48.89015837	1.17275753	-0.97873486	-0.07797264	3.74818587
3201	376044.70833029	-3672.75781887	-56.47238298	1.19242952	-1.03515102	-0.08266273	3.93908601
3251	376424.24926407	-3293.21688505	-62.19232512	1.21591618	-1.10078665	-0.08841009	4.14454234
3301	376771.35478812	-2946.11136104	-66.26097683	1.24170944	-1.17658590	-0.09513216	4.37080417
3351	377087.64436285	-2629.82178632	-68.87909796	1.26842211	-1.26351200	-0.10280397	4.62522059
3401	377374.80216491	-2342.66398421	-70.23593575	1.29468717	-1.36251314	-0.11140839	4.91700211
3451	377634.54115183	-2082.92499729	-70.50855333	1.31920622	-1.47438380	-0.12090143	5.25773258
3501	377868.57546077	-1848.89068834	-69.86158334	1.34100681	-1.59946795	-0.13117515	5.66122748
3551	378078.59956135	-1638.86658775	-68.44725381	1.35990429	-1.73726874	-0.14202014	6.14223150
3601	378266.27264167	-1451.19350743	-66.40556495	1.37694023	-1.88622245	-0.15310750	6.71393923
3651	378433.20684971	-1284.25929939	-63.86452406	1.39438208	-2.04392718	-0.16400713	7.38540754

$Az = 2000$ km	continued						
$\phi = 60^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	371212.91380379	-14730.31675780	109.66457803	0.61818704	-0.85382925	-0.02977463	4.11845114
2551	371751.94247574	-13796.69171127	71.93942744	0.91814002	-0.77445780	-0.02348055	3.13756321
2601	372282.33225327	-12878.02966877	37.65944606	1.06561432	-0.76385824	-0.02765167	2.84870941
2651	372800.70391065	-11980.18362099	6.88511317	1.17347805	-0.75885390	-0.03267672	2.68728230
2701	373304.02806577	-11108.40061163	-20.38110939	1.25565215	-0.75469339	-0.03840035	2.59008125
2751	373789.68048155	-10267.22595269	-44.19162953	1.31767194	-0.75036518	-0.04485316	2.53523018
2801	374255.48042359	-9460.43678691	-64.64841603	1.36259120	-0.74574406	-0.05206502	2.51331735
2851	374699.70831168	-8691.01151461	-81.89593436	1.39240673	-0.74106085	-0.05998546	2.52067695
2901	375121.10207954	-7961.13609868	-96.11295005	1.40855834	-0.73681553	-0.06836644	2.55741581
2951	375518.83442949	-7272.24346071	-107.50390092	1.41217470	-0.73388959	-0.07655286	2.62716730
3001	375892.47508405	-6625.07886323	-116.29049077	1.40439191	-0.73396745	-0.08316451	2.73769167
3051	376241.94302580	-6019.78263255	-122.70402026	1.38734273	-0.74065001	-0.08599009	2.90064635
3101	376567.45371169	-5455.98158618	-126.97879250	1.36683692	-0.76074073	-0.08366147	3.12342536
3151	376869.46558141	-4932.88168329	-129.34675344	1.35426151	-0.79985943	-0.07988331	3.38628035
3201	377148.62917525	-4449.35615512	-130.03337734	1.35805850	-0.85394786	-0.08014211	3.64960124
3251	377405.74107921	-4004.02527429	-129.25470053	1.37642887	-0.91698942	-0.08411638	3.90106896
3301	377641.70391132	-3595.32566038	-127.21534061	1.40395607	-0.98835302	-0.08996323	4.15311270
3351	377857.49274474	-3221.56843713	-124.10730975	1.43647952	-1.06971275	-0.09692666	4.42152294
3401	378054.12776956	-2880.98658358	-120.10942849	1.47138928	-1.16257474	-0.10476827	4.71974616
3451	378232.65260572	-2571.77249702	-115.38716174	1.50699273	-1.26783281	-0.11335279	5.06031788
3501	378394.11746499	-2292.10715704	-110.09272361	1.54226694	-1.38567009	-0.12251396	5.45604549
3551	378539.56627428	-2040.18242953	-104.36532556	1.57700480	-1.51533124	-0.13200802	5.91942164
3601	378670.02687311	-1814.21804396	-98.33147030	1.61200236	-1.65503335	-0.14150512	6.46092026

$Az = 2000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614917	-16781.21976891	-261.95096641	0.77369009	-0.73462788	-0.02977581	4.25593650
2551	379717.46614915	-15773.22890648	-279.16908319	0.96019572	-0.66116421	-0.02074732	3.41301085
2601	379717.46614917	-14783.66236130	-293.15691214	1.06170156	-0.64636456	-0.02092159	3.14947637
2651	379717.46614917	-13816.96397788	-304.00174152	1.14328955	-0.63613187	-0.02191987	2.98940416
2701	379717.46614915	-12877.30473170	-311.82222242	1.21260524	-0.62599493	-0.02329454	2.88135084
2751	379717.46614915	-11968.46025687	-316.76699785	1.27261042	-0.61477641	-0.02497769	2.80699781
2801	379717.46614915	-11093.71062607	-319.01145913	1.32525325	-0.60212374	-0.02698269	2.75700693
2851	379717.46614915	-10255.77104958	-318.75304038	1.37226887	-0.58798761	-0.02936064	2.72549842
2901	379717.46614915	-9456.75710635	-316.20560710	1.41531544	-0.57244879	-0.03219455	2.70833034
2951	379717.46614915	-8698.18333977	-311.59352705	1.45585888	-0.55564218	-0.03560413	2.70263572
3001	379717.46614914	-7980.99036735	-305.14594717	1.49492572	-0.53772883	-0.03975444	2.70701233
3051	379717.46614917	-7305.59350086	-297.09167207	1.53275845	-0.51892515	-0.04485936	2.72228648
3101	379717.46614917	-6671.94518329	-287.65488748	1.56834524	-0.49965152	-0.05114776	2.75314439
3151	379717.46614917	-6079.60405743	-277.05182666	1.59876947	-0.48101909	-0.05868594	2.81157883
3201	379717.46614917	-5527.80471137	-265.48836046	1.61878878	-0.46647052	-0.06676001	2.92379808
3251	379717.46614914	-5015.52370969	-253.15841041	1.62417263	-0.46661937	-0.07253955	3.13546633
3301	379717.46614917	-4541.53908291	-240.24303793	1.62533780	-0.50072895	-0.07358297	3.46736818
3351	379717.46614915	-4104.48182083	-226.91004569	1.64234936	-0.56839669	-0.07619680	3.84592072
3401	379717.46614917	-3702.87899052	-213.31393056	1.67702207	-0.64987829	-0.08200428	4.21348677
3451	379717.46614916	-3335.18887667	-199.59604406	1.72348205	-0.73646324	-0.08845488	4.57285535
3501	379717.46614913	-2999.82904230	-185.88483855	1.77713176	-0.82873900	-0.09482931	4.94677686
3551	379717.46614913	-2695.19849009	-172.29610145	1.83551836	-0.92801227	-0.10098407	5.35467703
3601	379717.46614913	-2419.69522839	-158.93310266	1.89781383	-1.03372313	-0.10673019	5.80770151

Table B.3 Initial conditions for short transfers to a 3000 km Az halo orbit

$Az = 3000$ km

$\phi = 0\,^{\circ}$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	355503.22830238	0.00000000	1392.47271708	0.48879381	-0.85514095	-0.04093687	3.51697776
2551	357028.26581736	0.00000001	1312.01047450	0.49191880	-0.87000116	-0.04369504	3.55897949
2601	358567.43278416	0.00000001	1226.23949032	0.49995037	-0.88571961	-0.04787082	3.59268908
2651	360100.08599041	0.00000001	1137.32199824	0.50856692	-0.90310061	-0.05225813	3.62976727
2701	361607.90004704	0.00000000	1047.22549207	0.51702999	-0.92247152	-0.05667891	3.67262823
2751	363075.17554625	0.00000000	957.66071472	0.52528193	-0.94410150	-0.06114618	3.72198118
2801	364488.98931166	0.00000000	870.05096782	0.53339130	-0.96829036	-0.06571715	3.77829303
2851	365839.19580812	0.00000000	785.52740697	0.54144587	-0.99538571	-0.07046493	3.84206566
2901	367118.30134194	0.00000000	704.94369661	0.54952493	-1.02578556	-0.07547280	3.91390039
2951	368321.24108598	0.00000001	628.90336639	0.55768343	-1.05993762	-0.08083251	3.99453190
3001	369445.09225326	0.00000000	557.79400938	0.56593686	-1.09833772	-0.08664278	4.08486698
3051	370488.75525299	0.00000002	491.82369031	0.57424515	-1.14152815	-0.09300763	4.18603643
3101	371452.62984262	0.00000002	431.05626258	0.58249599	-1.19009650	-0.10003521	4.29946497
3151	372338.30668264	0.00000002	375.44351365	0.59048738	-1.24467506	-0.10783720	4.42696578
3201	373148.28781607	0.00000001	324.85305335	0.59790875	-1.30594085	-0.11652917	4.57087082
3251	373885.74340277	0.00000000	279.09159523	0.60431968	-1.37461560	-0.12623100	4.73421363
3301	374554.30711502	0.00000002	237.92377137	0.60912611	-1.45146418	-0.13706654	4.92098761
3351	375157.90907588	0.00000001	201.08691049	0.61155646	-1.53728807	-0.14916135	5.13650823
3401	375700.64298316	0.00000001	168.30234898	0.61064650	-1.63290766	-0.16263726	5.38790635
3451	376186.66289406	0.00000000	139.28387947	0.60525462	-1.73912287	-0.17760110	5.68475791
3501	376620.10474028	0.00000000	113.74391535	0.59415029	-1.85663741	-0.19412234	6.03977707
3551	377005.02777236	0.00000000	91.39788601	0.57624103	-1.98593437	-0.21219276	6.46931827
3601	377345.37156126	0.00000004	71.96730186	0.55099212	-2.12711273	-0.23166493	6.99313745
3651	377644.92477953	0.00000000	55.18184785	0.51898575	-2.27974391	-0.25217823	7.63261735
3701	377907.30261432	0.00000005	40.78079126	0.48238687	-2.44284059	-0.27309792	8.40663186

$Az = 3000$ km continued

$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	363101.81369960	-9593.05141450	767.51346073	0.86542614	-0.82101345	-0.05858607	2.91656172
2551	364166.54091184	-8978.33087192	687.31223711	0.88784819	-0.82696274	-0.06505500	2.91609659
2601	365224.69346003	-8367.40621338	609.90531065	0.90265088	-0.83401252	-0.07044116	2.93489937
2651	366266.14125871	-7766.12604646	536.08404525	0.91258277	-0.84230707	-0.07502126	2.96863080
2701	367281.95143335	-7179.64776869	466.46973250	0.91931260	-0.85215787	-0.07898784	3.01543034
2751	368264.51412256	-6612.36493556	401.51481618	0.92403404	-0.86400802	-0.08248350	3.07459281
2801	369207.60558362	-6067.87082666	341.51186204	0.92775558	-0.87842187	-0.08564444	3.14590055
2851	370106.38768478	-5548.95873862	286.60865074	0.93143381	-0.89606556	-0.08864049	3.22921477
2901	370957.34966999	-5057.65560736	236.82742782	0.93599960	-0.91766278	-0.09169928	3.32423231
2951	371758.20335047	-4595.28251936	192.08628542	0.94229410	-0.94393313	-0.09509803	3.43045624
3001	372507.74581417	-4162.53397617	152.22084934	0.95094938	-0.97554746	-0.09911761	3.54742839
3051	373205.70420995	-3759.56750848	117.00482171	0.96228603	-1.01313195	-0.10398537	3.67511755
3101	373852.57570916	-3386.09607428	86.16838278	0.97629218	-1.05731115	-0.10985005	3.81422922
3151	374449.47306782	-3041.47722357	59.41389901	0.99267834	-1.10874885	-0.11680177	3.96631643
3201	374997.98309064	-2724.79481425	36.42875868	1.01094810	-1.16816627	-0.12490912	4.13379830
3251	375500.04228699	-2434.93080208	16.89543400	1.03043793	-1.23634821	-0.13424307	4.32005752
3301	375957.83148526	-2170.62608526	0.49904743	1.05031998	-1.31414911	-0.14488185	4.52970134
3351	376373.68927239	-1930.53047992	-13.06718684	1.06958740	-1.40249329	-0.15690437	4.76899037
3401	376750.04284729	-1713.24264213	-24.09824611	1.08705498	-1.50234554	-0.17037696	5.04640153
3451	377089.35414704	-1517.34117185	-32.87492216	1.10142990	-1.61461416	-0.18532893	5.37321498
3501	377394.07878297	-1341.40832126	-39.66243910	1.11153633	-1.73994443	-0.20170930	5.76381809
3551	377666.63530220	-1184.04774151	-44.70977389	1.11676905	-1.87839806	-0.21932516	6.23512132
3601	377909.38244766	-1043.89761178	-48.24944150	1.11769944	-2.02913882	-0.23778151	6.80443370
3651	378124.60235616	-919.64033962	-50.49755910	1.11646421	-2.19038329	-0.25645996	7.48589850

$Az = 3000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	367090.57005165	-12626.89609750	462.48858917	1.24305795	-0.80870942	-0.08554580	2.38508344
2551	367898.35319124	-11819.11295791	392.36781169	1.24890801	-0.80929085	-0.09041135	2.40511390
2601	368696.53624382	-11020.92990535	326.70917684	1.25137174	-0.81002974	-0.09544024	2.43283387
2651	369478.86041091	-10238.60573823	265.88075790	1.25035187	-0.81101503	-0.10048781	2.46944245
2701	370239.78094819	-9477.68520097	210.12518753	1.24587053	-0.81237486	-0.10535685	2.51641556
2751	370974.55005633	-8742.91609284	159.56510984	1.23805729	-0.81431116	-0.10977574	2.57566169
2801	371679.26597080	-8038.20017834	114.21303917	1.22716034	-0.81717695	-0.11337715	2.64969844
2851	372350.88444403	-7366.58170514	73.98476184	1.21361417	-0.82163313	-0.11569755	2.74177984
2901	372987.19381205	-6730.27233712	38.71506646	1.19823601	-0.82891874	-0.11626451	2.85569840
2951	373586.75900416	-6130.70714498	8.17446854	1.18264421	-0.84113877	-0.11492168	2.99452521
3001	374148.84251482	-5568.62363435	-17.91430957	1.16975980	-0.86103124	-0.11247694	3.15740444
3051	374673.31130656	-5044.15484258	-39.86109101	1.16342798	-0.89050655	-0.11097621	3.33653511
3101	375160.53815294	-4556.92799622	-57.99489373	1.16626293	-0.92933370	-0.11231129	3.52138445
3151	375611.30449040	-4106.16165877	-72.65281693	1.17798098	-0.97644350	-0.11669370	3.70791689
3201	376026.70996846	-3690.75618066	-84.17122967	1.19648447	-1.03171130	-0.12338263	3.89988114
3251	376408.09195860	-3309.37419053	-92.87912438	1.21956013	-1.09588824	-0.13180801	4.10396628
3301	376756.95659774	-2960.50955142	-99.09337112	1.24542881	-1.16997403	-0.14173730	4.32717796
3351	377074.92162544	-2642.54452373	-103.11554789	1.27260238	-1.25497641	-0.15310114	4.57705529
3401	377363.67034762	-2353.79580149	-105.23000995	1.29968782	-1.35187810	-0.16587006	4.86265868
3451	377624.91549746	-2092.55065170	-105.70288237	1.32535629	-1.46154581	-0.17998788	5.19533529
3501	377860.37147812	-1857.09467099	-104.78169874	1.34853639	-1.58447791	-0.19531359	5.58885003
3551	378071.73340136	-1645.73274780	-102.69545632	1.36883996	-1.72041964	-0.21156109	6.05839674
3601	378260.66139221	-1456.80475689	-99.65490430	1.38705036	-1.86805921	-0.22826058	6.61825532
3651	378428.76877745	-1288.69737172	-95.85292568	1.40525362	-2.02513636	-0.24477326	7.27897182

$Az = 3000$ km continued

$\phi = 60°$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	371183.02406723	-14782.08730014	167.32597875	0.61535672	-0.85444634	-0.04407131	4.12269030
2551	371723.18245571	-13846.50552719	110.45453855	0.91523853	-0.77557170	-0.03491798	3.14112210
2601	372254.80962692	-12925.70025593	58.75539984	1.06212721	-0.76563313	-0.04095762	2.85286245
2651	372774.50332683	-12025.56436335	12.32264418	1.16974482	-0.76143939	-0.04816902	2.69134975
2701	373279.21205525	-11151.38320267	-28.83720024	1.25206407	-0.75831552	-0.05629623	2.59350477
2751	373766.29093053	-10307.73784339	-64.80045224	1.31470479	-0.75530316	-0.06535735	2.53735318
2801	374233.54049977	-9498.43784964	-95.71830145	1.36084150	-0.75231743	-0.07538308	2.51322212
2851	374679.22469370	-8726.49018166	-121.80617417	1.39263505	-0.74959560	-0.08633305	2.51696666
2901	375102.06732785	-7994.10525567	-143.33138184	1.41173366	-0.74755329	-0.09799623	2.54786419
2951	375501.22934835	-7302.73635571	-160.60011197	1.41948151	-0.74676261	-0.10981831	2.60816209
3001	375876.27095522	-6653.14523766	-173.94474834	1.41703919	-0.74806740	-0.12058978	2.70359431
3051	376227.10363055	-6045.48521908	-183.71230044	1.40568474	-0.75319284	-0.12799235	2.84444129
3101	376553.93709264	-5479.39305712	-190.25445292	1.38820554	-0.76672046	-0.12882503	3.04387189
3151	376857.22552864	-4954.08207657	-193.91947748	1.37251560	-0.79731437	-0.12354696	3.30053845
3201	377137.61644529	-4468.43076300	-195.04602417	1.37012080	-0.84773482	-0.12113154	3.57666891
3251	377395.90436994	-4021.06295448	-193.95864609	1.38406030	-0.91021840	-0.12563545	3.84061533
3301	377632.99062423	-3610.41751632	-190.96481305	1.40958390	-0.98069830	-0.13397620	4.09728927
3351	377849.84957026	-3234.80680372	-186.35312564	1.44158110	-1.06033313	-0.14425053	4.36451810
3401	378047.50112932	-2892.46426123	-180.39243863	1.47673184	-1.15101867	-0.15589479	4.65824174
3451	378226.98898404	-2581.58217751	-173.33162519	1.51301213	-1.25397698	-0.16868540	4.99209749
3501	378389.36365704	-2300.34099402	-165.39975108	1.54920348	-1.36964855	-0.18238887	5.37939450
3551	378535.66957415	-2046.93171213	-156.80647001	1.58489874	-1.49754228	-0.19665952	5.83326397
3601	378666.93522219	-1819.57294045	-147.74249300	1.62070479	-1.63609003	-0.21101332	6.36510883

$Az = 3000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614915	-16828.33588819	-392.05556343	0.76743642	-0.73906499	-0.04410364	4.28999993
2551	379717.46614915	-15818.15288728	-418.06479149	0.95790341	-0.66296874	-0.03088934	3.41756836
2601	379717.46614915	-14826.30489391	-439.21880239	1.05971651	-0.64842826	-0.03107132	3.15231031
2651	379717.46614917	-13857.25774100	-455.64746525	1.14138057	-0.63855366	-0.03248791	2.99172373
2701	379717.46614915	-12915.20452908	-467.52785921	1.21057554	-0.62883014	-0.03445215	2.88379637
2751	379717.46614917	-12003.94234808	-475.08224365	1.27024613	-0.61808618	-0.03685366	2.81010959
2801	379717.46614915	-11126.77133473	-478.57320212	1.32233811	-0.60599023	-0.03970291	2.76129367
2851	379717.46614915	-10286.42481192	-478.29657770	1.36861675	-0.59252559	-0.04306396	2.73142471
2901	379717.46614915	-9485.03416338	-474.57303750	1.41081266	-0.57781710	-0.04704422	2.71626108
2951	379717.46614917	-8724.12728003	-467.73915372	1.45051306	-0.56205485	-0.05179981	2.71274162
3001	379717.46614914	-8004.65569563	-458.13879121	1.48892455	-0.54546416	-0.05754716	2.71912384
3051	379717.46614914	-7327.04336768	-446.11539908	1.52655870	-0.52832679	-0.06457189	2.73563389
3101	379717.46614917	-6691.24936398	-432.00557382	1.56284591	-0.51109262	-0.07320412	2.76577763
3151	379717.46614917	-6096.83722357	-416.13404255	1.59565156	-0.49469736	-0.08365782	2.81890060
3201	379717.46614917	-5543.04500058	-398.81003835	1.62087570	-0.48150590	-0.09544618	2.91519969
3251	379717.46614914	-5028.85157679	-380.32491627	1.63390559	-0.47828179	-0.10587205	3.09200534
3301	379717.46614916	-4553.03640136	-360.95078997	1.63868354	-0.50082197	-0.11033798	3.38445143
3351	379717.46614917	-4114.23119137	-340.93994191	1.65322580	-0.55866366	-0.11366368	3.75094853
3401	379717.46614913	-3710.96321688	-320.52476657	1.68487765	-0.63668598	-0.12177665	4.12281222
3451	379717.46614916	-3341.69056621	-299.91802944	1.72943138	-0.72221530	-0.13153444	4.48732252
3501	379717.46614913	-3004.83029540	-279.31325914	1.78219619	-0.81361651	-0.14127673	4.86237559
3551	379717.46614917	-2698.78064585	-258.88512562	1.84031639	-0.91204496	-0.15068462	5.26820269
3601	379717.46614916	-2421.93863871	-238.78969102	1.90264840	-1.01726234	-0.15949363	5.71777819

Table B.4 Initial conditions for short transfers to a 4000 km Az halo orbit

$Az = 4000$ km

$\phi = 0^\circ$

manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	355375.55097980	0.00000001	1867.32540877	0.48989413	-0.85508086	-0.05458321	3.50860590
2551	356903.51626884	0.00000001	1760.29310863	0.49220991	-0.87005043	-0.05796160	3.55220063
2601	358446.42047713	0.00000001	1646.00021568	0.49996852	-0.88595152	-0.06342945	3.58602849
2651	359983.48933663	0.00000000	1527.35239806	0.50852270	-0.90347896	-0.06924654	3.62255838
2701	361496.26712937	0.00000001	1406.99850813	0.51698083	-0.92294196	-0.07512485	3.66459462
2751	362968.92922973	0.00000000	1287.24540987	0.52523555	-0.94459870	-0.08106395	3.71296718
2801	364388.43597735	0.00000001	1170.01527453	0.53333973	-0.96873899	-0.08713319	3.76817457
2851	365744.53669120	0.00000001	1056.83821230	0.54137729	-0.99570138	-0.09342650	3.83072074
2901	367029.64536373	0.00000001	948.87129406	0.54942961	-1.02587581	-0.10005277	3.90119482
2951	368238.61815100	0.00000001	846.93493673	0.55755870	-1.05970259	-0.10713301	3.98030746
3001	369368.46617962	0.00000000	751.55869110	0.56579191	-1.09767021	-0.11479823	4.06892872
3051	370418.03574891	0.00000000	663.03013286	0.57410607	-1.14031319	-0.12318696	4.16813807
3101	371387.68318474	0.00000000	581.44236201	0.58241128	-1.18821029	-0.13244318	4.27929116
3151	372278.96495757	0.00000000	506.73727529	0.59053434	-1.24198370	-0.14271526	4.40410876
3201	373094.35673232	0.00000001	438.74312866	0.59820152	-1.30229903	-0.15415619	4.54479705
3251	373837.00877987	0.00000002	377.20590546	0.60501964	-1.36986544	-0.16692430	4.70421427
3301	374510.54020754	0.00000001	321.81467274	0.61045514	-1.44543470	-0.18118291	4.88610506
3351	375118.87090800	0.00000001	272.22150122	0.61381258	-1.52979636	-0.19709760	5.09542917
3401	375666.08786995	0.00000001	228.05671337	0.61421951	-1.62376406	-0.21482988	5.33881228
3451	376156.34130636	0.00000000	188.94027363	0.61063446	-1.72814422	-0.23452448	5.62513248
3501	376593.76565134	0.00000000	154.49009736	0.60191291	-1.84367436	-0.25628349	5.96619973
3551	376982.42059874	0.00000000	124.32797127	0.58698591	-1.97091889	-0.28011851	6.37734864
3601	377326.24779179	0.00000000	98.08367348	0.56520495	-2.11012500	-0.30587524	6.87752392
3651	377629.03936143	0.00000000	75.39777466	0.53683268	-2.26107928	-0.33313680	7.48818926
3701	377894.41515419	0.00000005	55.92350090	0.50349883	-2.42304505	-0.36113167	8.23034976

$Az = 4000$ km continued

$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	363014.79606842	-9643.29106731	1032.44986122	0.88594768	-0.82510859	-0.08291827	2.87088891
2551	364081.78131488	-9027.26684803	925.09568217	0.90083099	-0.83196819	-0.08931411	2.88453072
2601	365142.71521110	-8414.73637747	821.41098915	0.91201623	-0.83963827	-0.09515017	2.90949094
2651	366187.37560476	-7811.60141797	722.46707508	0.92034684	-0.84833395	-0.10052167	2.94516555
2701	367206.73917164	-7223.07158823	629.10714280	0.92648086	-0.85835612	-0.10547627	2.99158022
2751	368193.11050130	-6653.58983553	541.94750428	0.93103289	-0.87011099	-0.11004638	3.04910035
2801	369140.18763940	-6106.79459491	461.38932479	0.93465813	-0.88413134	-0.11428518	3.11821277
2851	370043.06312597	-5585.51918967	387.63871551	0.93810046	-0.90108371	-0.11830897	3.19930290
2901	370898.16646906	-5091.82504437	320.73250784	0.94219642	-0.92174105	-0.12233764	3.29243365
2951	371703.15934175	-4627.06219260	260.56696184	0.94781005	-0.94691055	-0.12670636	3.39723695
3001	372456.79777084	-4191.94884270	206.92692932	0.95569076	-0.97734474	-0.13181536	3.51308704
3051	373158.77605370	-3786.66149215	159.51350421	0.96630882	-1.01369992	-0.13802692	3.63957909
3101	373809.56567172	-3410.92793100	117.96880650	0.97976864	-1.05657513	-0.14558452	3.77704237
3151	374410.25975502	-3064.11704031	81.89714718	0.99584280	-1.10658571	-0.15461776	3.92677888
3201	374962.43048933	-2745.32111818	50.88232858	1.01406595	-1.16440892	-0.16520510	4.09104944
3251	375468.00381479	-2453.42822266	24.50121006	1.03380563	-1.23079444	-0.17742551	4.27306641
3301	375929.15321071	-2187.18349479	2.33391087	1.05428216	-1.30656490	-0.19137265	4.47717061
3351	376348.21244120	-1945.23953522	-16.02885167	1.07455615	-1.39261598	-0.20714651	4.70921317
3401	376727.60584666	-1726.19665049	-30.98075146	1.09351802	-1.48989918	-0.22483721	4.97710041
3451	377069.79402521	-1528.63421345	-42.89665302	1.10992801	-1.59935219	-0.24449705	5.29141691
3501	377377.23242733	-1351.13456922	-52.13075849	1.12258024	-1.72173534	-0.26608900	5.66590251
3551	377652.34036022	-1192.30093016	-59.01570957	1.13067327	-1.85735204	-0.28940913	6.11728337
3601	377897.47806219	-1050.77061189	-63.86232608	1.13438015	-2.00571894	-0.31399945	6.66374537
3651	378114.92977000	-925.22480990	-66.95973182	1.13534994	-2.16540147	-0.33909379	7.32177065

$Az = 4000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	367025.58360238	-12691.88254679	623.97603759	1.24761517	-0.81986683	-0.10957027	2.37604353
2551	367835.42648701	-11882.03966214	529.95233625	1.25642494	-0.82193237	-0.11606078	2.39163144
2601	368635.98497434	-11081.48117481	441.86200449	1.26188772	-0.82426845	-0.12281615	2.41445523
2651	369420.93929134	-10296.52685781	360.20665953	1.26398725	-0.82694217	-0.12973699	2.44541288
2701	370184.68584018	-9532.78030898	285.31927863	1.26280004	-0.83002296	-0.13668599	2.48562874
2751	370922.42179316	-8795.04435601	217.37135299	1.25847148	-0.83358521	-0.14346694	2.53659153
2801	371630.19547123	-8087.27067791	156.38602074	1.25119249	-0.83772632	-0.14979049	2.60034920
2851	372304.91864472	-7412.54750444	102.25601071	1.24118521	-0.84262791	-0.15521818	2.67978286
2901	372944.34195296	-6773.12419621	54.76475542	1.22873165	-0.84873014	-0.15908738	2.77893144
2951	373546.99886044	-6170.46728873	13.60886867	1.21435426	-0.85716320	-0.16049682	2.90306123
3001	374112.12626212	-5605.33988702	-21.57968768	1.19940119	-0.87051599	-0.15872398	3.05719015
3051	374639.57080967	-5077.89533947	-51.21308384	1.18710598	-0.89301647	-0.15477762	3.24052070
3101	375129.68956538	-4587.77658379	-75.72964864	1.18238861	-0.92768305	-0.15265988	3.44026374
3151	375583.25213525	-4134.21401388	-95.57890411	1.18826817	-0.97324406	-0.15571927	3.64080107
3201	376001.34952675	-3716.11662241	-111.20969795	1.20363054	-1.02736221	-0.16341571	3.83935170
3251	376385.31302999	-3332.15311917	-123.06125078	1.22549785	-1.08980250	-0.17413677	4.04358281
3301	376736.64471818	-2980.82143099	-131.55676453	1.25126167	-1.16158032	-0.18706208	4.26297021
3351	377056.95983066	-2660.50631846	-137.09915568	1.27903575	-1.24386372	-0.20193844	4.50627492
3401	377347.94037079	-2369.52577837	-140.06846156	1.30730820	-1.33772657	-0.21869612	4.78267299
3451	377611.29867919	-2106.16746998	-140.82049568	1.33470950	-1.44412595	-0.23727252	5.10315188
3501	377848.74945905	-1868.71669006	-139.68638086	1.36006459	-1.56374677	-0.25751620	5.48117698
3551	378061.98865404	-1655.47749504	-136.97265187	1.38272668	-1.69666601	-0.27910105	5.93224715
3601	378252.67764215	-1464.78850697	-132.96168213	1.40308238	-1.84198181	-0.30145682	6.47196243
3651	378422.43135009	-1295.03479900	-127.91224683	1.42286601	-1.99773316	-0.32375828	7.11301920

$Az = 4000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	371141.09557138	-14854.70958526	228.41456646	0.61137071	-0.85528362	-0.05765782	4.12890972
2551	371682.82740987	-13916.40251690	152.05533626	0.91112888	-0.77707800	-0.04600798	3.14627069
2601	372216.18051093	-12992.60784751	82.60075163	1.05718691	-0.76799353	-0.05367677	2.85884720
2651	372737.72020359	-12089.27460166	20.18258668	1.16439893	-0.76481869	-0.06272458	2.69731954
2701	373244.36383784	-11211.74208578	-35.18511385	1.24678852	-0.76296154	-0.07277549	2.59879148
2751	373733.43744722	-10364.64174572	-83.59978856	1.31005451	-0.76151296	-0.08380838	2.54121723
2801	374202.71519893	-9551.82883689	-125.25970050	1.35748077	-0.76042421	-0.09582997	2.51468436
2851	374650.43777756	-8776.35058302	-160.44968691	1.39137364	-0.75994872	-0.10879781	2.51460294
2901	375075.30908670	-8040.45188887	-189.52458402	1.41357093	-0.76047626	-0.12255825	2.53948138
2951	375476.47348418	-7345.61477027	-212.89175462	1.42565421	-0.76245671	-0.13675750	2.59023996
3001	375853.47772522	-6692.62427009	-230.99404931	1.42902633	-0.76635164	-0.15068121	2.67035076
3051	376206.22269185	-6081.65206581	-244.29425290	1.42492013	-0.77270681	-0.16292603	2.78675635
3101	376534.90998130	-5512.34898064	-253.26170580	1.41457039	-0.78293299	-0.17079684	2.95135504
3151	376839.98775152	-4983.93878239	-258.36142834	1.40081861	-0.80234821	-0.17062080	3.17790908
3201	377122.09919485	-4495.30742915	-260.04577241	1.39228754	-0.84142678	-0.16532499	3.45594928
3251	377382.03589592	-4045.08385615	-258.74840551	1.39858962	-0.90053647	-0.16710056	3.73977157
3301	377620.69730660	-3631.71016705	-254.88029962	1.41960327	-0.97020272	-0.17673489	4.00913746
3351	377839.05674308	-3253.50052869	-248.82733856	1.45004163	-1.04788092	-0.19001272	4.27773962
3401	378038.13370453	-2908.68911691	-240.94915326	1.48529062	-1.13552884	-0.20531251	4.56564090
3451	378218.97191944	-2595.46814074	-231.57882554	1.52254420	-1.23500802	-0.22219469	4.88934404
3501	378382.62230857	-2312.01735200	-221.02315102	1.56019615	-1.34723071	-0.24037217	5.26330489
3551	378530.12996553	-2056.52659565	-209.56320828	1.59752456	-1.47213353	-0.25942965	5.70153099
3601	378662.52426034	-1827.21295039	-197.45503674	1.63481256	-1.60854260	-0.27875484	6.21675967

$Az = 4000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614915	-16894.43327278	-521.09893689	0.75874389	-0.74527472	-0.05802159	4.33830270
2551	379717.46614915	-15881.18715011	-556.11885749	0.95487411	-0.66542452	-0.04075389	3.42327190
2601	379717.46614917	-14886.14993287	-584.64692318	1.05715644	-0.65125183	-0.04085551	3.15559837
2651	379717.46614917	-13913.81834397	-606.85430486	1.13898809	-0.64187206	-0.04259943	2.99420257
2701	379717.46614915	-12968.41657540	-622.97543023	1.20807969	-0.63271340	-0.04504325	2.88634545
2751	379717.46614917	-12053.77187343	-633.30532745	1.26734018	-0.62261112	-0.04802512	2.81349507
2801	379717.46614915	-11173.21258074	-638.19316778	1.31870075	-0.61126074	-0.05154229	2.76626025
2851	379717.46614915	-10329.49748912	-638.03283401	1.36395810	-0.59868842	-0.05565840	2.73868023
2901	379717.46614917	-9524.78021341	-633.25163876	1.40493460	-0.58507734	-0.06048715	2.72640056
2951	379717.46614917	-8760.60742524	-624.29838495	1.44337722	-0.57069033	-0.06619601	2.72611794
3001	379717.46614914	-8037.94602572	-611.63183044	1.48072616	-0.55583650	-0.07301824	2.73565963
3051	379717.46614914	-7357.23215368	-595.71036083	1.51782218	-0.54088497	-0.08126560	2.75452608
3101	379717.46614917	-6718.43422208	-576.98336527	1.55459575	-0.52635055	-0.09132109	2.78490371
3151	379717.46614914	-6121.12268770	-555.88451680	1.58975648	-0.51309498	-0.10354331	2.83337587
3201	379717.46614914	-5564.54051532	-532.82692024	1.62056525	-0.50276244	-0.11789622	2.91389650
3251	379717.46614914	-5047.66988498	-508.19992670	1.64329180	-0.49893904	-0.13290406	3.05222604
3301	379717.46614917	-4569.29227997	-482.36731976	1.65692950	-0.51040877	-0.14422157	3.28395116
3351	379717.46614917	-4128.04047901	-455.66654409	1.67149611	-0.55107318	-0.15047853	3.61175281
3401	379717.46614913	-3722.44207195	-428.40865388	1.69927967	-0.61957974	-0.15993131	3.97843319
3451	379717.46614917	-3350.95489872	-400.87869160	1.74061152	-0.70177587	-0.17286522	4.34841969
3501	379717.46614913	-3011.99531945	-373.33625220	1.79158337	-0.79145852	-0.18625482	4.72622366
3551	379717.46614913	-2703.96050741	-346.01603601	1.84899801	-0.88844189	-0.19921407	5.12983943
3601	379717.46614913	-2425.24607760	-319.12823766	1.91123001	-0.99269161	-0.21137807	5.57420605

Table B.5 Initial conditions for short transfers to a 5000 km Az halo orbit

$Az = 5000$ km

$\phi = 0^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	355211.07232563	0.00000001	2351.32397801	0.49036671	-0.85517612	-0.06771435	3.50043771
2551	356742.76645600	0.00000000	2217.95907901	0.49243368	-0.87017525	-0.07188055	3.54401187
2601	358290.44428800	0.00000000	2075.22246440	0.49998599	-0.88629682	-0.07862255	3.57762000
2651	359833.16258300	0.00000001	1926.78258824	0.50848017	-0.90403390	-0.08584572	3.61340875
2701	361352.29781037	0.00000000	1775.99168189	0.51693679	-0.92365058	-0.09316148	3.65439060
2751	362831.86422864	0.00000001	1625.77519261	0.52520173	-0.94538466	-0.10055027	3.70150227
2801	364258.67234834	0.00000000	1478.57545852	0.53330856	-0.96951099	-0.10808884	3.75527871
2851	365622.33625066	0.00000001	1336.34068069	0.54133479	-0.99635555	-0.11588875	3.81622837
2901	366915.15118027	0.00000000	1200.54783120	0.54936313	-1.02629751	-0.12408220	3.88492641
2951	368131.87163083	0.00000001	1072.24797022	0.55746349	-1.05976786	-0.13281805	3.96205315
3001	369269.42367458	0.00000000	952.12378014	0.56567771	-1.09724647	-0.14225891	4.04843028
3051	370326.58393757	0.00000002	840.55123742	0.57400394	-1.13925888	-0.15257767	4.14506821
3101	371303.65278986	0.00000000	737.65965102	0.58238086	-1.18637369	-0.16395400	4.25322908
3151	372202.14261514	0.00000002	643.38642267	0.59067239	-1.23920113	-0.17657233	4.37450858
3201	373024.49502421	0.00000000	557.52461500	0.59865265	-1.29839288	-0.19062188	4.51094328
3251	373773.83456541	0.00000002	479.76269381	0.60599063	-1.36464227	-0.20629769	4.66515522
3301	374453.76145969	0.00000001	409.71666351	0.61223403	-1.43868379	-0.22380040	4.84055213
3351	375068.18227800	0.00000000	346.95531933	0.61679319	-1.52128952	-0.24333279	5.04160630
3401	375621.17520650	0.00000001	291.01958060	0.61893017	-1.61325909	-0.26509275	5.27423551
3451	376116.88533169	0.00000000	241.43693408	0.61776573	-1.71539633	-0.28926045	5.54629872
3501	376559.44497145	0.00000000	197.73196860	0.61233107	-1.82846198	-0.31597139	5.86818037
3551	376952.91419348	0.00000004	159.43387586	0.60170529	-1.95309213	-0.34526407	6.25334412
3601	377301.23710162	0.00000004	126.08165884	0.58527997	-2.08968198	-0.37699733	6.71857216
3651	377608.21006436	0.00000004	97.22765306	0.56314525	-2.23825864	-0.41073969	7.28341719
3701	377877.45870205	0.00000004	72.43983762	0.53646537	-2.39840074	-0.44564579	7.96840221

$Az = 5000$ km	continued						
$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	362902.74151303	-9707.98579501	1305.24876808	0.89862132	-0.83202292	-0.10587322	2.84019768
2551	363972.57847979	-9090.31513428	1170.38878962	0.91080797	-0.83949056	-0.11249988	2.85805499
2601	365037.04479238	-8475.74522215	1040.02334733	0.92083764	-0.84772481	-0.11896630	2.88404484
2651	366085.79953280	-7870.24639046	915.51772008	0.92887371	-0.85688718	-0.12523389	2.91874638
2701	367109.70251504	-7279.09572803	797.94996446	0.93515694	-0.86720481	-0.13125988	2.96286528
2751	368100.94767054	-6706.80007066	688.11169219	0.94001511	-0.87899651	-0.13700526	3.01722688
2801	369053.13178767	-6157.05631432	586.52238694	0.94388146	-0.89270646	-0.14245332	3.08272179
2851	369961.25758334	-5632.74964173	493.45445993	0.94732033	-0.90893780	-0.14764512	3.16017195
2901	370821.67711757	-5135.98619202	408.96563744	0.95104737	-0.92846452	-0.15273471	3.25010025
2951	371631.98701882	-4668.15355243	332.93516649	0.95591043	-0.95218661	-0.15804550	3.35246931
3001	372390.89000542	-4230.00070881	265.10066923	0.96278302	-0.98101056	-0.16407079	3.46661238
3051	373098.03768605	-3821.72880506	205.09312838	0.97236341	-1.01571300	-0.17135857	3.59162570
3101	373753.86812188	-3443.08492639	152.46827064	0.98498022	-1.05690521	-0.18033110	3.72713723
3151	374359.44887058	-3093.45271811	106.73338263	1.00054277	-1.10512960	-0.19120281	3.87390429
3201	374916.33302574	-2771.93550122	67.36923981	1.01864219	-1.16097656	-0.20405651	4.03388949
3251	375426.43267562	-2477.42933102	33.84730764	1.03868003	-1.22512940	-0.21895632	4.21008501
3301	375891.91161520	-2208.68493995	5.64268231	1.05993351	-1.29835732	-0.23599358	4.40649743
3351	376315.09719264	-1964.35863290	-17.75660061	1.08155828	-1.38150428	-0.25527823	4.62841746
3401	376698.40987288	-1743.05295381	-36.84321177	1.10257134	-1.47547775	-0.27691856	4.88290368
3451	377044.30834347	-1543.34837866	-52.08647493	1.12186334	-1.58120557	-0.30099258	5.17938397
3501	377355.24766706	-1363.82747649	-63.93003198	1.13829854	-1.69952256	-0.32749255	5.53022989
3551	377633.64795461	-1203.09299552	-72.79073117	1.15097251	-1.83095974	-0.35623963	5.95097409
3601	377881.87119977	-1059.78123811	-79.05833811	1.15966588	-1.97545268	-0.38677907	6.45957111
3651	378102.20418061	-932.57193236	-83.09575567	1.16536928	-2.13209657	-0.41828190	7.07413747

$Az = 5000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	366941.85148136	-12775.61466781	791.81671348	1.25432171	-0.83290973	-0.13075592	2.36359243
2551	367754.31078331	-11963.15536586	673.43731484	1.26563426	-0.83662135	-0.13830498	2.37535610
2601	368557.89731214	-11159.56883701	562.44748318	1.27375448	-0.84076694	-0.14615246	2.39380008
2651	369346.21243799	-10371.25371115	459.49188278	1.27872632	-0.84542841	-0.15423705	2.41957045
2701	370113.57636616	-9603.88978300	365.00213825	1.28068353	-0.85068448	-0.16248325	2.45346666
2751	370855.11496428	-8862.35118488	279.20558334	1.27982978	-0.85660386	-0.17079662	2.49653267
2801	371566.81183097	-8150.65431817	202.14165312	1.27641551	-0.86323816	-0.17905447	2.55018513
2851	372245.52167129	-7471.94447785	133.68443297	1.27070958	-0.87061663	-0.18708410	2.61640694
2901	372888.94618360	-6828.51996554	73.56927478	1.26296353	-0.87875419	-0.19461065	2.69805533
2951	373495.57795648	-6221.88819266	21.42118273	1.25337334	-0.88771823	-0.20113552	2.79935677
3001	374064.62060145	-5652.84554769	-23.21716352	1.24208982	-0.89792382	-0.20569030	2.92658120
3051	374595.89433375	-5121.57181541	-60.85945023	1.22954643	-0.91115948	-0.20661282	3.08800765
3101	375089.73573714	-4627.73041199	-92.05298206	1.21786718	-0.93268135	-0.20291175	3.28843059
3151	375546.89896511	-4170.56718401	-117.35973506	1.21257758	-0.96962678	-0.19939144	3.51406302
3201	375968.46370164	-3749.00244752	-137.34132800	1.21875567	-1.02150751	-0.20355687	3.73847804
3251	376355.75322943	-3361.71291973	-152.54768326	1.23593259	-1.08291571	-0.21487682	3.95433050
3301	376710.26422719	-3007.20192193	-163.50893215	1.26034560	-1.15247611	-0.23026835	4.17289103
3351	377033.60856476	-2683.85758436	-170.73001459	1.28859796	-1.23145837	-0.24838098	4.40803326
3401	377327.46642708	-2389.99972204	-174.68740369	1.31847088	-1.32131213	-0.26886929	4.67128034
3451	377593.54951623	-2123.91663289	-175.82742095	1.34840171	-1.42319379	-0.29163745	4.97370682
3501	377833.57279583	-1883.89335328	-174.56567448	1.37713409	-1.53797909	-0.31654590	5.32802691
3551	378049.23316401	-1668.23298505	-171.28723215	1.40379094	-1.66610762	-0.34327669	5.74926893
3601	378242.19350536	-1475.27264375	-166.34722081	1.42826596	-1.80724881	-0.37123229	6.25380008
3651	378414.07071569	-1303.39543348	-160.07161458	1.45167379	-1.96003283	-0.39947074	6.85668906

$Az = 5000$ km	continued						
$\phi = 60^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	371087.04581525	-14948.32650899	294.12676191	0.60620821	-0.85631415	-0.07030880	4.13737529
2551	371630.78652265	-14006.53997763	197.82268430	0.90576886	-0.77892774	-0.05666015	3.15316080
2601	372166.34753105	-13078.92110053	110.16213013	1.05074621	-0.77082972	-0.06567098	2.86681049
2651	372690.25218518	-12171.49162124	31.32011341	1.15734738	-0.76878897	-0.07615010	2.70541817
2701	373199.37746771	-11289.66076449	-38.67712337	1.23963405	-0.76828733	-0.08758727	2.60633004
2751	373691.01170252	-10438.12529109	-99.94435018	1.30335629	-0.76844424	-0.09989979	2.54749006
2801	374162.89483935	-9620.79972284	-152.72398707	1.35186387	-0.76922171	-0.11304479	2.51883191
2851	374613.23739641	-8840.78353322	-197.36817560	1.38754445	-0.77086850	-0.12694678	2.51546443
2901	375040.71742369	-8100.36640672	-234.31788642	1.41233608	-0.77375426	-0.14146272	2.53538424
2951	375444.45772828	-7401.06768610	-264.08087261	1.42795095	-0.77829612	-0.15635207	2.57864281
3001	375823.98758375	-6743.70269344	-287.21015546	1.43597799	-0.78490406	-0.17123870	2.64717796
3051	376179.19407235	-6128.46700800	-304.28437731	1.43791317	-0.79394004	-0.18553167	2.74513003
3101	376510.26820156	-5555.02979513	-315.89089719	1.43513597	-0.80580748	-0.19819288	2.87973166
3151	376817.65024710	-5022.62847497	-322.61204703	1.42901651	-0.82178631	-0.20713312	3.06249984
3201	377101.97773899	-4530.15881297	-325.01458164	1.42241490	-0.84736011	-0.20943551	3.30449108
3251	377364.03837458	-4076.25647749	-323.64207857	1.42303304	-0.89310346	-0.20939260	3.58865264
3301	377604.72910780	-3659.36789868	-319.00987561	1.43739494	-0.95815382	-0.21765389	3.87380339
3351	377825.02182404	-3277.80972155	-311.60205986	1.46427248	-1.03348459	-0.23301869	4.14907402
3401	378025.93540073	-2929.81719886	-301.87001685	1.49897131	-1.11741165	-0.25173884	4.43091426
3451	378208.51355329	-2613.58256219	-290.23208748	1.53750634	-1.21198272	-0.27256049	4.73968242
3501	378373.80765024	-2327.28478808	-277.07394387	1.57750330	-1.31886134	-0.29508729	5.09232567
3551	378522.86358925	-2069.11232853	-262.74936586	1.61774560	-1.43865650	-0.31888888	5.50401035
3601	378656.71183385	-1837.28036847	-247.58116934	1.65800808	-1.57087782	-0.34329041	5.98896520
3651	378776.35976774	-1630.04406796	-231.86209817	1.69919301	-1.71384923	-0.36733469	6.55880663

$Az = 5000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614915	-16979.64713194	-648.70025976	0.74766222	-0.75324871	-0.07175043	4.40143162
2551	379717.46614915	-15962.47275729	-693.02551602	0.95130425	-0.66845922	-0.05024738	3.42936792
2601	379717.46614917	-14963.34331544	-729.20672295	1.05425766	-0.65477166	-0.05016382	3.15860091
2651	379717.46614917	-13986.79542824	-757.45464255	1.13641619	-0.64601940	-0.05212328	2.99600248
2701	379717.46614915	-13037.09346042	-778.05960766	1.20549737	-0.63756560	-0.05491140	2.88803315
2751	379717.46614917	-12118.10363403	-791.38828250	1.26434308	-0.62825247	-0.05830456	2.81606302
2801	379717.46614917	-11233.19075609	-797.87561922	1.31484526	-0.61780670	-0.06227483	2.77071347
2851	379717.46614915	-10385.14655446	-798.01304881	1.35882135	-0.60630548	-0.06686998	2.74602137
2901	379717.46614915	-9576.15340476	-792.33432340	1.39819509	-0.59400288	-0.07218921	2.73753569
2951	379717.46614917	-8807.78228529	-781.40051451	1.43490552	-0.58125019	-0.07838280	2.74168922
3001	379717.46614917	-8081.01999984	-765.78550934	1.47067423	-0.56845636	-0.08566036	2.75581251
3051	379717.46614917	-7396.31848049	-746.06302155	1.50671349	-0.55609238	-0.09430100	2.77859960
3101	379717.46614917	-6753.65827324	-722.79574338	1.54345365	-0.54476288	-0.10465439	2.81092523
3151	379717.46614917	-6152.61883674	-696.52689537	1.58035849	-0.53536119	-0.11710168	2.85695617
3201	379717.46614917	-5592.44954811	-667.77412975	1.61590856	-0.52929676	-0.13190342	2.92555834
3251	379717.46614917	-5072.13691954	-637.02553590	1.64795252	-0.52876297	-0.14882105	3.03183185
3301	379717.46614917	-4590.46513274	-604.73737858	1.67487534	-0.53718520	-0.16641007	3.19744857
3351	379717.46614917	-4146.06840557	-571.33315554	1.69832091	-0.56073086	-0.18174477	3.44319086
3401	379717.46614917	-3737.47480182	-537.20357036	1.72570751	-0.60773126	-0.19498017	3.76209225
3451	379717.46614916	-3363.14189045	-502.70705695	1.76328140	-0.67726445	-0.21064252	4.11950930
3501	379717.46614913	-3021.48516579	-468.17054882	1.81100077	-0.76099983	-0.22808529	4.49664140
3551	379717.46614917	-2710.90043023	-433.89024558	1.86656408	-0.85460840	-0.24532486	4.89776843
3601	379717.46614916	-2429.78146084	-400.13218419	1.92808550	-0.95673744	-0.26154689	5.33500197
3651	379717.46614913	-2176.53429556	-367.13246842	1.99476677	-1.06592813	-0.27614002	5.81779676

Table B.6 Initial conditions for short transfers to a 6000 km Az halo orbit

$Az = 6000$ km

$\phi = 0\,^{\circ}$

manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	355009.54611248	0.00000001	2846.72484671	0.49085549	-0.85532933	-0.08040737	3.49085678
2551	356545.74468152	0.00000000	2687.35293066	0.49271981	-0.87037124	-0.08539153	3.53415375
2601	358099.21006405	0.00000001	2516.29526149	0.50003724	-0.88677431	-0.09335341	3.56747164
2651	359648.79169413	0.00000000	2338.00712256	0.50845180	-0.90480293	-0.10193685	3.60240198
2701	361175.66051668	0.00000001	2156.57181269	0.51690423	-0.92465930	-0.11065069	3.64213451
2751	362663.63366881	0.00000000	1975.56179526	0.52518647	-0.94655208	-0.11944733	3.68772460
2801	364099.33843756	0.00000000	1797.96664326	0.53330640	-0.97073554	-0.12840434	3.73975480
2851	365472.22354910	0.00000001	1626.17703156	0.54133109	-0.99751907	-0.13764629	3.79874329
2901	366774.43904378	0.00000001	1462.01088237	0.54934262	-1.02726839	-0.14732532	3.86525110
2951	368000.61507135	0.00000000	1306.76746713	0.55741878	-1.06040382	-0.15761573	3.93992236
3001	369147.57363327	0.00000002	1161.29687262	0.56561789	-1.09739656	-0.16871045	4.02351752
3051	370214.00606176	0.00000002	1026.07482674	0.57396348	-1.13876419	-0.18081612	4.11695653
3101	371200.14417411	0.00000002	901.27572917	0.58242910	-1.18506646	-0.19414748	4.22137703
3151	372107.44628737	0.00000000	786.83935907	0.59092421	-1.23690284	-0.20892321	4.33820801
3201	372938.31218739	0.00000002	682.52887362	0.59928217	-1.29491209	-0.22536509	4.46926062
3251	373695.83476646	0.00000001	587.97929176	0.60725024	-1.35977299	-0.24369976	4.61684199
3301	374383.59092659	0.00000000	502.73671483	0.61448142	-1.43220432	-0.26415856	4.78390531
3351	375005.47070807	0.00000002	426.28915562	0.62052935	-1.51296239	-0.28697177	4.97425182
3401	375565.54127686	0.00000000	358.09014804	0.62485087	-1.60283451	-0.31235841	5.19279281
3451	376067.94118174	0.00000001	297.57638849	0.62682915	-1.70262439	-0.34051250	5.44585648
3501	376516.79987208	0.00000000	244.18060271	0.62584404	-1.81312054	-0.37157193	5.74147272
3551	376916.17758077	0.00000000	197.34070118	0.62142964	-1.93504124	-0.40554742	6.08946462
3601	377270.02111913	0.00000000	156.50612250	0.61356363	-2.06896827	-0.44220914	6.50096144
3651	377582.13172447	0.00000000	121.14209659	0.60315128	-2.21530850	-0.48088192	6.98645525
3701	377856.14175389	0.00000000	90.73240123	0.59278715	-2.37440005	-0.51982291	7.55060490

$Az = 6000$ km continued

$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	362765.52415720	-9787.20827235	1587.95471976	0.90819918	-0.84098449	-0.12699403	2.81478809
2551	363838.76714203	-9167.57114613	1425.15628704	0.91974743	-0.84913445	-0.13407053	2.83280592
2601	364907.48349433	-8550.54747245	1267.61231416	0.92976235	-0.85807668	-0.14121532	2.85749593
2651	365961.18654458	-7942.19173274	1116.99991452	0.93817117	-0.86790629	-0.14833576	2.88975784
2701	366990.59241315	-7347.86397742	974.64848527	0.94504088	-0.87877268	-0.15535963	2.93049181
2751	367987.75876489	-6772.14971583	841.53953586	0.95055209	-0.89089817	-0.16222776	2.98067309
2801	368946.15755611	-6218.81791571	718.32330261	0.95499334	-0.90460935	-0.16889670	3.04137489
2851	369860.68066623	-5690.81775190	605.34870837	0.95877427	-0.92038191	-0.17535633	3.11371604
2901	370727.58451007	-5190.31058431	502.70246855	0.96245450	-0.93889101	-0.18167282	3.19868858
2951	371544.38532248	-4718.73041539	410.25300817	0.96677257	-0.96103625	-0.18806489	3.29683459
3001	372309.71987528	-4276.86430529	327.69527978	0.97262722	-0.98788006	-0.19498687	3.40787124
3051	373023.18691265	-3864.94391923	254.59337356	0.98093822	-1.02045796	-0.20311653	3.53063840
3101	373685.18305045	-3482.74027085	190.41877831	0.99238127	-1.05956075	-0.21314316	3.66379487
3151	374296.74407257	-3129.65535013	134.58309692	1.00716288	-1.10570911	-0.22549076	3.80697481
3201	374859.39928421	-2804.80621220	86.46481416	1.02502401	-1.15934938	-0.24028297	3.96141010
3251	375375.04344529	-2507.09891702	45.43030278	1.04542257	-1.22103103	-0.25753719	4.12969748
3301	375845.82815553	-2235.29123780	10.84963307	1.06770064	-1.29143081	-0.27730566	4.31539275
3351	376274.07259485	-1988.04419547	-17.89205239	1.09114726	-1.37130972	-0.29967760	4.52297858
3401	376662.19218773	-1763.96324404	-41.38677519	1.11499703	-1.46148695	-0.32474955	4.75815812
3451	377012.64300018	-1561.63037314	-60.19877661	1.13844085	-1.56280905	-0.35260010	5.02824178
3501	377327.87934660	-1379.62858367	-74.86168377	1.16071039	-1.67606670	-0.38321992	5.34245089
3551	377610.32205559	-1216.56020960	-85.87718762	1.18127969	-1.80185320	-0.41641712	5.71186657
3601	377862.33501111	-1071.06046194	-93.71474729	1.20024699	-1.94036456	-0.45170415	6.14837188
3651	378086.20785246	-941.80741667	-98.81194192	1.21894477	-2.09120593	-0.48806816	6.66134955

$Az = 6000$ km continued

$\phi = 45\,^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	366839.24306427	-12878.22308489	967.69287852	1.26272894	-0.84710534	-0.14888466	2.34850886
2551	367654.85091133	-12062.61523782	824.39314828	1.27567405	-0.85219935	-0.15671302	2.35765057
2601	368462.09791802	-11255.36823115	689.91888326	1.28555705	-0.85780967	-0.16475735	2.37303686
2651	369254.48836900	-10462.97778017	565.06992923	1.29242143	-0.86401184	-0.17295585	2.39520326
2701	370026.24853266	-9691.21761651	450.38717686	1.29639470	-0.87087683	-0.18124309	2.42480869
2751	370772.41627620	-8945.04987297	346.16276130	1.29767217	-0.87846692	-0.18955407	2.46270610
2801	371488.89525157	-8228.57089760	252.45968915	1.29650123	-0.88683362	-0.19783014	2.51003387
2851	372172.46962206	-7544.99652711	169.13906953	1.29316705	-0.89601883	-0.20602527	2.56833957
2901	372820.78054228	-6896.68560688	95.89238564	1.28798111	-0.90606216	-0.21410739	2.63975309
2951	373432.26999223	-6285.19615693	32.27598657	1.28127384	-0.91702112	-0.22204072	2.72723617
3001	374006.10033411	-5711.36581502	-22.25481680	1.27339226	-0.92902639	-0.22971241	2.83495098
3051	374542.05897880	-5175.40717037	-68.31414171	1.26471280	-0.94246145	-0.23672075	2.96877570
3101	375040.45705327	-4677.00909590	-106.55781771	1.25578229	-0.95863593	-0.24194754	3.13654615
3151	375502.02945362	-4215.43669554	-137.66029185	1.24817967	-0.98188688	-0.24377279	3.34440148
3201	375927.84169891	-3789.62445025	-162.29630396	1.24638117	-1.02066376	-0.24486842	3.58124035
3251	376319.20699832	-3398.25915084	-181.12705798	1.25532439	-1.07709104	-0.25321608	3.81859943
3301	376677.61517818	-3039.85097094	-194.79034974	1.27532622	-1.14465285	-0.26931086	4.04566670
3351	377004.67375371	-2712.79239546	-203.89398513	1.30302615	-1.22061846	-0.28996252	4.27347360
3401	377302.06046817	-2415.40568095	-209.01179737	1.33492611	-1.30599389	-0.31363143	4.51767473
3451	377571.48603865	-2145.98011051	-210.68161606	1.36879329	-1.40225904	-0.33993227	4.79099381
3501	377814.66555519	-1902.80059398	-209.40462153	1.40334593	-1.51046684	-0.36869318	5.10437123
3551	378033.29690387	-1684.16924524	-205.64561480	1.43791166	-1.63122079	-0.39959126	5.46881213
3601	378229.04464864	-1488.42150051	-199.83382911	1.47254486	-1.76458587	-0.43200114	5.89503615
3651	378403.52795049	-1313.93819861	-192.36399594	1.50856545	-1.90992430	-0.46473330	6.38975940

$Az = 6000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	371020.76928149	-15063.12083283	365.70583377	0.59984758	-0.85750507	-0.08183427	4.14838961
2551	371566.94334772	-14117.11960033	248.88284868	0.89911561	-0.78106315	-0.06680352	3.16195716
2601	372105.18560688	-13184.85666070	142.44975169	1.04276144	-0.77401933	-0.07684353	2.87690500
2651	372631.96761785	-12272.44345317	46.63188516	1.14850471	-0.77313535	-0.08833255	2.71587401
2701	373144.11653748	-11385.37550335	-38.52632640	1.23042642	-0.77394699	-0.10062206	2.61649763
2751	373638.87411497	-10528.43024168	-113.15213835	1.29428773	-0.77557262	-0.11355852	2.55678734
2801	374113.93801503	-9705.59542993	-177.52839468	1.34344617	-0.77794843	-0.12703839	2.52663810
2851	374567.48145676	-8920.03514545	-232.07184171	1.38029060	-0.78127780	-0.14093630	2.52104100
2901	374998.15050407	-8174.09447422	-277.30779924	1.40675014	-0.78587014	-0.15508377	2.53778956
2951	375405.04128061	-7469.33897613	-313.84339745	1.42451973	-0.79208165	-0.16926583	2.57660687
3001	375787.66139242	-6806.62150251	-342.34143858	1.43518057	-0.80029421	-0.18323199	2.63886936
3051	376145.88079426	-6186.16729822	-363.49651459	1.44028696	-0.81093108	-0.19671847	2.72763820
3101	376479.87732283	-5607.66834123	-378.01445208	1.44146912	-0.82456162	-0.20945486	2.84780913
3151	376790.08142071	-5070.37908294	-386.59559683	1.44062346	-0.84226177	-0.22107859	3.00595495
3201	377077.12352079	-4573.20758168	-389.92198264	1.44039273	-0.86665015	-0.23102935	3.20810997
3251	377341.78641186	-4114.79800753	-388.64809027	1.44517712	-0.90334166	-0.23987502	3.45034273
3301	377584.96385134	-3693.60232709	-383.39469847	1.45999677	-0.95693049	-0.25167312	3.71072975
3351	377807.62584475	-3307.94044152	-374.74523847	1.48610949	-1.02460257	-0.26898438	3.97149662
3401	378010.79038854	-2956.04912944	-363.24405728	1.52133400	-1.10253422	-0.29054669	4.23450943
3451	378195.50107158	-2636.12084164	-349.39604268	1.56265433	-1.19029346	-0.31475385	4.51280227
3501	378362.80970992	-2346.33377950	-333.66713958	1.60774390	-1.28904888	-0.34095141	4.82050012
3551	378513.76309788	-2084.87484197	-316.48537300	1.65538168	-1.39968986	-0.36864440	5.16932435
3601	378649.39296696	-1849.95701770	-298.24207628	1.70546061	-1.52243186	-0.39703344	5.56747413
3651	378770.70830076	-1639.83269584	-279.29309531	1.75955396	-1.65740939	-0.42404762	6.01314343

$Az = 6000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614917	-17084.15185652	-774.45518152	0.73423143	-0.76296631	-0.08565697	4.48019536
2551	379717.46614917	-16062.19160530	-828.45709011	0.94745328	-0.67198047	-0.05927296	3.43484796
2601	379717.46614915	-15058.07304048	-872.64339289	1.05133763	-0.65890951	-0.05889355	3.16032138
2651	379717.46614915	-14076.38183387	-907.26229573	1.13408199	-0.65091481	-0.06094328	2.99597619
2701	379717.46614915	-13121.43175193	-932.65822547	1.20336031	-0.64329427	-0.06392327	2.88751334
2751	379717.46614915	-12197.13696462	-949.26806228	1.26189905	-0.63489600	-0.06753790	2.81625537
2801	379717.46614915	-11306.90715271	-957.61152930	1.31150850	-0.62547947	-0.07172142	2.77290078
2851	379717.46614915	-10453.57458931	-958.27699271	1.35399758	-0.61517891	-0.07648933	2.75155739
2901	379717.46614915	-9639.35707002	-951.90438993	1.39138573	-0.60433105	-0.08190475	2.74773903
2951	379717.46614917	-8865.85552544	-939.16711304	1.42582955	-0.59339245	-0.08807143	2.75763184
3001	379717.46614914	-8134.08130498	-920.75447879	1.45938370	-0.58288862	-0.09513373	2.77801923
3051	379717.46614914	-7444.50583974	-897.35602238	1.49368096	-0.57340112	-0.10327444	2.80670071
3101	379717.46614914	-6797.12468310	-869.64837909	1.52963840	-0.56562449	-0.11270156	2.84326256
3151	379717.46614914	-6191.52845801	-838.28506791	1.56730731	-0.56051419	-0.12361113	2.88995741
3201	379717.46614914	-5626.97452875	-803.88912755	1.60596985	-0.55950107	-0.13610514	2.95236151
3251	379717.46614914	-5102.45483864	-767.04830225	1.64459700	-0.56467724	-0.15006817	3.03927181
3301	379717.46614917	-4616.75699443	-728.31233310	1.68276600	-0.57877451	-0.16509936	3.16076154
3351	379717.46614914	-4168.51708667	-688.19185645	1.72159630	-0.60462157	-0.18048071	3.32391835
3401	379717.46614913	-3756.26385773	-647.15842221	1.76332555	-0.64428035	-0.19499837	3.53054148
3451	379717.46614917	-3378.45462423	-605.64519420	1.81033005	-0.69973480	-0.20676813	3.77723935
3501	379717.46614913	-3033.50387475	-564.04796237	1.86104826	-0.77032196	-0.20925244	4.07928473
3551	379717.46614917	-2719.80575394	-522.72616847	1.90993654	-0.86773876	-0.18212098	4.49005395
3601	379717.46614913	-2435.75176373	-482.00371153	1.92287507	-1.00463096	-0.35401902	5.29438467
3651	379717.46614913	-2179.74503013	-442.16935383	2.01296259	-1.03542630	-0.41628039	5.48385659

Table B.7 Initial conditions for short transfers to a 7000 km Az halo orbit

$Az = 7000$ km

$\phi = 0^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	354770.66579917	0.00000000	3355.75907911	0.44422433	-0.85859290	-0.07161611	3.60674237
2551	356312.11453777	0.00000000	3170.81386520	0.48197556	-0.87077886	-0.09208224	3.55271880
2601	357872.35520848	0.00000001	2971.61971607	0.49712151	-0.88734073	-0.10561532	3.56396069
2651	359429.99092692	0.00000000	2763.44733951	0.50756608	-0.90578018	-0.11679910	3.59213151
2701	360965.94905974	0.00000000	2551.14454789	0.51661328	-0.92600633	-0.12724156	3.62877189
2751	362463.81346403	0.00000001	2338.96545808	0.52509616	-0.94817943	-0.13749449	3.67210731
2801	363909.99475328	0.00000001	2130.48002217	0.53329132	-0.97253272	-0.14781779	3.72195786
2851	365293.74616023	0.00000001	1928.55134188	0.54133780	-0.99935822	-0.15840106	3.77861571
2901	366607.04605442	0.00000001	1735.36419668	0.54934038	-1.02900725	-0.16942959	3.84255510
2951	367844.37753908	0.00000000	1552.48771464	0.55739176	-1.06188995	-0.18110485	3.91435623
3001	369002.43949294	0.00000002	1380.95697722	0.56557049	-1.09847193	-0.19364883	3.99469770
3051	370079.82227893	0.00000000	1221.36144755	0.57393005	-1.13926859	-0.20730018	4.08438154
3101	371076.67649421	0.00000000	1073.93154645	0.58248516	-1.18483891	-0.22230544	4.18438134
3151	371994.39632199	0.00000002	938.61787324	0.59119906	-1.23578111	-0.23890982	4.29590664
3201	372835.33185440	0.00000000	815.16015801	0.59997468	-1.29273266	-0.25735234	4.42047496
3251	373602.53827787	0.00000000	703.14494275	0.60865167	-1.35637461	-0.27786644	4.55998403
3301	374299.56461952	0.00000004	602.05226517	0.61701090	-1.42743732	-0.30067749	4.71678481
3351	374930.28104594	0.00000002	511.29236924	0.62478838	-1.50670438	-0.32598104	4.89376256
3401	375498.74134308	0.00000001	430.23382952	0.63170472	-1.59501866	-0.35389306	5.09441285
3451	376009.07596187	0.00000000	358.22457238	0.63752617	-1.69330423	-0.38436794	5.32282856
3501	376465.41057580	0.00000000	294.60721020	0.64219733	-1.80259319	-0.41697343	5.58345692
3551	376871.80521546	0.00000000	238.72994781	0.64606154	-1.92378764	-0.45011490	5.88106351
3601	377232.20948177	0.00000000	189.95412468	0.64957563	-2.05570895	-0.48033258	6.22552662
3651	377550.42994430	0.00000000	147.65925450	0.64835402	-2.19416853	-0.50692264	6.65738622
3701	377830.10648570	0.00000000	111.24623365	0.62427231	-2.35457534	-0.53614153	7.28318122

$Az = 7000$ km continued

$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	362602.99606587	-9881.04390961	1882.66364500	0.72645968	-0.83772028	-0.08912432	3.19390341
2551	363680.15034123	-9259.14859879	1691.42036431	0.81580827	-0.84340457	-0.11200569	3.03797868
2601	364753.79263899	-8639.28092915	1506.10965483	0.86590535	-0.85475355	-0.13110391	2.97936387
2651	365813.26322196	-8027.59530287	1328.74228781	0.89797767	-0.86789906	-0.14685092	2.96344904
2701	366849.10717358	-7429.55051858	1160.91924311	0.92010335	-0.88196814	-0.16019957	2.97260234
2751	367853.21967489	-6849.82589565	1003.82990544	0.93608903	-0.89688139	-0.17188430	2.99988434
2801	368818.92362856	-6292.27645805	858.27061274	0.94803981	-0.91284816	-0.18240458	3.04248023
2851	369740.97842034	-5759.92787579	724.67942886	0.95732116	-0.93024849	-0.19210755	3.09946172
2901	370615.52602305	-5255.00758194	603.18208504	0.96498846	-0.94963781	-0.20127109	3.17080470
2951	371439.98638488	-4779.00517012	493.64386562	0.97201484	-0.97179330	-0.21018975	3.25676111
3001	372212.91721253	-4332.75334869	395.72272124	0.97942027	-0.99774406	-0.21927816	3.35726585
3051	372933.85379089	-3916.52042111	308.91985922	0.98829853	-1.02870096	-0.22916490	3.47140461
3101	373603.14290426	-3530.10617136	232.62522505	0.99968493	-1.06582124	-0.24065280	3.59738142
3151	374221.78204873	-3172.93469477	166.15642446	1.01428320	-1.10993073	-0.25443492	3.73345830
3201	374791.27177604	-2844.13964740	108.79059045	1.03226656	-1.16151447	-0.27080833	3.87929688
3251	375313.48580150	-2542.63923923	59.78940517	1.05335672	-1.22100937	-0.28976917	4.03633609
3301	375790.56080780	-2267.19985592	18.41794119	1.07708221	-1.28902056	-0.31128318	4.20708992
3351	376224.80586172	-2016.48835711	-16.04177731	1.10298139	-1.36628297	-0.33528194	4.39453398
3401	376618.63000460	-1789.11388224	-44.28151908	1.13067340	-1.45359765	-0.36146842	4.60205802
3451	376974.48580185	-1583.66044186	-66.96095839	1.15990057	-1.55190677	-0.38915038	4.83336781
3501	377294.82629814	-1398.71177014	-84.70431867	1.19064456	-1.66193436	-0.41639381	5.09324707
3551	377582.07279756	-1232.86992637	-98.09883980	1.22256779	-1.78159616	-0.43935831	5.39723143
3601	377838.59105578	-1084.76904089	-107.69449721	1.24980491	-1.90882218	-0.45754138	5.79735781
3651	378066.67374454	-953.08543914	-114.00452686	1.25605762	-2.07220055	-0.48114751	6.35687626

$Az = 7000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	366717.60214004	-12999.86400913	1153.34969943	0.89386001	-0.81097171	-0.08887123	2.95459284
2551	367536.85989536	-12180.60625379	984.45428499	0.99341265	-0.81531776	-0.10631238	2.79807767
2601	368348.37447305	-11369.09167610	825.79360473	1.06231918	-0.82258983	-0.12289218	2.71375857
2651	369145.53442735	-10571.93172180	678.33762866	1.11185928	-0.83120235	-0.13835635	2.67004154
2701	369922.45385967	-9795.01228948	542.74961667	1.14787028	-0.84068086	-0.15271155	2.65365364
2751	370674.06542418	-9043.40072496	419.39757865	1.17388029	-0.85089105	-0.16603436	2.65826655
2801	371396.17708865	-8321.28906049	308.37709784	1.19224675	-0.86184074	-0.17841477	2.68090183
2851	372085.48850953	-7631.97763964	209.54333376	1.20468036	-0.87362531	-0.18994218	2.72053311
2901	372739.56824987	-6977.89789929	122.54913315	1.21253054	-0.88643390	-0.20070678	2.77748572
2951	373356.79755088	-6360.66859829	46.88587059	1.21697558	-0.90060474	-0.21080368	2.85314462
3001	373936.28921239	-5781.17693678	-18.07611675	1.21919199	-0.91674644	-0.22033572	2.94969095
3051	374477.79117135	-5239.67497781	-73.05000467	1.22055681	-0.93595878	-0.22943640	3.06951759
3101	374981.58386047	-4735.88228866	-118.79955813	1.22291681	-0.96014537	-0.23842211	3.21369998
3151	375448.37888919	-4269.08725994	-156.11168258	1.22880154	-0.99207787	-0.24825905	3.37905782
3201	375879.22457620	-3838.24157293	-185.77463601	1.24092181	-1.03418746	-0.26074528	3.55677304
3251	376275.42181734	-3442.04433179	-208.56158175	1.26058054	-1.08662361	-0.27681350	3.73902809
3301	376638.45197482	-3079.01417431	-225.21884594	1.28711472	-1.14851821	-0.29587319	3.92562725
3351	376969.91708323	-2747.54906594	-236.45809254	1.31914426	-1.22005854	-0.31731854	4.12067143
3401	377271.49169051	-2445.97445861	-242.95159938	1.35558392	-1.30178281	-0.34006270	4.32915828
3451	377544.88505945	-2172.58108972	-245.32987070	1.39562539	-1.39439569	-0.36226084	4.55705407
3501	377791.81215614	-1925.65399302	-244.18091742	1.43838205	-1.49791874	-0.38100388	4.81488351
3551	378013.97177843	-1703.49437068	-240.05065186	1.48069533	-1.60640004	-0.39365898	5.14269805
3601	378213.03023874	-1504.43591042	-233.44395575	1.50992535	-1.74256803	-0.40715196	5.59495858
3651	378390.60916573	-1326.85698344	-224.82608282	1.53864107	-1.89491175	-0.41495474	6.12882947

$Az = 7000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	370942.13791164	-15199.31436048	444.45428830	1.04352980	-0.78034213	-0.08132822	2.77031753
2551	371491.15609605	-14248.38697082	306.41956780	1.14897217	-0.78300959	-0.09237845	2.61944249
2601	372032.54207759	-13310.67894425	180.52906201	1.23406120	-0.78612282	-0.10388601	2.51824718
2651	372562.70554119	-12392.40888898	67.06717978	1.30288204	-0.78930408	-0.11573261	2.45038659
2701	373078.41405802	-11499.17553593	-33.89608999	1.35795470	-0.79258486	-0.12782608	2.40752583
2751	373576.85363999	-10635.85285546	-122.49450633	1.40109923	-0.79612623	-0.14006232	2.38506803
2801	374055.67131463	-9806.51631540	-199.04672507	1.43377134	-0.80012729	-0.15231060	2.38053006
2851	374512.99560472	-9014.40740948	-264.03075742	1.45721690	-0.80478834	-0.16441063	2.39285315
2901	374947.43421834	-8261.93765789	-318.05405813	1.47255040	-0.81029601	-0.17618088	2.42213745
2951	375358.05125263	-7550.72809203	-361.82187020	1.48080046	-0.81682569	-0.18744121	2.46962426
3001	375744.32827720	-6881.67665967	-396.10627924	1.48295323	-0.82457234	-0.19805362	2.53786117
3051	376106.11463251	-6255.04431079	-421.71792112	1.48003531	-0.83384186	-0.20797982	2.63099379
3101	376443.57226581	-5670.55054451	-439.48162145	1.47331413	-0.84527469	-0.21733205	2.75498125
3151	376757.11971578	-5127.47043058	-450.21658073	1.46475357	-0.86035608	-0.22635238	2.91695038
3201	377047.37877841	-4624.72698678	-454.72116278	1.45790614	-0.88248618	-0.23538990	3.12115213
3251	377315.12621771	-4160.97481829	-453.76194202	1.45908544	-0.91812575	-0.24605582	3.35636608
3301	377561.25181113	-3734.67278548	-448.06642293	1.47493245	-0.97121910	-0.26154617	3.59038215
3351	377786.72315671	-3344.14495928	-438.31873782	1.50488509	-1.03520669	-0.27864844	3.81238284
3401	377992.55703812	-2987.63021872	-425.15762185	1.54482947	-1.10960852	-0.29536542	4.03149111
3451	378179.79673683	-2663.32154740	-409.17602078	1.59053630	-1.19077201	-0.30696988	4.27239476
3501	378349.49445378	-2369.39647965	-390.92177742	1.63682676	-1.28141674	-0.31342726	4.56927309
3551	378502.69791671	-2104.04029795	-370.89894409	1.68154933	-1.39626002	-0.31700604	4.92574048
3601	378640.44025100	-1865.46357661	-349.56936552	1.72910328	-1.52466012	-0.30803158	5.33346122
3651	378763.73225572	-1651.91556025	-327.35426073	1.76944477	-1.67525231	-0.27939519	5.86856686

$Az = 7000$ km	continued						
$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614915	-17208.16142428	-897.92955686	0.88216459	-0.68698190	-0.06777941	3.59096344
2551	379717.46614917	-16180.56681795	-962.05813739	0.90382595	-0.68425811	-0.07206048	3.60686603
2601	379717.46614917	-15170.56964282	-1014.67643659	0.92657920	-0.68211222	-0.07732151	3.62685752
2651	379717.46614917	-14182.81394180	-1056.06751406	0.95397594	-0.67947666	-0.08314241	3.63484600
2701	379717.46614917	-13221.67229808	-1086.62770679	0.98681042	-0.67578435	-0.08909142	3.62684419
2751	379717.46614915	-12291.11598794	-1106.86240039	1.02430021	-0.67109665	-0.09490901	3.60680744
2801	379717.46614915	-11394.60815732	-1117.37487493	1.06551235	-0.66571330	-0.10056497	3.57982905
2851	379717.46614915	-10535.02940851	-1118.84969802	1.10996818	-0.65989265	-0.10620985	3.54896098
2901	379717.46614917	-9714.63977428	-1112.03269237	1.15762120	-0.65383205	-0.11214286	3.51526561
2951	379717.46614917	-8935.07592681	-1097.70963977	1.20858804	-0.64780020	-0.11878952	3.47914979
3001	379717.46614917	-8197.37853134	-1076.68565408	1.26277986	-0.64233210	-0.12657360	3.44212835
3051	379717.46614917	-7502.04233845	-1049.76669043	1.31957658	-0.63837027	-0.13564590	3.40827111
3101	379717.46614914	-6849.08088530	-1017.74409852	1.37777706	-0.63726080	-0.14567973	3.38435988
3151	379717.46614914	-6238.09821504	-981.38259626	1.43590598	-0.64072041	-0.15593893	3.37874732
3201	379717.46614917	-5668.36133757	-941.41160882	1.49267862	-0.65096287	-0.16533876	3.40005949
3251	379717.46614917	-5138.86880772	-898.51962045	1.54733057	-0.67078436	-0.17180422	3.45670458
3301	379717.46614917	-4648.41245741	-853.35101777	1.65054505	-0.64369634	-0.14675819	3.29236991
3351	379717.46614914	-4195.63075287	-806.50484024	1.71073450	-0.65871524	-0.13423158	3.36125575
3401	379717.46614917	-3779.05338252	-758.53486635	1.75265484	-0.68512227	-0.11057903	3.55790206
3451	379717.46614917	-3397.13748476	-709.95052178	1.79525773	-0.75298206	-0.07174807	3.82010848
3501	379717.46614916	-3048.29644805	-661.21817616	1.85277317	-0.85273734	0.02910336	4.01091071
3551	379717.46614916	-2730.92250289	-612.76247753	1.93593249	-0.96101632	0.32636126	3.78090215
3601	379717.46614913	-2443.40445171	-564.96745015	2.02332005	-0.87177954	0.17886008	4.10058881

Table B.8 Initial conditions for short transfers to a 8000 km Az halo orbit

$Az = 8000$ km

$\phi = 0^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	354494.06056376	0.00000001	3880.62173670	0.44413436	-0.85695527	-0.08025872	3.59588017
2551	356041.47172835	0.00000000	3670.66996965	0.48109292	-0.87044698	-0.10298019	3.54330903
2601	357609.44631981	0.00000000	3443.60757395	0.49649845	-0.88783481	-0.11835684	3.55275770
2651	359176.30122904	0.00000000	3205.55361514	0.50719176	-0.90692649	-0.13111636	3.57891871
2701	360722.68170178	0.00000000	2962.15970654	0.51639947	-0.92769159	-0.14295451	3.61353638
2751	362231.90193570	0.00000000	2718.40273659	0.52497714	-0.95029615	-0.15448600	3.65475197
2801	363690.12234830	0.00000000	2478.47263236	0.53321783	-0.97496108	-0.16600821	3.70231250
2851	365086.37053928	0.00000000	2245.74084711	0.54126676	-1.00196132	-0.17773361	3.75646650
2901	366412.42675484	0.00000001	2022.79016544	0.54923266	-1.03163335	-0.18986503	3.81765356
2951	367662.60435431	0.00000001	1811.48563078	0.55721738	-1.06437916	-0.20262209	3.88640589
3001	368833.46003025	0.00000000	1613.06850524	0.56531865	-1.10066561	-0.21624858	3.96332016
3051	369923.46746490	0.00000002	1428.25882404	0.57362205	-1.14101895	-0.23100764	4.04906557
3101	370932.68330972	0.00000000	1257.35617479	0.58218773	-1.18601588	-0.24716601	4.14442223
3151	371862.42746750	0.00000002	1100.33211032	0.59103650	-1.23627476	-0.26497039	4.25034619
3201	372714.99236523	0.00000001	956.91068615	0.60013988	-1.29245308	-0.28462310	4.36804754
3251	373493.38931829	0.00000000	826.63588898	0.60941867	-1.35525667	-0.30626403	4.49905697
3301	374201.13479004	0.00000000	708.92624256	0.61875326	-1.42545926	-0.32994864	4.64526496
3351	374842.07558450	0.00000000	603.11776939	0.62800282	-1.50390575	-0.35556809	4.80899389
3401	375420.24959310	0.00000001	508.49691985	0.63700851	-1.59139896	-0.38261892	4.99343110
3451	375939.77744410	0.00000000	424.32519648	0.64546956	-1.68822497	-0.40993041	5.20439068
3501	376404.77995793	0.00000000	349.85712316	0.65233916	-1.79345004	-0.43627032	5.45470420
3551	376819.31641929	0.00000000	284.35302511	0.65438177	-1.90758226	-0.46232474	5.76724204
3601	377187.33912138	0.00000000	227.08785474	0.64748234	-2.03918389	-0.49081059	6.16047127
3651	377512.66024530	0.00000000	177.35705970	0.63856712	-2.17655907	-0.51822961	6.63282757
3701	377798.92779883	0.00000004	134.48026416	0.59396656	-2.34274314	-0.55009594	7.38165375

$Az = 8000$ km continued

$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	362414.99101715	-9989.58867512	2191.53180595	0.72275243	-0.83915356	-0.09955286	3.19117332
2551	363496.50264343	-9365.17764655	1971.27132271	0.81153599	-0.84699546	-0.12388825	3.03615095
2601	364575.69628398	-8742.10490766	1757.52092174	0.86244558	-0.86013249	-0.14392822	2.97516012
2651	365641.71144453	-8126.64076777	1552.65104875	0.89582625	-0.87481013	-0.16035528	2.95568517
2701	366684.89423749	-7524.35890144	1358.55851991	0.91937030	-0.89017796	-0.17423314	2.96075081
2751	367696.95042299	-6940.04799029	1176.66221633	0.93668970	-0.90614386	-0.18635183	2.98366459
2801	368671.02885729	-6377.66354405	1007.92309003	0.94978065	-0.92288622	-0.19725493	3.02170721
2851	369601.73401500	-5840.32067069	852.88361265	0.95994275	-0.94074475	-0.20733597	3.07398707
2901	370485.07391229	-5330.32414320	711.72067575	0.96819249	-0.96023110	-0.21692068	3.14050024
2951	371318.35566638	-4849.22869819	584.30574428	0.97548803	-0.98208493	-0.22634156	3.22152759
3001	372100.04422666	-4397.92059749	470.26665847	0.98286781	-1.00732904	-0.23602417	3.31703880
3051	372829.60032459	-3976.71118794	369.04663125	0.99150710	-1.03724896	-0.24658018	3.42605441
3101	373507.31209695	-3585.43411373	279.95736256	1.00262869	-1.07319367	-0.25880957	3.54633424
3151	374134.13186915	-3223.53954954	202.22453919	1.01721633	-1.11620244	-0.27342308	3.67514328
3201	374711.52615281	-2890.18080444	135.02511637	1.03567606	-1.16677079	-0.29056921	3.81114391
3251	375241.34362446	-2584.29054457	77.51661103	1.05776520	-1.22510780	-0.30975674	3.95572610
3301	375725.70307969	-2304.64548270	28.85917378	1.08288295	-1.29165598	-0.33032881	4.11229663
3351	376166.90130327	-2049.91956952	-11.76851587	1.11046138	-1.36731276	-0.35175180	4.28451482
3401	376567.33940449	-1818.72652402	-45.15839876	1.14001469	-1.45255819	-0.37293554	4.47753695
3451	376929.46537457	-1609.65299767	-72.06614010	1.17009646	-1.54490216	-0.39188190	4.70897445
3501	377255.73028068	-1421.28386630	-93.20721687	1.19573515	-1.64469450	-0.40803190	5.01554192
3551	377548.55547818	-1252.22115970	-109.25516857	1.21187766	-1.77543628	-0.43099627	5.38699257
3601	377810.30839706	-1101.09804157	-120.84135026	1.24035686	-1.90525355	-0.44662482	5.77344063
3651	378043.28473455	-966.58909035	-128.55567302	1.24422730	-2.05870595	-0.46021385	6.37604398

$Az = 8000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	366576.74919165	-13140.71695752	1350.60804450	0.88865187	-0.81369392	-0.09903276	2.95603295
2551	367400.12074593	-12317.34540323	1155.33251527	0.98686310	-0.81963885	-0.11718243	2.80174264
2601	368216.47903440	-11500.98711475	971.66670193	1.05545835	-0.82830187	-0.13402806	2.71747297
2651	369019.07774540	-10698.38840375	800.76866966	1.10526644	-0.83810144	-0.14939978	2.67281771
2701	369801.90000470	-9915.56614444	643.43984510	1.14183740	-0.84853152	-0.16337640	2.65500562
2751	370559.75542238	-9157.71072678	500.13749038	1.16848291	-0.85942417	-0.17609329	2.65799792
2801	371288.33992739	-8429.12622178	371.00066416	1.18739010	-0.87075968	-0.18769387	2.67902175
2851	371984.25412030	-7733.21202886	255.88709636	1.20014048	-0.88262210	-0.19832443	2.71721487
2901	372644.98138905	-7072.48476009	154.41735573	1.20800374	-0.89522162	-0.20814283	2.77302460
2951	373268.83162796	-6448.63452120	66.02232974	1.21215069	-0.90897214	-0.21733003	2.84786470
3001	373854.85934473	-5862.60680441	-10.00968210	1.21386087	-0.92463576	-0.22610506	2.94371259
3051	374402.76597260	-5314.70017654	-74.48921261	1.21476989	-0.94354601	-0.23477304	3.06224266
3101	374912.79570290	-4804.67044624	-128.28720519	1.21714785	-0.96784307	-0.24390262	3.20291926
3151	375385.63256290	-4331.83358627	-172.30296226	1.22399396	-1.00033545	-0.25469036	3.36006643
3201	375822.30440287	-3895.16174630	-207.43869105	1.23827837	-1.04316804	-0.26869348	3.52265948
3251	376224.09736300	-3493.36878612	-234.58028105	1.26105512	-1.09582478	-0.28558415	3.68343287
3301	376592.48254771	-3124.98360146	-254.58357688	1.29068181	-1.15635948	-0.30283525	3.84795956
3351	376929.05521920	-2788.41092992	-268.26523364	1.32452683	-1.22485414	-0.31898124	4.02855589
3401	377235.48582345	-2481.98032567	-276.39720762	1.36124649	-1.30432398	-0.33427197	4.23086751
3451	377513.48155475	-2203.98459441	-279.70399538	1.39977223	-1.39154718	-0.34646104	4.47013516
3501	377764.75686756	-1952.70928155	-278.86184740	1.43445684	-1.48793913	-0.35537990	4.78722877
3551	377991.01126304	-1726.45488613	-274.49931515	1.46172247	-1.61311595	-0.36519614	5.18225824
3601	378193.91274534	-1523.55340377	-267.19862204	1.50087184	-1.74127082	-0.36550093	5.58461912
3651	378375.08549498	-1342.38065416	-257.49746622	1.50185618	-1.92061386	-0.36237518	6.28320843

$Az = 8000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	370851.00175841	-15357.16680828	531.74671209	1.03774128	-0.78358903	-0.09070518	2.77391067
2551	371403.25804384	-14400.63086311	371.68660847	1.14095013	-0.78720686	-0.10211847	2.62642365
2601	371948.23690296	-13456.69979007	225.53288305	1.22439884	-0.79122615	-0.11375725	2.52715896
2651	372482.27571263	-12531.71743848	93.63953702	1.29200061	-0.79526698	-0.12547168	2.46050040
2701	373002.07233823	-11631.40327338	-23.88897683	1.34615514	-0.79931681	-0.13714123	2.41846874
2751	373504.74753201	-10760.74429804	-127.18570411	1.38857100	-0.80347127	-0.14863975	2.39669790
2801	373987.88898851	-9923.91874814	-216.59954218	1.42058593	-0.80784995	-0.15982604	2.39290337
2851	374449.57282004	-9124.25889487	-292.66572706	1.44331497	-0.81256763	-0.17054698	2.40624457
2901	374888.36172305	-8364.25422104	-356.07116187	1.45772973	-0.81773443	-0.18065160	2.43710057
2951	375303.28217227	-7645.59092193	-407.61765778	1.46471621	-0.82348571	-0.19001610	2.48709196
3001	375693.78511261	-6969.21998872	-448.18596010	1.46515114	-0.83006138	-0.19857941	2.55927476
3051	376059.69559348	-6335.44444483	-478.70283496	1.46006012	-0.83798065	-0.20638339	2.65839135
3101	376401.15679067	-5744.01630252	-500.11271671	1.45097822	-0.84840976	-0.21360043	2.79074483
3151	376718.57312611	-5194.23508239	-513.35463879	1.44071301	-0.86388640	-0.22056130	2.96217077
3201	377012.55609393	-4685.04164552	-519.34452153	1.43459428	-0.88933479	-0.22816553	3.17022139
3251	377283.87520692	-4215.10315675	-518.96242095	1.44091841	-0.93123361	-0.23932151	3.38925683
3301	377533.41537846	-3782.88690117	-513.04406037	1.46494012	-0.98840592	-0.25392925	3.58538972
3351	377762.14117920	-3386.72219322	-502.37584195	1.50037339	-1.04789047	-0.26298082	3.77940498
3401	377971.06776307	-3024.85073497	-487.69252690	1.53763992	-1.11210758	-0.26625483	4.01793938
3451	378161.23784224	-2695.46649570	-469.67683901	1.57898926	-1.20501747	-0.27128205	4.26987015
3501	378333.70386557	-2396.74658079	-448.96035138	1.62554193	-1.28991174	-0.26304827	4.56913065
3551	378489.51446088	-2126.87471335	-426.12513302	1.65751207	-1.41894586	-0.24871555	4.99501343
3601	378629.70421113	-1884.05894322	-401.70574484	1.68574838	-1.56892864	-0.20953588	5.51523241
3651	378755.28589335	-1666.54508902	-376.19126923	1.75726132	-1.68313428	-0.14253869	5.81767527

$Az = 8000$ km	continued						
$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614915	-17351.92988032	-1018.65290390	0.87974199	-0.69010133	-0.07565759	3.58697614
2551	379717.46614915	-16317.86322486	-1093.43933790	0.90068420	-0.68810745	-0.08030615	3.60546477
2601	379717.46614915	-15301.10665225	-1154.99398972	0.92208896	-0.68707602	-0.08614310	3.63108397
2651	379717.46614915	-14306.37210499	-1203.63173170	0.94815616	-0.68585736	-0.09265374	3.64490218
2701	379717.46614915	-13338.10061615	-1239.79824816	0.98009154	-0.68372962	-0.09926530	3.64077483
2751	379717.46614917	-12400.32994968	-1264.06542512	1.01713499	-0.68070994	-0.10559954	3.62240617
2801	379717.46614917	-11496.58552561	-1277.11868016	1.05817881	-0.67716677	-0.11154640	3.59574132
2851	379717.46614915	-10629.80426132	-1279.73792874	1.10255191	-0.67347035	-0.11717654	3.56480717
2901	379717.46614917	-9802.29543046	-1272.77453582	1.15005996	-0.66993748	-0.12265879	3.53140808
2951	379717.46614917	-9015.73740378	-1257.12676332	1.20076939	-0.66694072	-0.12821561	3.49621491
3001	379717.46614917	-8271.20508014	-1233.71596152	1.25473018	-0.66507749	-0.13400894	3.46013917
3051	379717.46614914	-7569.22048142	-1203.46521263	1.31170201	-0.66531149	-0.13985624	3.42559735
3101	379717.46614917	-6909.81822188	-1167.28148661	1.37098126	-0.66896644	-0.14481146	3.39718842
3151	379717.46614917	-6292.61812590	-1126.04175093	1.43136072	-0.67746399	-0.14676056	3.38171221
3201	379717.46614917	-5716.89860653	-1080.58297650	1.49092446	-0.69156753	-0.14216580	3.38893531
3251	379717.46614914	-5181.66610029	-1031.69563580	1.54604614	-0.70981368	-0.12675304	3.43644145
3301	379717.46614916	-4685.71755075	-980.12009426	1.64134820	-0.67806912	-0.09720479	3.30057223
3351	379717.46614914	-4227.69438450	-926.54522259	1.69122659	-0.68798682	-0.06506789	3.40421981
3401	379717.46614913	-3806.12757985	-871.60857262	1.74013896	-0.72708813	-0.02144360	3.55149830
3451	379717.46614913	-3419.47424249	-815.89752642	1.78963813	-0.75585832	0.04639821	3.71618546
3501	379717.46614913	-3066.14662856	-759.95091998	1.89713766	-0.88054101	0.22253255	3.49337485
3551	379717.46614913	-2744.53485015	-704.26073894	2.04484083	-0.82237690	0.23662253	3.24453121

Table B.9 Initial conditions for short transfers to a 9000 km Az halo orbit

$Az = 9000$ km

$\phi = 0^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	354179.29002363	0.00000001	4423.45786577	0.44415285	-0.85506675	-0.08829543	3.58355783
2551	355733.33975417	0.00000001	4189.22958888	0.48017008	-0.86995037	-0.11301654	3.53282056
2601	357309.97589515	0.00000000	3934.67741507	0.49576703	-0.88830051	-0.13010989	3.54060672
2651	358887.18791278	0.00000000	3666.80571923	0.50668090	-0.90819931	-0.14433917	3.56475993
2701	360445.29968677	0.00000001	3392.11510625	0.51603226	-0.92965732	-0.15743885	3.59731077
2751	361967.31905980	0.00000001	3116.35314871	0.52467968	-0.95283683	-0.17006342	3.63637388
2801	363439.12264139	0.00000000	2844.37624267	0.53292095	-0.97793891	-0.18253458	3.68166214
2851	364849.48227879	0.00000001	2580.10657845	0.54089889	-1.00521409	-0.19507751	3.73341466
2901	366189.95369100	0.00000000	2326.56180579	0.54871869	-1.03497774	-0.20790270	3.79207330
2951	367454.65785323	0.00000001	2085.93377091	0.55648460	-1.06762111	-0.22123793	3.85816253
3001	368639.99023436	0.00000001	1859.69504637	0.56430871	-1.10361655	-0.23533914	3.93223671
3051	369744.29212475	0.00000002	1648.71620537	0.57230620	-1.14351428	-0.25048458	4.01486567
3101	370767.51347035	0.00000002	1453.38157403	0.58058102	-1.18792860	-0.26694856	4.10666635
3151	371710.88968311	0.00000000	1273.69563658	0.58920437	-1.23751302	-0.28495147	4.20840007
3201	372576.64746662	0.00000002	1109.37590663	0.59818835	-1.29292646	-0.30459201	4.32115605
3251	373367.74798530	0.00000000	959.93075841	0.60745683	-1.35479305	-0.32578337	4.44663586
3301	374087.67031678	0.00000002	824.72250135	0.61681216	-1.42366215	-0.34824051	4.58753826
3351	374740.23426483	0.00000002	703.01703463	0.62589831	-1.50002280	-0.37159463	4.74793742
3401	375329.45914715	0.00000000	594.02192973	0.63418023	-1.58450478	-0.39564697	4.93330489
3451	375859.45387148	0.00000001	496.91492664	0.64094810	-1.67777102	-0.42034493	5.15092788
3501	376334.33314609	0.00000000	410.86474278	0.64465268	-1.77757688	-0.44511499	5.41857163
3551	376758.15477979	0.00000000	335.04587918	0.63739033	-1.88890252	-0.47116040	5.77651511
3601	377134.87347065	0.00000000	268.64884051	0.61522845	-2.02340744	-0.50248270	6.24369234
3651	377468.30709706	0.00000000	210.88690660	0.59746940	-2.16497678	-0.53238330	6.76587948
3701	377762.11219540	0.00000000	161.00032774	0.59649651	-2.31337411	-0.55984392	7.27326419

$Az = 9000$ km continued

$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	362201.32916033	-10112.94640566	2516.78385836	0.71857405	-0.84056484	-0.10920075	3.18829956
2551	363287.57414028	-9485.80257409	2266.87763341	0.80646288	-0.85047736	-0.13446625	3.03493664
2601	364372.88459069	-8859.19829339	2023.93707206	0.85781054	-0.86518503	-0.15490007	2.97239269
2651	365446.17117171	-8239.53599692	1790.72275450	0.89200729	-0.88107246	-0.17142973	2.95047426
2701	366497.55242295	-7632.52074849	1569.45590210	0.91634560	-0.89731211	-0.18521585	2.95295167
2751	367518.51691749	-7043.06662272	1361.81047497	0.93424148	-0.91380480	-0.19710053	2.97345470
2801	368502.01357873	-6475.24456061	1168.93401818	0.94759218	-0.93072198	-0.20767348	3.00943021
2851	369442.46866408	-5932.27256393	991.49158539	0.95765982	-0.94841353	-0.21737820	3.06007128
2901	370335.73587569	-5416.54449884	829.72572002	0.96547664	-0.96742928	-0.22659376	3.12538341
2951	371178.99219899	-4929.69023358	683.52521307	0.97207111	-0.98858070	-0.23570481	3.20555260
3001	371970.59546075	-4472.65787733	552.49605461	0.97860759	-1.01299448	-0.24518117	3.30029709
3051	372709.92016362	-4045.80856112	436.02933903	0.98643657	-1.04208214	-0.25566322	3.40816699
3101	373397.18647972	-3649.01516851	333.36250167	0.99698584	-1.07732177	-0.26795319	3.52619291
3151	374033.29425105	-3281.75817547	243.63183699	1.01142835	-1.11983847	-0.28269672	3.65075654
3201	374619.67029545	-2943.21380839	165.91557038	1.03024334	-1.17004080	-0.29977955	3.78003767
3251	375158.13393479	-2632.33168127	99.26772936	1.05298625	-1.22766679	-0.31811833	3.91657718
3301	375650.78282502	-2347.90071187	42.74368473	1.07838800	-1.29211042	-0.33628158	4.06835514
3351	376099.89904676	-2088.60334038	-4.58144148	1.10468658	-1.36322009	-0.35352287	4.24751663
3401	376507.87399465	-1853.05889436	-43.60020283	1.13076163	-1.44485565	-0.37121445	4.45901547
3451	376877.14979425	-1639.85741205	-75.16484122	1.15766482	-1.54079549	-0.38985153	4.69617860
3501	377210.17461757	-1447.58544071	-100.08277186	1.18454952	-1.63940254	-0.40480935	4.99347557
3551	377509.36924220	-1274.84534364	-119.11460340	1.19227987	-1.76643647	-0.42237557	5.42381700
3601	377777.10237134	-1120.26954941	-132.97393922	1.19415662	-1.91777721	-0.44119851	5.93899667
3651	378015.67251663	-982.53101185	-142.32837437	1.21353648	-2.06161785	-0.44658570	6.47272164

$Az = 9000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	366416.48429142	-13300.98185775	1561.37732622	0.88280234	-0.81645830	-0.10840720	2.95772715
2551	367244.38875807	-12473.07739109	1338.83047772	0.97925011	-0.82384728	-0.12684002	2.80646663
2601	368066.12979097	-11651.33635819	1129.22475358	1.04706700	-0.83361391	-0.14352521	2.72304471
2651	368874.80651893	-10842.65963022	933.92757921	1.09656716	-0.84419876	-0.15840469	2.67842304
2701	369664.25161321	-10053.21453595	753.89729625	1.13298884	-0.85507901	-0.17164382	2.66042490
2751	370429.13308577	-9288.33306340	589.69633388	1.15942503	-0.86607222	-0.18344767	2.66336778
2801	371165.01774934	-8552.44839982	441.52021972	1.17790835	-0.87716004	-0.19402133	2.68474229
2851	371868.39191246	-7849.07423671	309.23943326	1.18992533	-0.88845745	-0.20356944	2.72390270
2901	372536.64057091	-7180.82557823	192.44988225	1.19672034	-0.90025229	-0.21230595	2.78146136
2951	373167.99110566	-6549.47504350	90.52736111	1.19953184	-0.91310335	-0.22046568	2.85888200
3001	373761.43051134	-5956.03563783	2.68168266	1.19983446	-0.92800274	-0.22832619	2.95790988
3051	374316.60626599	-5400.85988318	-71.99295979	1.19961670	-0.94658629	-0.23628087	3.07937869
3101	374833.72040996	-4883.74573920	-134.47372784	1.20162387	-0.97124359	-0.24504603	3.22093575
3151	375313.42478170	-4404.04136743	-185.77218670	1.20923404	-1.00468360	-0.25590789	3.37446072
3201	375756.72322810	-3960.74292103	-226.90494233	1.22535447	-1.04849369	-0.27001117	3.52777959
3251	376164.88445594	-3552.58169319	-258.87145515	1.25045506	-1.10151152	-0.28598026	3.67563502
3301	376539.36730919	-3178.09883997	-282.63819029	1.28179741	-1.16067175	-0.30030895	3.82986604
3351	376881.75879721	-2835.70735191	-299.12805925	1.31461935	-1.22354209	-0.31090670	4.01792041
3401	377193.72418101	-2523.74196815	-309.21406860	1.34543498	-1.29607225	-0.31909770	4.25928201
3451	377476.96780723	-2240.49834194	-313.71616120	1.37856747	-1.39541861	-0.33232765	4.50955353
3501	377733.20307183	-1984.26307733	-313.40036533	1.41950522	-1.49003265	-0.33543537	4.79053108
3551	377964.12981688	-1753.33633222	-308.97951991	1.44231452	-1.61876115	-0.33787998	5.20781057
3601	378171.41753261	-1546.04861650	-301.11499522	1.45448297	-1.76909358	-0.33017285	5.76439539
3651	378356.69289049	-1360.77325868	-290.41896147	1.45850484	-1.94738174	-0.30759981	6.46054835

$Az = 9000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	370747.18985659	-15536.97429665	629.04315947	1.03081421	-0.79147398	-0.09767864	2.77585291
2551	371303.05809960	-14574.18225746	446.02090988	1.13362297	-0.79592730	-0.10904790	2.62877284
2601	371852.06296791	-13623.27793193	278.67417511	1.21661640	-0.80070397	-0.12040150	2.52992212
2651	372390.45869118	-12690.74918467	127.43903223	1.28371672	-0.80538311	-0.13156129	2.46371042
2701	372914.86288374	-11782.45447941	-7.53503743	1.33728135	-0.80989762	-0.14239113	2.42224300
2751	373422.32109156	-10903.51108076	-126.37179015	1.37894582	-0.81428022	-0.15276065	2.40127589
2801	373910.35257483	-10058.21575607	-229.44373786	1.40995317	-0.81858616	-0.16253838	2.39869130
2851	374376.97294715	-9250.00556336	-317.33852612	1.43131002	-0.82287591	-0.17159755	2.41387801
2901	374820.69289822	-8481.46006379	-390.81929301	1.44387880	-0.82723460	-0.17983023	2.44753273
2951	375240.49538947	-7754.34081975	-450.78255638	1.44846041	-0.83183357	-0.18716739	2.50171001
3001	375635.79589452	-7069.66026079	-498.21694839	1.44592138	-0.83706200	-0.19360198	2.58002127
3051	376006.39127346	-6427.77023537	-534.16543109	1.43745638	-0.84379133	-0.19921008	2.68776185
3101	376352.40285741	-5828.46059195	-559.69272968	1.42515737	-0.85388631	-0.20417477	2.83115754
3151	376674.21857368	-5271.05942075	-575.85882494	1.41309108	-0.87100931	-0.20893347	3.01327619
3201	376972.43780648	-4754.52855774	-583.69859645	1.40842440	-0.90078426	-0.21489325	3.22297610
3251	377247.82146272	-4277.55007351	-584.20716825	1.41968883	-0.94714923	-0.22446223	3.42630012
3301	377501.24859276	-3838.60140828	-578.33018353	1.44858955	-1.00408538	-0.23357634	3.60189027
3351	377733.68001487	-3436.01837595	-566.95809159	1.48511350	-1.05865717	-0.23382873	3.79197579
3401	377946.12873680	-3068.04639549	-550.92352111	1.52080464	-1.12535335	-0.22925144	4.03387238
3451	378139.63654757	-2732.88103565	-531.00088959	1.55776830	-1.21797499	-0.22200854	4.30892883
3501	378315.25591763	-2428.69936391	-507.90751879	1.60443773	-1.31262240	-0.20089748	4.58781206
3551	378474.03625862	-2153.68374600	-482.30566082	1.70862205	-1.34948095	-0.16582973	4.60995057
3601	378617.01359664	-1906.03973221	-454.80496640	1.76314614	-1.46348405	-0.11685477	4.92736946
3651	378745.20277836	-1684.00955656	-425.96503473	1.85465279	-1.53773393	-0.05300468	5.09162018

$Az = 9000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614917	-17515.75189071	-1136.11152669	0.87766185	-0.69333467	-0.08282357	3.57973930
2551	379717.46614915	-16474.38791942	-1222.17106269	0.89804254	-0.69203771	-0.08769221	3.59991120
2601	379717.46614915	-15450.00114105	-1293.24683347	0.91790001	-0.69218547	-0.09400088	3.63181947
2651	379717.46614915	-14447.38116893	-1349.68202195	0.94225773	-0.69258083	-0.10114168	3.65312897
2701	379717.46614915	-13471.04737430	-1391.96871028	0.97295221	-0.69229455	-0.10835126	3.65447578
2751	379717.46614917	-12525.11364963	-1420.74298061	1.00934900	-0.69124685	-0.11507621	3.63870381
2801	379717.46614915	-11613.17674799	-1436.77076134	1.05016249	-0.68986878	-0.12108662	3.61258980
2851	379717.46614915	-10738.23812091	-1440.92634369	1.09450273	-0.68865722	-0.12633982	3.58127324
2901	379717.46614917	-9902.66350313	-1434.16625216	1.14199856	-0.68806343	-0.13082067	3.54744422
2951	379717.46614915	-9108.17910692	-1417.50134538	1.19259608	-0.68857527	-0.13443690	3.51233848
3001	379717.46614917	-8355.89915109	-1391.96972648	1.24631649	-0.69083824	-0.13686268	3.47693307
3051	379717.46614914	-7646.37702656	-1358.61242601	1.30300570	-0.69569335	-0.13721344	3.44304702
3101	379717.46614917	-6979.67164895	-1318.45307827	1.36203991	-0.70390185	-0.13357773	3.41436448
3151	379717.46614914	-6355.42110315	-1272.48210332	1.42187631	-0.71522596	-0.12288555	3.39778574
3201	379717.46614916	-5772.91706890	-1221.64533542	1.47930995	-0.72724976	-0.10209821	3.40644174
3251	379717.46614917	-5231.17523657	-1166.83664230	1.52918801	-0.73848802	-0.06959270	3.46423855
3301	379717.46614914	-4728.99864394	-1108.89385663	1.62017923	-0.71267774	-0.04122522	3.34081347
3351	379717.46614914	-4265.03235508	-1048.59725739	1.66703930	-0.71905998	0.00646930	3.44117422
3401	379717.46614917	-3837.80907272	-986.66985589	1.72130201	-0.74496720	0.06299505	3.53200188
3451	379717.46614917	-3445.78610146	-923.77881748	1.78281465	-0.79424021	0.13616103	3.59878191
3501	379717.46614913	-3087.37461582	-860.53745470	1.87572824	-0.84324647	0.22599401	3.50189658
3551	379717.46614913	-2760.96248077	-797.50733633	1.92168425	-0.76826920	0.28549441	3.70213517

Table B.10 Initial conditions for short transfers to a 10000 km Az halo orbit

$Az = 10000$ km

$\phi = 0^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	353825.83731760	0.00000001	4986.34426241	0.44433231	-0.85290972	-0.09566791	3.56973826
2551	355387.16413684	0.00000000	4728.76910312	0.47924718	-0.86923229	-0.12211926	3.52126439
2601	356973.35780218	0.00000001	4447.24787819	0.49492842	-0.88865138	-0.14075711	3.52765207
2651	358562.03733992	0.00000001	4149.71077339	0.50598951	-0.90948355	-0.15628794	3.54996210
2701	360133.16501293	0.00000000	3843.55849599	0.51541595	-0.93175114	-0.17043827	3.58059964
2751	361669.40516411	0.00000000	3535.36435139	0.52404400	-0.95559030	-0.18387501	3.61773457
2801	363156.31686122	0.00000001	3230.70511818	0.53215629	-0.98116112	-0.19692741	3.66112055
2851	364582.38612195	0.00000001	2934.10315650	0.53987637	-1.00866890	-0.20982331	3.71106358
2901	365938.91785103	0.00000001	2649.05412215	0.54729155	-1.03839008	-0.22277680	3.76808896
2951	367219.81811115	0.00000000	2378.11289194	0.55449795	-1.07069493	-0.23602666	3.83279543
3001	368421.30220469	0.00000001	2123.01284997	0.56161720	-1.10606316	-0.24985231	3.90576789
3051	369541.56336785	0.00000000	1884.79854648	0.56879603	-1.14508464	-0.26456854	3.98752953
3101	370580.43209332	0.00000000	1663.95730662	0.57618918	-1.18843567	-0.28049039	4.07856317
3151	371539.04906275	0.00000000	1460.54056210	0.58392383	-1.23682320	-0.29785946	4.17945954
3201	372419.56712940	0.00000000	1274.26993406	0.59204509	-1.29089238	-0.31673989	4.29126414
3251	373224.89092951	0.00000000	1104.62623747	0.60043878	-1.35108597	-0.33692886	4.41611429
3301	373958.45720782	0.00000000	950.92166936	0.60871397	-1.41744936	-0.35797645	4.55829293
3351	374624.05498115	0.00000002	812.35667906	0.61602569	-1.48959965	-0.37943339	4.72554428
3401	375225.68214981	0.00000002	688.06361652	0.62100208	-1.56817182	-0.40147602	4.92792605
3451	375767.43382414	0.00000000	577.13942161	0.62274049	-1.65833273	-0.42627854	5.16724572
3501	376253.41715385	0.00000000	478.66951889	0.62346507	-1.76140310	-0.45384578	5.43747068
3551	376687.68754860	0.00000000	391.74483737	0.62155648	-1.87031982	-0.48077084	5.76705957
3601	377074.20162829	0.00000000	315.47356568	0.59259443	-2.00572415	-0.51399123	6.26427747
3651	377416.78285871	0.00000000	248.98892995	0.55493314	-2.15000586	-0.54673300	6.90082151
3701	377719.09651144	0.00000004	191.45397240	0.49745971	-2.31585039	-0.58272011	7.78226340

$Az = 10000$ km continued

$\phi = 30^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	361961.82266984	-10251.22554243	2860.71974149	0.71394904	-0.84189837	-0.11804942	3.18530165
2551	363053.09531897	-9621.17898468	2580.49518936	0.80057388	-0.85371580	-0.14376958	3.03444306
2601	364145.01794652	-8990.75716173	2307.54559990	0.85192006	-0.86968848	-0.16413088	2.97129752
2651	365226.24386765	-8366.51108511	2045.05686837	0.88636973	-0.88636579	-0.18030869	2.94817300
2701	366286.63470806	-7754.29414795	1795.60785784	0.91081729	-0.90295779	-0.19356609	2.94963592
2751	367317.43315479	-7159.16238725	1561.15752757	0.92850324	-0.91938753	-0.20481142	2.96965721
2801	368311.36129172	-6585.31770985	1343.06582466	0.94126381	-0.93586867	-0.21469362	3.00584123
2851	369262.64282832	-6036.09505862	1142.14179440	0.95038003	-0.95282757	-0.22371200	3.05741906
2901	370166.95583388	-5513.98970141	958.71074764	0.95697138	-0.97092758	-0.23229621	3.12430798
2951	371021.32898196	-5020.71713440	792.69199880	0.96221360	-0.99112099	-0.24087585	3.20644005
3001	371823.99784105	-4557.29605253	643.67949326	0.96746004	-1.01467373	-0.24996003	3.30307352
3051	372574.23833813	-4124.14449958	511.01920477	0.97425191	-1.04308293	-0.26021143	3.41212134
3101	373272.19279138	-3721.18030810	393.87906574	0.98414793	-1.07780857	-0.27240094	3.52998687
3151	373918.70075813	-3347.91875948	291.30902255	0.99834287	-1.11986861	-0.28705158	3.65273060
3201	374515.14328821	-3003.56250416	202.29034093	1.01722840	-1.16953904	-0.30385123	3.77871184
3251	375063.30567235	-2687.08080414	125.77441682	1.04016955	-1.22633765	-0.32148983	3.91136295
3301	375565.26085797	-2397.27684260	60.71207099	1.06546721	-1.28898250	-0.33828766	4.06147985
3351	376023.27351640	-2132.84311093	6.07468383	1.09017294	-1.35580536	-0.35292938	4.24995830
3401	376439.72328889	-1892.40572272	-39.13135527	1.11145508	-1.43305834	-0.36693517	4.49013651
3451	376817.04490308	-1674.55898715	-75.85546535	1.13331539	-1.53145770	-0.38659926	4.74729845
3501	377157.68248918	-1477.89178512	-104.99769526	1.16250447	-1.63363040	-0.40148076	5.02296940
3551	377464.05539311	-1301.00730656	-127.40648775	1.17706413	-1.76129123	-0.41792605	5.40817432
3601	377738.53296542	-1142.53760634	-143.87853522	1.17973810	-1.90099128	-0.42778581	5.94484401
3651	377983.41609216	-1001.15426715	-155.16006921	1.11559771	-2.11058099	-0.44790206	6.95890706
3701	378200.92357661	-875.57626250	-161.94908824	1.19057169	-2.23884059	-0.43250337	7.25565972

$Az = 10000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	366236.59072310	-13480.87542607	1787.66832944	0.87634403	-0.81919773	-0.11700504	2.95965244
2551	367069.39440898	-12648.07174017	1536.85536380	0.97058234	-0.82783000	-0.13536168	2.81227990
2601	367897.01330371	-11820.45284545	1300.26010164	1.03712711	-0.83839039	-0.15156590	2.73055607
2651	368712.37166134	-11005.09448783	1079.48420410	1.08573832	-0.84937521	-0.16569615	2.68694637
2701	369509.13145573	-10208.33469342	875.66493582	1.12134359	-0.86027820	-0.17801679	2.66991724
2751	370281.79971858	-9435.66643056	689.48862717	1.14684194	-0.87094088	-0.18880930	2.67415643
2801	371025.79623335	-8691.66991580	521.22260813	1.16415416	-0.88139144	-0.19834065	2.69741015
2851	371737.47698052	-7979.98916864	370.76215006	1.17472971	-0.89182580	-0.20686551	2.73921928
2901	372414.11461816	-7303.35153098	237.68753580	1.17985808	-0.90265992	-0.21463609	2.80029981
2951	373053.84219398	-6663.62395516	121.32589188	1.18092391	-0.91464085	-0.22191663	2.88205069
3001	373655.56940312	-6061.89674602	20.81280089	1.17967278	-0.92901152	-0.22901894	2.98578094
3051	374218.88182752	-5498.58432162	-64.85028816	1.17848806	-0.94766702	-0.23640546	3.11118782
3101	374743.93303106	-4973.53311808	-136.74554744	1.18051693	-0.97305833	-0.24489257	3.25396306
3151	375231.33770135	-4486.12844781	-195.99656893	1.18921600	-1.00743859	-0.25567680	3.40433110
3201	375682.07183963	-4035.39430950	-243.73480619	1.20697326	-1.05158606	-0.26930890	3.55105886
3251	376097.38377598	-3620.08237315	-281.07420105	1.23351464	-1.10407606	-0.28387780	3.69201163
3301	376478.71785600	-3238.74829317	-309.09304594	1.26566287	-1.16202219	-0.29595318	3.84159561
3351	376827.65114204	-2889.81500708	-328.82189744	1.29812624	-1.22251410	-0.30329611	4.03150212
3401	377145.84243119	-2571.62371797	-341.23631209	1.32691967	-1.29759434	-0.30958826	4.27728850
3451	377434.99225706	-2282.47389209	-347.25325465	1.35684786	-1.39340799	-0.31704319	4.55014780
3501	377696.81223145	-2020.65391767	-347.73017836	1.39757113	-1.49357323	-0.31696799	4.82066247
3551	377933.00199990	-1784.46414926	-343.46594998	1.43445930	-1.60655925	-0.30835400	5.17070809
3601	378145.23215910	-1572.23399007	-335.20296478	1.44468024	-1.76716063	-0.29309448	5.70954102
3651	378335.13163974	-1382.33450942	-323.62994686	1.40014243	-1.98273151	-0.24990727	6.71769310

$Az = 10000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	370630.51137227	-15739.06735964	737.90317326	1.02440881	-0.79038101	-0.10743150	2.78177648
2551	371190.34157556	-14769.41300393	530.85642022	1.12206977	-0.79554347	-0.11879197	2.64294006
2601	371743.78652970	-13810.81822416	341.25952796	1.20112844	-0.80081747	-0.12990544	2.54918652
2651	372287.00600925	-12869.93448593	169.64529866	1.26505311	-0.80582528	-0.14061897	2.48664487
2701	372816.52633811	-11952.77837270	16.22065358	1.31593003	-0.81048492	-0.15081774	2.44824132
2751	373329.30741643	-11064.61549192	-119.11878823	1.35519647	-0.81480351	-0.16039691	2.43023387
2801	373822.79049641	-10209.87772470	-236.76134849	1.38393787	-0.81881874	-0.16925751	2.43088864
2851	374294.92216662	-9392.12168401	-337.34139895	1.40303719	-0.82259628	-0.17731188	2.44995213
2901	374744.15372461	-8614.02980121	-421.69450606	1.41327623	-0.82626729	-0.18449428	2.48850280
2951	375169.41838163	-7877.44980859	-490.80966983	1.41544607	-0.83011731	-0.19077406	2.54901777
3001	375570.09099625	-7183.46448290	-545.78245864	1.41053380	-0.83476364	-0.19616972	2.63550787
3051	375945.93608454	-6532.48169421	-587.77205914	1.40010246	-0.84149515	-0.20076790	2.75331583
3101	376297.04984127	-5924.33482831	-617.96423475	1.38704910	-0.85285458	-0.20479432	2.90727303
3151	376623.80113337	-5358.38498894	-637.54116234	1.37673958	-0.87317059	-0.20894515	3.09529786
3201	376926.77526302	-4833.61840297	-647.65826097	1.37710337	-0.90716881	-0.21493166	3.29770971
3251	377206.72303305	-4348.73464186	-649.42750969	1.39451007	-0.95506660	-0.22338511	3.48233217
3301	377464.51650231	-3902.22325525	-643.90638129	1.42700979	-1.00965783	-0.22853203	3.64482282
3351	377701.11189237	-3492.42801878	-632.09135617	1.46457335	-1.06272222	-0.22413448	3.83045382
3401	377917.51943833	-3117.59915408	-614.91496953	1.50255068	-1.13593768	-0.21692263	4.05140094
3451	378114.77954569	-2775.93462582	-593.24543185	1.53722572	-1.21631085	-0.19653798	4.34785759
3501	378293.94437969	-2465.61203034	-567.88799920	1.56597996	-1.34554723	-0.16854066	4.69502361
3551	378456.06392098	-2184.81274792	-539.58742181	1.67428823	-1.37139660	-0.12510232	4.68895812
3601	378602.17552968	-1931.74001815	-509.03094307	1.71111590	-1.49824791	-0.05061446	5.08780114
3651	378733.29612363	-1704.63248743	-476.85144216	1.82371100	-1.56140295	0.01203640	5.08756998

$Az = 10000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	z (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
2501	379717.46614917	-17699.96335462	-1249.74123040	0.87621600	-0.69659089	-0.08919856	3.56813330
2551	379717.46614915	-16650.49089387	-1347.77655733	0.89637940	-0.69589090	-0.09408195	3.58822823
2601	379717.46614917	-15617.61435972	-1429.04204038	0.91454222	-0.69720862	-0.10070303	3.62668619
2651	379717.46614915	-14606.21108956	-1493.90519752	0.93672114	-0.69939024	-0.10839560	3.65743625
2701	379717.46614915	-13620.88897734	-1542.90116282	0.96569163	-0.70124956	-0.11614319	3.66650614
2751	379717.46614915	-12665.84797950	-1576.72760524	1.00112781	-0.70252141	-0.12312092	3.65481841
2801	379717.46614915	-11744.76552669	-1596.22912799	1.04157770	-0.70367532	-0.12890754	3.62982888
2851	379717.46614915	-10860.71609177	-1602.37330861	1.08589460	-0.70534592	-0.13329012	3.59795955
2901	379717.46614915	-10016.12932705	-1596.22141314	1.13350271	-0.70811650	-0.13598917	3.56289808
2951	379717.46614915	-9212.78564376	-1578.89704556	1.18418223	-0.71253393	-0.13646123	3.52656535
3001	379717.46614917	-8451.84384915	-1551.55566222	1.23778976	-0.71909421	-0.13369547	3.49037559
3051	379717.46614917	-7733.89296407	-1515.35718387	1.29394649	-0.72798439	-0.12601289	3.45640772
3101	379717.46614917	-7059.01957030	-1471.44309691	1.35160754	-0.73847354	-0.11124875	3.42886316
3151	379717.46614914	-6426.88261849	-1420.91863280	1.40838560	-0.74804870	-0.08754494	3.41676083
3201	379717.46614914	-5836.78903609	-1364.83996586	1.46019713	-0.75217960	-0.05368743	3.43638893
3251	379717.46614914	-5287.76524760	-1304.20592199	1.50393762	-0.76182588	-0.00830620	3.50592440
3301	379717.46614917	-4778.62147231	-1239.95343744	1.59620374	-0.74721561	0.01676621	3.37138786
3351	379717.46614917	-4308.00719220	-1172.95591300	1.65206035	-0.76619709	0.06884833	3.41469979
3401	379717.46614914	-3874.45737056	-1104.02362772	1.68548411	-0.78723593	0.14980343	3.56183186
3451	379717.46614917	-3476.42984537	-1033.90546293	1.77846757	-0.80201860	0.19463564	3.47125237
3501	379717.46614913	-3112.33486233	-963.29130486	1.83404847	-0.58239530	0.39131343	3.37374793

C. Initial Conditions for Long Transfers

In the following tables of initial conditions, manifolds are identified by the point on the orbit from which they were propagated using an offset distance of $d = 50$ km in the direction of the corresponding eigenvector. There are 5,000 points spaced equally in time about each orbit. Point 1 occurs at the xz-plane crossing in the negative y-direction and the points proceed in a clockwise manner about the orbit. Also, all initial conditions are given in dimensional Earth-centered rotating frame coordinates.

Table C.1 Initial conditions for long transfers to a 1000 km Az halo orbit

$Az = 1000$ km

$\phi = 30^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378133.40552993	-914.55782493	14.74323786	0.36093210	-2.57530598	0.08442160	20.07428948
51	377901.05057658	-1048.70801979	19.52368131	0.31330963	-2.43442814	0.07989227	18.39348938
101	377636.45121375	-1201.47453311	24.99404435	0.27439351	-2.30267580	0.07523058	16.81475717
151	377337.16797320	-1374.26579260	31.20312785	0.24281158	-2.18020912	0.07056738	15.37726193
201	377000.86890422	-1568.42815061	38.19492365	0.21736672	-2.06679243	0.06599499	14.09390941
251	376625.37973179	-1785.21692543	46.00790274	0.19708156	-1.96198417	0.06157796	12.96096540
301	376208.73364881	-2025.76765359	54.67441956	0.18116788	-1.86525311	0.05736020	11.96609985
351	375749.22005935	-2291.06794816	64.22023347	0.16898509	-1.77603660	0.05336953	11.09364945
401	375245.43177191	-2581.93025150	74.66414027	0.16000767	-1.69376811	0.04962109	10.32757892
451	374696.31034686	-2898.96565407	86.01769890	0.15380230	-1.61789129	0.04611998	9.65293749
501	374101.18951384	-3242.55882722	98.28503134	0.15001160	-1.54786851	0.04286358	9.05644577
551	373459.83676177	-3612.84401128	111.46266819	0.14834184	-1.48318680	0.03984353	8.52662276
601	372772.49335647	-4009.68191136	125.53940791	0.14855296	-1.42336208	0.03704746	8.05369177
651	372039.91312663	-4432.63730426	140.49615507	0.15045022	-1.36794225	0.03446043	7.62939540
701	371263.40037095	-4880.95715280	156.30570194	0.15387712	-1.31650934	0.03206607	7.24678646
751	370444.84715934	-5353.54906987	172.93241809	0.15870927	-1.26868095	0.02984754	6.90002685
801	369586.77012263	-5848.96007798	190.33181496	0.16484934	-1.22411138	0.02778822	6.58420774
851	368692.34654144	-6365.35577335	208.44995573	0.17222281	-1.18249261	0.02587223	6.29519464
901	367765.44915574	-6900.50022850	227.22268653	0.18077448	-1.14355527	0.02408482	6.02949844
951	366810.67862429	-7451.73725186	246.57467218	0.19046700	-1.10706935	0.02241262	5.78416063
1001	365833.39197378	-8015.97396259	266.41823026	0.20127342	-1.07284765	0.02084345	5.55669987
1051	364839.72471146	-8589.66802399	286.65197075	0.21322084	-1.04072783	0.01936917	5.34478424
1101	363836.60355458	-9168.82029394	307.15926707	0.22599923	-1.01073636	0.01795440	5.14829034
1151	362831.74600061	-9748.97507322	327.80660899	0.24348843	-0.98123022	0.01698053	4.94615655
1201	361833.64228699	-10325.23052097	348.44191909	0.24980078	-0.96238654	0.06880330	4.80982195
1251	360851.51475762	-10892.26211442	368.89295485	-0.17328327	-1.09154721	0.02012319	7.64596723

$Az = 1000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4951	378458.70173976	-1258.76440935	26.13344067	0.80029667	-2.47786955	0.08489770	16.63180568
1	378269.32448087	-1448.14166823	32.77015411	0.64626411	-2.38900240	0.08084712	18.10913923
51	378051.86811348	-1665.59803569	40.29725814	0.58709538	-2.25854666	0.07623666	16.49675261
101	377803.99523594	-1913.47091318	48.77006943	0.53697220	-2.13620793	0.07155087	15.01840637
151	377523.46340600	-2194.00274312	58.23502174	0.49463373	-2.02211344	0.06689729	13.69645542
201	377208.18301652	-2509.28313260	68.72840579	0.45899698	-1.91609459	0.06235229	12.53151972
251	376856.27583359	-2861.19031554	80.27529553	0.42914975	-1.81782545	0.05796997	11.51249870
301	376466.13289827	-3251.33325089	92.88867764	0.40432088	-1.72689704	0.05378761	10.62338297
351	376036.47061269	-3680.99553644	106.56878760	0.38385481	-1.64285585	0.04982915	9.84715618
401	375566.38402059	-4151.08212858	121.30264125	0.36719366	-1.56522643	0.04610773	9.16774020
451	375055.39652237	-4662.06962677	137.06373807	0.35386415	-1.49352716	0.04262771	8.57080106
501	374503.50551288	-5213.96063629	153.81190151	0.34346726	-1.42728244	0.03938653	8.04395320
551	373911.22365057	-5806.24249857	171.49321430	0.33566930	-1.36603227	0.03637628	7.57667491
601	373279.61564304	-6437.85050610	190.04000279	0.33019392	-1.30933995	0.03358526	7.16010442
651	372610.33052310	-7107.13562605	209.37082503	0.32681529	-1.25679799	0.03099929	6.78680312
701	371905.62938295	-7811.83676621	229.39042214	0.32535207	-1.20803291	0.02860286	6.45052646
751	371168.40841277	-8549.05773637	249.98960160	0.32566263	-1.16270923	0.02638015	6.14601952
801	370402.21685575	-9315.24929342	271.04503455	0.32764144	-1.12053293	0.02431582	5.86884203
851	369611.26914927	-10106.19699988	292.41896630	0.33121688	-1.08125450	0.02239562	5.61522157
901	368800.45009213	-10917.01605702	313.95886089	0.33635066	-1.04467142	0.02060678	5.38193156
951	367975.31138580	-11742.15476337	335.49702521	0.34303913	-1.01062975	0.01893825	5.16618898
1001	367142.05738298	-12575.40876616	356.85028719	0.35131698	-0.97902380	0.01738053	4.96556752
1051	366307.51739341	-13409.94875575	377.81983449	0.36126355	-0.94979324	0.01592522	4.77792150
1101	365479.10150667	-14238.36464248	398.19135385	0.37300746	-0.92291873	0.01456389	4.60134031
1151	364664.73667903	-15052.72947014	417.73564494	0.38867518	-0.89756427	0.01349721	4.42508716
1201	363872.77989116	-15844.68625799	436.20991235	0.43842522	-0.86330777	0.02429059	4.12210542
1251	363111.90562311	-16605.56052605	453.35995837	-0.01232144	-1.05091088	0.01990620	6.80991379

$Az = 1000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4901	378820.14187309	-1554.21123695	36.43039586	1.14312255	-2.32339530	0.08310498	15.86000602
4951	378682.04979547	-1793.39373158	44.96834472	1.05629944	-2.19371043	0.07874365	14.53455211
1	378522.02646918	-2070.56226312	54.63381489	0.96705440	-2.07938726	0.07421321	13.61306942
51	378338.04859522	-2389.22128829	65.49353343	0.81946445	-2.02313643	0.07055832	14.60483967
101	378128.16047961	-2752.75816836	77.59969589	0.75985106	-1.91331961	0.06604401	13.27526000
151	377890.53257137	-3164.34177874	90.98769662	0.70832640	-1.81052122	0.06157965	12.10028119
201	377623.52208594	-3626.81750567	105.67415611	0.66393208	-1.71468534	0.05722419	11.07243954
251	377325.73393113	-4142.60171968	121.65530701	0.62581972	-1.62561598	0.05302029	10.17720292
301	376996.08015501	-4713.57880888	138.90577679	0.59324073	-1.54302551	0.04899843	9.39789104
351	376633.83625327	-5341.00365139	157.37777909	0.56553839	-1.46656585	0.04517935	8.71823203
401	376238.69289746	-6025.41201993	177.00070005	0.54214182	-1.39585201	0.04157556	8.12349520
451	375810.80193450	-6766.54090787	197.68104278	0.52256031	-1.33048136	0.03819245	7.60085219
501	375350.81582478	-7563.26022072	219.30267655	0.50637779	-1.27004974	0.03502947	7.13935718
551	374859.91997142	-8413.51677993	241.72732875	0.49324734	-1.21416482	0.03208124	6.72976115
601	374339.85761411	-9314.29120593	264.79525829	0.48288650	-1.16245728	0.02933891	6.36427167
651	373792.94706912	-10261.56805704	288.32606051	0.47507348	-1.11459045	0.02679140	6.03631180
701	373222.09108019	-11250.31963365	312.11957390	0.46964510	-1.07026894	0.02442684	5.74030104
751	372630.77789035	-12274.50412164	335.95688826	0.46649687	-1.02924632	0.02223373	5.47146518
801	372023.07336828	-13327.07922986	359.60148964	0.46558624	-0.99133195	0.02020210	5.22567315
851	371403.60315059	-14400.03312067	382.80061796	0.46694031	-0.95639571	0.01832431	4.99929404
901	370777.52334161	-15484.43515942	405.28695453	0.47067048	-0.92436921	0.01659548	4.78906376
951	370150.47790823	-16570.50970869	426.78079621	0.47699732	-0.89524149	0.01501345	4.59194877
1001	369528.54060022	-17647.73672529	446.99290356	0.48628689	-0.86905064	0.01357828	4.40501563
1051	368918.13911943	-18704.98310306	465.62822639	0.49905674	-0.84589471	0.01228686	4.22552572
1101	368325.95946881	-19730.66834513	482.39070148	0.51568160	-0.82604159	0.01109375	4.05236442
1151	367758.82905886	-20712.96702969	496.98927514	0.53491248	-0.81020005	0.00976657	3.89159570
1201	367223.57834901	-21640.04845391	509.14521602	0.54937720	-0.79976535	0.00770020	3.77034986
1251	366726.88262263	-22500.35068791	518.60064730	0.53239506	-0.79819651	0.00431865	3.78016598

$Az = 1000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4751	379717.46614913	-1800.04511086	45.33761303	1.78313842	-1.86435599	0.07424969	15.06106639
4801	379717.46614917	-2078.76074784	56.66893416	1.65487928	-1.77581370	0.07181943	14.13654613
4851	379717.46614914	-2411.79274953	69.66047668	1.53701467	-1.68370801	0.06854639	13.07731492
4901	379717.46614917	-2806.04645685	84.45606156	1.42606348	-1.59645665	0.06479692	12.12178607
4951	379717.46614914	-3268.59179234	101.17355036	1.33528871	-1.49570688	0.06006595	10.87188459
1	379717.46614914	-3806.43756418	119.89702452	1.22377431	-1.44477567	0.05719408	10.62141751
51	379717.46614915	-4426.26952092	140.66914083	1.10336241	-1.42544948	0.05527800	10.95715341
101	379717.46614915	-5134.16056952	163.48407112	1.03334116	-1.34740706	0.05156172	9.98723998
151	379717.46614915	-5935.26431830	188.28142415	0.97138594	-1.27387927	0.04785633	9.13637600
201	379717.46614917	-6833.50480985	214.94149353	0.91677886	-1.20500688	0.04419043	8.39296179
251	379717.46614915	-7831.27579849	243.28208633	0.86884165	-1.14079547	0.04058936	7.74377082
301	379717.46614915	-8929.16201816	273.05707630	0.82695716	-1.08115105	0.03707569	7.17582439
351	379717.46614915	-10125.69289373	303.95671648	0.79058777	-1.02591268	0.03366839	6.67720205
401	379717.46614915	-11417.13655488	335.60966361	0.75929229	-0.97488443	0.03038197	6.23727720
451	379717.46614915	-12797.33953402	367.58663236	0.73274735	-0.92786467	0.02722634	5.84662166
501	379717.46614916	-14257.61592660	399.40562580	0.71077467	-0.88468128	0.02420857	5.49679955
551	379717.46614916	-15786.68977518	430.53878300	0.69340338	-0.84521173	0.02133621	5.17988437
601	379717.46614916	-17370.69643865	460.42103285	0.68093481	-0.80946402	0.01862967	4.88831456
651	379717.46614916	-18993.25285062	488.46091747	0.67601971	-0.77589517	0.01607949	4.59851221
701	379717.46614916	-20635.61238849	514.05409979	0.60456363	-0.81127960	0.01764911	4.92705398
751	379717.46614916	-22276.92639123	536.60012841	0.60551700	-0.78058368	0.01418990	4.64317409
801	379717.46614916	-23894.63901680	555.52290909	0.60881631	-0.75751980	0.01090984	4.40267294
851	379717.46614916	-25465.04191303	570.29493186	0.60811167	-0.74486375	0.00812026	4.23933582
901	379717.46614916	-26964.00614417	580.46455813	0.57957758	-0.74947542	0.00674763	4.28516966
951	379717.46614916	-28367.88746451	585.68460558	0.57966235	-0.74240117	0.00396867	4.16489805
1001	379717.46614916	-29654.56647240	585.73925443	0.57763960	-0.73916284	0.00175190	4.08195878
1051	379717.46614916	-30804.54189265	580.56530670	0.57486773	-0.73791764	0.00001760	4.02204736
1101	379717.46614916	-31801.95474318	570.26355988	0.57158599	-0.73778635	-0.00135524	3.98008177
1151	379717.46614916	-32635.40008306	555.09693470	0.56675289	-0.73837316	-0.00245375	3.95870293
1201	379717.46614916	-33298.39641754	535.47409496	0.55835093	-0.73954062	-0.00331274	3.96606111
1251	379717.46614916	-33789.43473304	511.92013270	0.54223521	-0.74179746	-0.00390294	4.02329244

Table C.2 Initial conditions for long transfers to a 2000 km Az halo orbit

$Az = 2000$ km

$\phi = 30\,^{\circ}$

manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378137.93828102	-911.94083981	29.42372177	0.36196936	-2.57513982	0.16904797	20.13215261
51	377905.73198349	-1046.00520825	38.97862926	0.31449769	-2.43411797	0.15996756	18.43501491
101	377641.30390112	-1198.67283279	49.91377378	0.27571124	-2.30237159	0.15062608	16.84255053
151	377342.21599471	-1371.35131602	62.32640802	0.24422097	-2.18002275	0.14128418	15.39420811
201	377006.13697701	-1565.38662741	76.30419302	0.21882260	-2.06679625	0.13212534	14.10270168
251	376630.89239121	-1782.03419000	91.92378858	0.19854073	-1.96221588	0.12327795	12.96386949
301	376214.51433058	-2022.43017538	109.24967168	0.18259452	-1.86572360	0.11482952	11.96490373
351	375755.29011761	-2287.56339837	128.33318588	0.17035272	-1.77673793	0.10683585	11.08970792
401	375251.80944134	-2578.24810234	149.21180832	0.16129895	-1.69468027	0.09932750	10.32189056
451	374703.00965794	-2895.09780505	171.90860545	0.15500769	-1.61898751	0.09231496	9.64622282
501	374108.21916871	-3238.50025409	196.43183428	0.15112770	-1.54911910	0.08579321	9.04921471
551	373467.19897895	-3608.59343320	222.77463439	0.14936969	-1.48456178	0.07974565	8.51922870
601	372780.18269089	-4005.24247208	250.91474745	0.14949658	-1.42483289	0.07414753	8.04637343
651	372047.91527221	-4428.01726335	280.81419514	0.15131545	-1.36948272	0.06896885	7.62230850
701	371271.69095356	-4876.17058268	312.41884452	0.15467066	-1.31809615	0.06417675	7.24002748
751	370453.39052922	-5348.61655295	345.65779044	0.15943811	-1.27029375	0.05973736	6.89365062
801	369595.51815984	-5843.90939636	380.44248881	0.16552024	-1.22573266	0.05561725	6.57824045
851	368701.23749235	-6360.22258046	416.66558184	0.17284207	-1.18410738	0.05178452	6.28964315
901	367774.40652662	-6895.32868802	454.19936654	0.18134762	-1.14515081	0.04820951	6.02435802
951	366819.61016757	-7446.58062294	492.89387322	0.19099950	-1.10863441	0.04486544	5.77941472
1001	365842.18881514	-8010.89510386	532.57454041	0.20176507	-1.07437438	0.04172724	5.55235715
1051	364848.26068002	-8584.73978024	573.03950022	0.21371293	-1.04219204	0.03878475	5.34061240
1101	363844.73479472	-9164.12572025	614.05652445	0.22607241	-1.01229907	0.03588994	5.14651797
1151	362839.31096107	-9744.60744126	655.35973048	0.25010692	-0.98020661	0.03572923	4.91187581
1201	361840.46219975	-10321.29304248	696.64620841	0.26182915	-0.97051355	0.12780162	4.73643600
1251	360857.39473012	-10888.86731071	737.57281044	-0.17472339	-1.09353851	0.04026805	7.65810983

$Az = 2000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4951	378462.69332131	-1254.77282786	52.14983242	0.80149617	-2.47752694	0.17000582	16.68581314
1	378273.47272288	-1443.99342628	65.41830691	0.64783951	-2.38826295	0.16188072	18.15117637
51	378056.19680548	-1661.26934369	80.46816473	0.58879199	-2.25773226	0.15264296	16.52242635
101	377808.52994662	-1908.93620255	97.40957121	0.53876833	-2.13546496	0.14325838	15.03119686
151	377528.23071979	-2189.23542938	116.33498279	0.49649270	-2.02154478	0.13394009	13.69968424
201	377213.20965994	-2504.25648922	137.31664713	0.46087815	-1.91576301	0.12483926	12.52800329
251	376861.58770018	-2855.87844899	160.40446908	0.43101576	-1.81776105	0.11606326	11.50446121
301	376471.75398357	-3245.71216556	185.62427795	0.40614108	-1.72710551	0.10768651	10.61250478
351	376042.42187449	-3675.04427464	212.97650361	0.38560625	-1.64332581	0.09975726	9.83466882
401	375572.68217966	-4144.78396947	242.43524075	0.36886068	-1.56593553	0.09230234	9.15452413
451	375062.05282156	-4655.41332758	273.94765464	0.35543738	-1.49444679	0.08533110	8.55747004
501	374510.52445103	-5206.94169814	307.43365979	0.34494239	-1.42838125	0.07883885	8.03092211
551	373918.60170953	-5798.86443963	342.78578794	0.33704581	-1.36727870	0.07281009	7.56421244
601	373287.34002447	-6430.12612467	379.86915404	0.33147403	-1.31070387	0.06722153	7.14837354
651	372618.37791356	-7099.08823560	418.52142998	0.32800294	-1.25825168	0.06204476	6.77589175
701	371913.96476670	-7803.50138247	458.55274498	0.32645222	-1.20955153	0.05724865	6.44047057
751	371176.98395485	-8540.48219432	499.74545014	0.32668063	-1.16427088	0.05280137	6.13682039
801	370410.97088303	-9306.49526612	541.85371063	0.32858266	-1.12211842	0.04867200	5.86047880
851	369620.12526402	-10097.34088513	584.60292364	0.33208635	-1.08284692	0.04483180	5.60766039
901	368809.31646134	-10908.14968781	627.68900234	0.33715286	-1.04625570	0.04125506	5.37513191
951	367984.08026107	-11733.38588808	670.77761601	0.34377779	-1.01219206	0.03791944	5.16010815
1001	367150.60491772	-12566.86123144	713.50353361	0.35199492	-0.98055109	0.03480574	4.96016341
1051	366315.70383689	-13401.76231226	755.47028163	0.36188140	-0.95127328	0.03189686	4.77315995
1101	365486.77186640	-14230.69428275	796.25039441	0.37359449	-0.92432523	0.02918149	4.59704203
1151	364671.72195149	-15045.74419766	835.38660269	0.39041159	-0.89841772	0.02733624	4.41576291
1201	363878.89896418	-15838.56718497	872.39436515	0.43951005	-0.86646528	0.04908343	4.11527611
1251	363116.96794474	-16600.49820443	906.76618761	-0.01345680	-1.05305140	0.03987101	6.81680938

$Az = 2000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4901	378823.36551297	-1548.62772889	72.66851707	1.14410017	-2.32329543	0.16642445	15.93210844
4951	378685.43138677	-1787.53664357	89.73735474	1.05809649	-2.19271415	0.15766469	14.56537299
1	378525.58868706	-2064.39232070	109.06202150	0.96508000	-2.08125835	0.14870336	13.73557897
51	378341.81577257	-2382.69634565	130.77539354	0.82137004	-2.02199260	0.14128061	14.61715548
101	378132.15788859	-2745.83445291	154.98137895	0.76182058	-1.91231492	0.13224880	13.27655965
151	377894.78557634	-3156.97535804	181.75040939	0.71033501	-1.80974059	0.12331712	12.09376130
201	377628.05517275	-3618.96596899	211.11551552	0.66595270	-1.71417843	0.11460140	11.06065367
251	377330.56962848	-4134.22604619	243.06911066	0.62782706	-1.62540507	0.10618596	10.16210082
301	377001.23786659	-4704.64539034	277.56056065	0.59521290	-1.54311263	0.09813174	9.38092081
351	376639.33102418	-5331.48642900	314.49456575	0.56745744	-1.46693865	0.09048093	8.70044728
401	376244.53413994	-6015.29469121	353.73032803	0.54399374	-1.39648854	0.08325957	8.10564659
451	375816.99214055	-6755.81915648	395.08143226	0.52433477	-1.33135389	0.07647960	7.58346030
501	375357.34929317	-7551.94392153	438.31633389	0.50806775	-1.27112771	0.07014088	7.12276926
551	374866.78157752	-8401.63212955	483.15933089	0.49484859	-1.21541705	0.06423341	6.71419550
601	374347.02165114	-9301.88272978	529.29189727	0.48439708	-1.16385353	0.05873990	6.34985244
651	373800.37619132	-10248.70043992	576.35427795	0.47649313	-1.11610234	0.05363841	6.02309628
701	373229.73538133	-11237.07931569	623.94728538	0.47097472	-1.07187025	0.04890512	5.72830078
751	372638.57415600	-12261.00059343	671.63429605	0.46773802	-1.03091287	0.04451686	5.46066190
801	372030.94454795	-13313.44594676	718.94351640	0.46674074	-0.99304113	0.04045336	5.21603032
851	371411.45810469	-14386.42794108	765.37066795	0.46800990	-0.95812581	0.03669895	4.99076500
901	370785.25692880	-15471.04019349	810.38232466	0.47165632	-0.92609881	0.03324342	4.78159741
951	370157.97148912	-16557.53044586	853.42021371	0.47789929	-0.89694911	0.03008203	4.58549443
1001	369535.66304131	-17635.40029545	893.90685312	0.48710124	-0.87071550	0.02721431	4.39953375
1051	368924.74838392	-18693.53552116	931.25293245	0.49976662	-0.84749965	0.02463189	4.22102759
1101	368331.90487427	-19720.37060079	964.86682702	0.51623391	-0.82757213	0.02223718	4.04899127
1151	367763.95426205	-20704.08991734	994.16655391	0.53520980	-0.81161218	0.01956058	3.88958611
1201	367227.72508026	-21632.86610471	1018.59430690	0.54935848	-0.80093183	0.01541149	3.76967685
1251	366729.89513240	-22495.13286793	1037.63343761	0.53205255	-0.79902253	0.00864876	3.78057794

$Az = 2000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4751	379717.46614917	-1790.90764539	90.26160977	1.78519737	-1.86511737	0.14871832	15.14012293
4801	379717.46614917	-2068.97509889	112.89447199	1.65658329	-1.77601273	0.14384497	14.20233818
4851	379717.46614914	-2401.26837601	138.84910931	1.53857306	-1.68348187	0.13728931	13.12574878
4901	379717.46614917	-2794.68543660	168.41253604	1.42733114	-1.59638261	0.12980487	12.16371112
4951	379717.46614914	-3256.29152871	201.81998460	1.33740109	-1.49449810	0.12021129	10.87367001
1	379717.46614917	-3793.09431567	239.23936433	1.22275404	-1.44818112	0.11489585	10.71009275
51	379717.46614915	-4411.78275872	280.75604732	1.10499834	-1.42461983	0.11080043	10.95588634
101	379717.46614915	-5118.43812752	326.35879746	1.03500455	-1.34676666	0.10338898	9.97943342
151	379717.46614915	-5918.22821491	375.92763795	0.97309655	-1.27346662	0.09599214	9.12385909
201	379717.46614917	-6815.09760502	429.22434868	0.91855316	-1.20484758	0.08866465	8.37711270
251	379717.46614917	-7811.46729028	485.88610411	0.87069132	-1.14090697	0.08145638	7.72564644
301	379717.46614915	-8907.95606266	545.42254177	0.82888808	-1.08154511	0.07441302	7.15625842
351	379717.46614917	-10103.13411264	607.21633330	0.79259970	-1.02659670	0.06757426	6.65687270
401	379717.46614915	-11393.31668469	670.52716367	0.76137955	-0.97586195	0.06097175	6.21674653
451	379717.46614915	-12772.40315188	734.49895436	0.73489927	-0.92913643	0.05462861	5.82637076
501	379717.46614917	-14231.76525506	798.17022141	0.71297704	-0.88624433	0.04856267	5.47724163
551	379717.46614916	-15760.18820363	860.48764635	0.69563464	-0.84706332	0.04279370	5.16143084
601	379717.46614916	-17343.87030515	920.32323365	0.68318484	-0.81157530	0.03736420	4.87119918
651	379717.46614916	-18966.49089868	976.49577695	0.67792692	-0.77856204	0.03228758	4.58595134
701	379717.46614916	-20609.36217790	1027.79766251	0.60698048	-0.81277246	0.03524854	4.90717067
751	379717.46614916	-22251.68684064	1073.02816214	0.60770920	-0.78257020	0.02831437	4.62708900
801	379717.46614916	-23870.94826170	1111.03413282	0.61067828	-0.75979279	0.02175815	4.39035334
851	379717.46614916	-25443.45987839	1140.75825484	0.60969704	-0.74710619	0.01617943	4.22938415
901	379717.46614916	-26945.09175444	1161.29346907	0.58091381	-0.75159498	0.01341233	4.27605667
951	379717.46614916	-28352.17129659	1171.94015108	0.58076521	-0.74430161	0.00787860	4.15719158
1001	379717.46614916	-29642.52083131	1172.26012724	0.57862271	-0.74078783	0.00346245	4.07479437
1051	379717.46614916	-30796.55149514	1162.11962518	0.57576943	-0.73929141	0.00000517	4.01519663
1101	379717.46614916	-31798.29200272	1141.71265514	0.57238953	-0.73895475	-0.00273210	3.97362925
1151	379717.46614916	-32636.20893466	1111.55800999	0.56740440	-0.73938413	-0.00492176	3.95286995
1201	379717.46614916	-33303.68746096	1072.46721567	0.55873585	-0.74044677	-0.00663235	3.96132191
1251	379717.46614916	-33799.09240777	1025.48642851	0.54205248	-0.74269811	-0.00779974	4.02110081

Table C.3 Initial conditions for long transfers to a 3000 km Az halo orbit

$Az = 3000$ km

$\phi = 30^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378145.49340266	-907.57888830	43.97870654	0.36380834	-2.57488917	0.25409101	20.22720388
51	377913.53770065	-1041.49857535	58.29605733	0.31660685	-2.43364699	0.24041653	18.50213062
101	377649.39797794	-1193.99971536	74.68475803	0.27805387	-2.30193843	0.22635944	16.88620926
151	377350.63860833	-1366.48851778	93.28981228	0.24672842	-2.17982036	0.21230769	15.41943302
201	377014.92943974	-1560.31029668	114.24190260	0.22141181	-2.06694798	0.19853334	14.11420665
251	376640.09574077	-1776.72063365	137.65531130	0.20113161	-1.96278313	0.18522704	12.96562035
301	376224.16780038	-2016.85674200	163.62617259	0.18512059	-1.86671945	0.17251963	11.96001607
351	375765.42950019	-2281.70942310	192.23106252	0.17276528	-1.77814164	0.16049538	11.08052151
401	375262.46535971	-2572.09590500	223.52590952	0.16356680	-1.69644997	0.14920122	10.31010693
451	374714.20575834	-2888.63373347	257.54518357	0.15711461	-1.62107014	0.13865398	9.63304772
501	374119.97024865	-3231.71576493	294.30130133	0.15306907	-1.55145765	0.12884692	9.03548193
551	373479.50906274	-3601.48620302	333.78416641	0.15114914	-1.48710011	0.11975548	8.50549941
601	372793.04306396	-3997.81753222	375.96075094	0.15112306	-1.42751874	0.11134252	8.03301250
651	372061.30248599	-4420.28815189	420.77461598	0.15280094	-1.37226925	0.10356271	7.60954169
701	371285.56481339	-4868.16050597	468.14526493	0.15602847	-1.32094255	0.09636627	7.22798355
751	370467.69208100	-5340.35954820	517.96722498	0.16068165	-1.27316518	0.08970182	6.88239205
801	369610.16769687	-5835.45148221	570.10875764	0.16666230	-1.22859979	0.08351870	6.56778553
851	368716.13261246	-6351.62287885	624.41010976	0.17389429	-1.18694573	0.07776855	6.27998195
901	367789.42028279	-6886.66049186	680.68123205	0.18232042	-1.14793988	0.07240648	6.01546258
951	366834.58937007	-7437.93237635	738.69891401	0.19190115	-1.11135722	0.06739189	5.77125180
1001	365856.95256572	-8002.37124849	798.20331366	0.20260624	-1.07701470	0.06268752	5.54486618
1051	364862.59924066	-8576.46140840	858.89390094	0.21447784	-1.04474643	0.05827309	5.33387326
1101	363858.40892248	-9156.23095891	920.42488721	0.22689410	-1.01469243	0.05395788	5.13980722
1151	362852.05186646	-9737.25147610	982.40028503	0.25820343	-0.98038562	0.05880421	4.86907357
1201	361851.97231527	-10314.64767419	1044.36883501	0.27580484	-0.98551441	0.17096994	4.65036092
1251	360867.34949742	-10883.11992314	1105.81915417	-0.17717719	-1.09696243	0.06044542	7.67880044

$Az = 3000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4951	378469.34436677	-1248.12178240	77.93192049	0.80356443	-2.47697435	0.25554153	16.77602775
1	378280.38739458	-1437.07875459	97.82213169	0.65058243	-2.38703904	0.24329554	18.21917945
51	378063.41480704	-1654.05134207	120.38592635	0.59176260	-2.25640385	0.22939835	16.56229397
101	377816.09396188	-1901.37218724	145.78737797	0.54192827	-2.13428562	0.21529047	15.04896149
151	377536.18514015	-2181.28100897	174.16413988	0.49977436	-2.02069286	0.20128595	13.70115988
201	377221.59912906	-2495.86702006	205.62374638	0.46420513	-1.91534583	0.18760722	12.51814417
251	376870.45549077	-2847.01065835	240.24044523	0.43431693	-1.81782717	0.17441317	11.48718341
301	376481.14022593	-3236.32592320	278.05261858	0.40935780	-1.72765910	0.16181527	10.59075662
351	376052.36165990	-3665.10448926	319.06080701	0.38869474	-1.64434015	0.14988716	9.81059256
401	375583.20356590	-4134.26258326	363.22630851	0.37179157	-1.56736441	0.13867104	9.12962883
451	375073.17476808	-4644.29138109	410.47028478	0.35819377	-1.49623354	0.12818282	8.53278436
501	374522.25471284	-5195.21143630	460.67327401	0.34751730	-1.43046548	0.11841699	8.00711887
551	373930.93471855	-5786.53143062	513.67498627	0.33943965	-1.36960104	0.10935121	7.54170632
601	373300.25478669	-6417.21136245	569.27424577	0.33369224	-1.31320896	0.10095083	7.12739588
651	372631.83595232	-7085.63019682	627.22894502	0.33005412	-1.26088976	0.09317310	6.75654692
701	371927.90814443	-7789.55800473	687.25588994	0.32834658	-1.21227904	0.08597084	6.42277785
751	371191.33341044	-8526.13273873	749.03044145	0.32842894	-1.16705029	0.07929566	6.12074452
801	370425.62413070	-9291.84201845	812.18589809	0.33019541	-1.12491762	0.07310049	5.84595189
851	369634.95551026	-10082.51063889	876.31261520	0.33357327	-1.08563832	0.06734157	5.59459724
901	368824.17121257	-10893.29493657	940.95691860	0.33852252	-1.04901517	0.06197968	5.36344048
951	367998.78051114	-11718.68563802	1005.61994494	0.34503732	-1.01489791	0.05698073	5.14969662
1001	367164.94482696	-12552.52132220	1069.75662555	0.35314968	-0.98318312	0.05231543	4.95094471
1051	366329.45103394	-13388.01511521	1132.77512522	0.36293343	-0.95381255	0.04795738	4.76506067
1101	365499.66852537	-14217.79762378	1194.03714801	0.37465931	-0.92670214	0.04392327	4.58942613
1151	364683.48680963	-15033.97933954	1252.85962300	0.39349274	-0.89992732	0.04198657	4.39935889
1201	363889.23045178	-15828.23569737	1308.51837230	0.44141625	-0.87219385	0.07482931	4.10325438
1251	363125.54858806	-16591.91756109	1360.25442510	-0.01540106	-1.05675172	0.05994553	6.82857991

$Az = 3000$ km continued

$\phi = 60\,^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4901	378828.73461611	-1539.32816954	108.52174595	1.14581286	-2.32310843	0.25017799	16.05230843
4951	378691.06572556	-1777.77768259	134.10713587	1.06111771	-2.19110893	0.23694894	14.61768808
1	378531.52610227	-2054.10841596	163.07824453	0.96177701	-2.08445611	0.22375359	13.94602932
51	378348.09686826	-2371.81716886	195.63293639	0.82469503	-2.02010452	0.21234510	14.63424991
101	378138.82483919	-2734.28695574	231.92586158	0.76527841	-1.91068874	0.19879304	13.27470573
151	377901.88071629	-3144.68621523	272.06177185	0.71387829	-1.80852403	0.18539084	12.07856534
201	377635.61938387	-3605.86437107	316.08968469	0.66952866	-1.71345681	0.17230639	11.03661783
251	377338.64054817	-4120.24680322	363.99808755	0.63138545	-1.62521443	0.15966332	10.13267179
301	377009.84794814	-4689.73229164	415.71130376	0.59870980	-1.54345202	0.14755312	9.34865635
351	376648.50548681	-5315.59579362	471.08706267	0.57085677	-1.46778072	0.13604124	8.66719759
401	376254.28885131	-5998.39903550	529.91523785	0.54726756	-1.39778845	0.12517005	8.07271329
451	375827.33147636	-6737.91090155	591.91764781	0.52746298	-1.33305661	0.11496096	7.55172604
501	375368.26402001	-7533.03906008	656.74876217	0.51103727	-1.27317386	0.10541679	7.09280126
551	374878.24680582	-8381.77377161	723.99712940	0.49765223	-1.21774729	0.09652469	6.68632797
601	374358.99490537	-9281.14444512	793.18734392	0.48703231	-1.16641150	0.08825997	6.32425199
651	373812.79564813	-10227.18930972	863.78240151	0.47896079	-1.11883627	0.08059012	5.99981319
701	373242.51833077	-11214.93859781	935.18635252	0.47327788	-1.07473348	0.07347916	5.70730837
751	372651.61574952	-12238.41189086	1006.74724776	0.46988099	-1.03386347	0.06689163	5.44188575
801	372044.11690905	-13290.63074809	1077.76047795	0.46872825	-0.99604088	0.06079616	5.19936919
851	371424.60989308	-14363.64837541	1147.47272735	0.46984638	-0.96113893	0.05516809	4.97610510
901	370798.21346698	-15448.59881106	1215.08688633	0.47334517	-0.92909072	0.04999091	4.76882216
951	370170.53557647	-16535.76880822	1279.76838497	0.47944154	-0.89988579	0.04525638	4.57449287
1001	369547.61659560	-17614.69613208	1340.65350428	0.48849122	-0.87356478	0.04096212	4.39022053
1051	368935.85505406	-18674.29820415	1396.86027234	0.50097516	-0.85023558	0.03708949	4.21341262
1101	368341.91375909	-19703.03470376	1447.50253362	0.51717059	-0.83017068	0.03347515	4.04330481
1151	367772.60483595	-20689.10668383	1491.70766105	0.53571414	-0.81399629	0.02940459	3.88620596
1201	367234.75336634	-21620.69275613	1528.63813142	0.54933245	-0.80289147	0.02314176	3.76853931
1251	366735.04106674	-22486.21984820	1557.51678771	0.53148184	-0.80040803	0.01299994	3.78126913

$Az = 3000$ km continued

$\phi = 90\,^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4751	379717.46614913	-1775.71615767	134.35941930	1.78866731	-1.86639409	0.22362819	15.27364667
4801	379717.46614917	-2052.69962559	168.23374266	1.65946631	-1.77632812	0.21628574	14.31292238
4851	379717.46614914	-2383.75778701	207.09407972	1.54119581	-1.68312302	0.20643149	13.20768596
4901	379717.46614916	-2775.77629531	251.36937878	1.42955771	-1.59616868	0.19523672	12.23145132
4951	379717.46614914	-3235.81258698	301.41125541	1.34095608	-1.49265704	0.18051794	10.87746410
1	379717.46614914	-3770.87237606	357.47093271	1.22104046	-1.45389970	0.17362191	10.86213421
51	379717.46614917	-4387.64990645	419.67660709	1.10782800	-1.42324204	0.16684580	10.95125943
101	379717.46614915	-5092.24025859	488.01246409	1.03789758	-1.34571915	0.15579065	9.96361918
151	379717.46614915	-5889.83470011	562.30054051	0.97608827	-1.27281612	0.14473754	9.09998034
201	379717.46614915	-6784.41183773	642.18647361	0.92167347	-1.20464021	0.13376130	8.34752620
251	379717.46614915	-7778.43780764	727.12990993	0.87396105	-1.14117613	0.12293401	7.69217799
301	379717.46614915	-8872.58787983	816.40001454	0.83231623	-1.08231497	0.11232560	7.12037730
351	379717.46614915	-10065.49988370	909.07619320	0.79618243	-1.02788314	0.10200047	6.61980291
401	379717.46614915	-11353.56728122	1004.05388878	0.76510119	-0.97767226	0.09201372	6.17952816
451	379717.46614915	-12730.77722383	1100.05520492	0.73873377	-0.93146967	0.08240979	5.78990357
501	379717.46614916	-14188.59728131	1195.64418845	0.71689040	-0.88909008	0.07322630	5.44230570
551	379717.46614916	-15715.91443704	1289.24687806	0.69958205	-0.85040457	0.06450529	5.12875667
601	379717.46614916	-17299.03185840	1379.17666810	0.68713307	-0.81535775	0.05631704	4.84127187
651	379717.46614916	-18921.73300400	1463.66606001	0.68130484	-0.78321004	0.04874988	4.56370383
701	379717.46614916	-20565.42842489	1540.90634083	0.61118368	-0.81550312	0.05273073	4.87287411
751	379717.46614916	-22209.40702101	1609.09693239	0.61147561	-0.78609815	0.04229138	4.59968694
801	379717.46614916	-23831.21845019	1666.50583081	0.61384962	-0.76373199	0.03246833	4.36952318
851	379717.46614916	-25407.21372057	1711.54141855	0.61238776	-0.75093008	0.02410418	4.21259819
901	379717.46614916	-26913.26278083	1742.83376717	0.58316864	-0.75519727	0.01990230	4.26074991
951	379717.46614916	-28325.64753974	1759.32039342	0.58261688	-0.74749906	0.01166640	4.14431395
1001	379717.46614916	-29622.09496592	1760.32777336	0.58026440	-0.74350335	0.00508863	4.06289261
1051	379717.46614916	-30782.87175216	1745.63682890	0.57726973	-0.74157548	-0.00006708	4.00385981
1101	379717.46614916	-31791.82049774	1715.51957317	0.57372590	-0.74089047	-0.00415105	3.96296175
1151	379717.46614916	-32637.19403066	1670.73647086	0.56849123	-0.74105597	-0.00741716	3.94321055
1201	379717.46614916	-33312.15491467	1612.49015480	0.55938457	-0.74194587	-0.00996531	3.95343578
1251	379717.46614916	-33814.85663608	1542.33961315	0.54175377	-0.74419777	-0.01168489	4.01742649

Table C.4 Initial conditions for long transfers to a 4000 km Az halo orbit

$Az = 4000$ km

$\phi = 30^\circ$

manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378156.07142795	-901.47166255	58.34547860	0.36664037	-2.57459970	0.33977810	20.35661840
51	377924.47248823	-1035.18537275	77.40708921	0.31986973	-2.43309884	0.32144690	18.59062908
101	377660.74251386	-1187.44994449	99.23235538	0.28169440	-2.30151559	0.30262163	16.94036413
151	377362.44932193	-1359.66959915	124.01297336	0.25063734	-2.17981190	0.28381255	15.44681707
201	377027.26441131	-1553.18869749	151.92166952	0.22545158	-2.06753577	0.26537538	14.12202064
251	376653.01272608	-1769.26300874	183.10949435	0.20516670	-1.96404996	0.24756044	12.95994341
301	376237.72208832	-2009.03117024	217.70353724	0.18903778	-1.86866927	0.23054202	11.94559537
351	375779.67162267	-2273.48672986	255.80507611	0.17648254	-1.78072341	0.21443507	11.06086460
401	375277.43867321	-2563.45105842	297.48814262	0.16703367	-1.69957977	0.19930580	10.28769600
451	374729.94391620	-2879.54730377	342.79845133	0.16030765	-1.62464900	0.18518009	9.60957436
501	374136.49458299	-3222.17543607	391.75261206	0.15598529	-1.55538437	0.17205124	9.01205606
551	373496.82589235	-3591.48832680	444.33752065	0.15379941	-1.49127943	0.15988749	8.48281734
601	372811.14094472	-3987.36871587	500.50980502	0.15352655	-1.43186572	0.14863903	8.01148422
651	372080.14941879	-4409.40687015	560.19519200	0.15498090	-1.37671105	0.13824439	7.58938365
701	371305.10542709	-4856.87872739	623.28765494	0.15800928	-1.32541843	0.12863568	7.20928460
751	370487.84481171	-5328.72436370	689.64820340	0.16248694	-1.27762553	0.11974282	6.86515946
801	369630.82199318	-5823.52671868	759.10318336	0.16831383	-1.23300473	0.11149679	6.55197657
851	368737.14620787	-6339.49067389	831.44197005	0.17541138	-1.19126346	0.10383183	6.26552569
901	367810.61659452	-6874.42279558	906.41395515	0.18371994	-1.15214499	0.09668710	6.00227257
951	366855.75510593	-7425.71233305	983.72475898	0.19319591	-1.11542982	0.09000737	5.75924599
1001	365877.83564843	-7990.31439508	1063.03163633	0.20381851	-1.08093371	0.08374553	5.53389173
1051	364882.90719434	-8564.73660588	1143.93809693	0.21549647	-1.04854355	0.07783349	5.32452338
1101	363877.80790113	-9145.03095336	1225.98783170	0.22965383	-1.01764661	0.07276695	5.12172480
1151	362870.16654741	-9726.79296018	1308.65812915	0.26532731	-0.98446644	0.09007570	4.82797013
1201	361868.38691457	-10305.17070087	1391.35308751	0.28770109	-1.00579450	0.19846715	4.57518135
1251	360881.61020011	-10874.88650259	1473.39708218	-0.18072913	-1.10199029	0.08063980	7.70873964

$Az = 4000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4951	378478.65226599	-1238.81388312	103.36205611	0.80659149	-2.47625941	0.34173749	16.90341533
1	378290.06965334	-1427.39649577	129.85867069	0.65469958	-2.38534572	0.32530503	18.30908635
51	378073.52712147	-1643.93902769	159.92288834	0.59627039	-2.25461519	0.30670538	16.61055723
101	377826.69623270	-1890.76991646	193.77126841	0.54676993	-2.13278345	0.28784221	15.06455898
151	377547.33968884	-2170.12646032	231.58541339	0.50483904	-2.01974770	0.26912164	13.69294017
201	377233.36866261	-2484.09748655	273.50713194	0.46936149	-1.91511764	0.25083036	12.49375432
251	376882.90083386	-2834.56531526	319.63427761	0.43943890	-1.81838058	0.23317548	11.45270634
301	376494.31784705	-3223.14830212	370.01734679	0.41433994	-1.72898484	0.21630614	10.55075669
351	376066.32102395	-3651.14512518	424.65686153	0.39345872	-1.64637740	0.20032465	9.76833496
401	375597.98434998	-4119.48179915	483.50150568	0.37628646	-1.57002120	0.18529298	9.08734413
451	375088.80397876	-4628.66217037	546.44692831	0.36239255	-1.49940358	0.17123786	8.49191865
501	374538.74374538	-5178.72240378	613.33508387	0.35141166	-1.43404071	0.15815598	7.96854620
551	373948.27639686	-5769.18975228	683.95394679	0.34303457	-1.37347985	0.14601973	7.50589800
601	373318.42042505	-6399.04572412	758.03742160	0.33700121	-1.31730081	0.13478341	7.09454961
651	372650.77247914	-7066.69367002	835.26526998	0.33309531	-1.26511703	0.12438916	6.72668189
701	371947.53533350	-7769.93081566	915.26289387	0.33114012	-1.21657693	0.11477255	6.39580273
751	371211.54127100	-8505.92487815	997.60084825	0.33099500	-1.17136567	0.10586718	6.09650485
801	370446.27051962	-9271.19562952	1081.79400772	0.33255301	-1.12920714	0.09760844	5.82426219
851	369655.86404465	-10061.60210450	1167.30037828	0.33573958	-1.08986645	0.08993628	5.57526207
901	368845.12958276	-10872.33656640	1253.51962696	0.34051242	-1.05315212	0.08279696	5.34626782
951	368019.53931881	-11697.92683036	1339.79149997	0.34686307	-1.01891780	0.07614379	5.13450592
1001	367185.21710139	-12532.24904775	1425.39441067	0.35482032	-0.98706248	0.06993654	4.93757328
1051	366348.91261059	-13368.55353856	1509.54460414	0.36446192	-0.95752558	0.06414170	4.75332648
1101	365517.95949616	-14199.50665299	1591.39643757	0.37638959	-0.93009275	0.05891860	4.57752555
1151	364700.21427856	-15017.25187061	1670.04445018	0.39821050	-0.90232923	0.05825542	4.37449411
1201	363903.97283297	-15813.49331620	1744.52801645	0.44430511	-0.88130272	0.10181597	4.08500874
1251	363137.86167334	-16579.60447581	1813.83946121	-0.01823786	-1.06223451	0.08016078	6.84564554

$Az = 4000$ km continued

manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
$\phi = 60^\circ$							
4901	378836.24356042	-1526.32229649	143.79680183	1.14839604	-2.32280156	0.33459619	16.22036604
4951	378698.95014626	-1764.12146528	177.87669940	1.06540782	-2.18899176	0.31680129	14.69297655
1	378539.83907702	-2039.70992126	216.47460144	0.95714351	-2.08911218	0.29966301	14.25426793
51	378356.89534640	-2356.57775768	259.85160611	0.82971962	-2.01750593	0.28396513	14.64932063
101	378148.16797515	-2718.10416962	308.21163930	0.77056640	-1.90853427	0.26590113	13.26159305
151	377911.82790258	-3127.45718313	361.69268867	0.71934829	-1.80704006	0.24803347	12.04583936
201	377646.22800412	-3587.48970175	420.35911676	0.67508475	-1.71277258	0.23057201	10.99126768
251	377349.96348093	-4100.63490840	484.19531896	0.63693258	-1.62537888	0.21367459	10.08010352
301	377021.93086456	-4668.80406649	553.10089766	0.60416291	-1.54445152	0.19746352	9.29289042
351	376661.38399444	-5293.28956405	626.88741662	0.57614578	-1.46955616	0.18203201	8.61111344
401	376267.98554231	-5974.67567076	705.27669384	0.55233940	-1.40025110	0.16744559	8.01828268
451	375841.85294219	-6712.75898493	787.90049737	0.53228139	-1.33610219	0.15374231	7.50021886
501	375383.59789684	-7506.48000631	874.30143842	0.51558093	-1.27669407	0.14093379	7.04496123
551	374894.35891486	-8353.86678013	963.93481959	0.50191199	-1.22163816	0.12900827	6.64251857
601	374375.82655475	-9251.99117322	1056.17119610	0.49100804	-1.17057855	0.11793541	6.28457392
651	373830.26116532	-10196.93814657	1150.29944844	0.48265848	-1.12319684	0.10767223	5.96419554
701	373260.50290237	-11183.78840603	1245.53024328	0.47670716	-1.07921673	0.09816950	5.67557646
751	372669.97365621	-12206.61506373	1340.99987159	0.47305320	-1.03840899	0.08937774	5.41380944
801	372062.67026070	-13258.49540037	1435.77459232	0.47165498	-1.00059630	0.08125249	5.17469548
851	371443.14798955	-14331.53945044	1528.85576811	0.47253834	-0.96565737	0.07375814	4.95457906
901	370816.49293521	-15416.93784339	1619.18624371	0.47581106	-0.93352847	0.06687012	4.75020007
951	370188.28145807	-16505.03203966	1705.65857491	0.48168607	-0.90420113	0.06057501	4.55855397
1001	369564.52457872	-17585.41064626	1787.12584234	0.49050792	-0.87771959	0.05486575	4.37679911
1051	368951.59505165	-18647.03572862	1862.41585710	0.50272088	-0.85420008	0.04970439	4.20250108
1101	368356.13502160	-19678.40275453	1930.34954569	0.51851529	-0.83391143	0.04484122	4.03521038
1151	367784.94274567	-20667.73679733	1989.76415366	0.53643803	-0.81739836	0.03931065	3.88141124
1201	367244.83797366	-21603.22570387	2039.54158899	0.54930649	-0.80566702	0.03089233	3.76691426
1251	366742.50730026	-22473.28795241	2078.64171116	0.53068310	-0.80236592	0.01737813	3.78224615

$Az = 4000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4751	379717.46614917	-1754.52749192	177.22061817	1.79360750	-1.86819779	0.29920861	15.46433729
4801	379717.46614917	-2029.98573154	222.24498257	1.66359409	-1.77673493	0.28935715	14.46970630
4851	379717.46614914	-2359.30660586	273.92367838	1.54492443	-1.68265739	0.27618879	13.32494331
4901	379717.46614914	-2749.35852571	332.82568814	1.43294117	-1.59565840	0.26130873	12.32082179
4951	379717.46614917	-3207.18795828	399.41751433	1.34602134	-1.49050014	0.24107439	10.88448917
1	379717.46614914	-3739.79780044	474.03290436	1.21862434	-1.46200048	0.23391981	11.08414708
51	379717.46614917	-4353.88953293	556.84302129	1.11203611	-1.42132284	0.22377961	10.93858425
101	379717.46614915	-5055.57731878	647.82869103	1.04224149	-1.34429772	0.20918938	9.93451682
151	379717.46614915	-5850.08493820	746.75633148	0.98062527	-1.27199317	0.19455867	9.05897600
201	379717.46614915	-6741.43818295	853.15895791	0.92645355	-1.20449088	0.17996928	8.29804839
251	379717.46614915	-7732.16585914	966.32330655	0.87901812	-1.14176110	0.16550928	7.63694630
301	379717.46614915	-8823.02170921	1085.28367459	0.83766060	-1.08368292	0.15127359	7.06167718
351	379717.46614915	-10012.73761893	1208.82263581	0.80179748	-1.03006770	0.13735868	6.55963610
401	379717.46614915	-11297.81590893	1335.47845188	0.77094477	-0.98068689	0.12385616	6.11966963
451	379717.46614916	-12672.36600941	1463.55884896	0.74474279	-0.93530395	0.11084908	5.73191216
501	379717.46614916	-14127.98912723	1591.16092556	0.72298702	-0.89370750	0.09841407	5.38751843
551	379717.46614916	-15653.71436289	1716.19731816	0.70567743	-0.85574323	0.08663352	5.07831021
601	379717.46614917	-17235.99156028	1836.42933348	0.69314562	-0.82131246	0.07561908	4.79598483
651	379717.46614916	-18858.75015959	1949.50845680	0.68651050	-0.79022084	0.06558096	4.52946722
701	379717.46614916	-20503.53908218	2053.02828202	0.61747199	-0.81992002	0.06998293	4.82224628
751	379717.46614916	-22149.76915273	2144.58921296	0.61700042	-0.79154045	0.05599632	4.56001685
801	379717.46614916	-23775.08473226	2221.87790800	0.61843649	-0.76958239	0.04292714	4.33972349
851	379717.46614916	-25355.89203611	2282.76199767	0.61625708	-0.75646846	0.03179363	4.18867939
901	379717.46614916	-26868.06409587	2325.39780007	0.58638330	-0.76038673	0.02610592	4.23907321
951	379717.46614917	-28287.82279033	2348.34460915	0.58523617	-0.75203592	0.01525872	4.12622253
1001	379717.46614916	-29592.76530699	2350.67424037	0.58256774	-0.74731766	0.00658404	4.04631990
1051	379717.46614916	-30762.95938688	2332.06027410	0.57936340	-0.74475988	-0.00022832	3.98816474
1101	379717.46614916	-31781.98935288	2292.82981769	0.57558954	-0.74357518	-0.00563016	3.94821489
1151	379717.46614917	-32637.80964803	2233.96345582	0.57001373	-0.74336850	-0.00995071	3.92982389
1201	379717.46614916	-33323.27045658	2157.03691824	0.56030722	-0.74402057	-0.01331717	3.94242683
1251	379717.46614916	-33836.22718861	2064.10923351	0.54134781	-0.74629361	-0.01555409	4.01223777

Table C.5 Initial conditions for long transfers to a 5000 km Az halo orbit

$Az = 5000$ km

$\phi = 30^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378169.67255973	-893.61904546	72.46140730	0.37080402	-2.57435182	0.42636390	20.51435509
51	377938.54241503	-1027.06209677	96.24275534	0.32472607	-2.43263190	0.40329750	18.69143365
101	377675.34955381	-1179.01656600	123.48165484	0.28718123	-2.30138343	0.37963668	16.99316407
151	377377.66633182	-1350.88405435	154.41507051	0.25658787	-2.18044282	0.35600287	15.46254935
201	377043.16647611	-1544.00763609	189.25645751	0.23163395	-2.06919705	0.33282468	14.11148106
251	376669.67461556	-1759.64326232	228.19248593	0.21133851	-1.96684527	0.31040732	12.93242504
301	376255.21550255	-1998.93134282	271.38025702	0.19499091	-1.87256342	0.28897176	11.90833879
351	375798.06224899	-2262.86889679	318.94503695	0.18206819	-1.78558310	0.26867278	11.01906405
401	375296.78307990	-2552.28256001	370.97849125	0.17216719	-1.70521840	0.24960685	10.24480735
451	374750.28630714	-2867.80261891	427.53736156	0.16495919	-1.63086519	0.23181766	9.56772926
501	374157.86343589	-3209.83812307	488.64248912	0.16016419	-1.56198837	0.21530314	8.97245706
551	373519.23050222	-3578.55301926	554.27805820	0.15753879	-1.49810724	0.20002476	8.44605611
601	372834.56789224	-3973.84316144	624.39090942	0.15687113	-1.43878371	0.18591769	7.97777197
651	372104.55898271	-4395.31400185	698.88975756	0.15797871	-1.38361488	0.17290041	7.55870672
701	371330.42796215	-4842.25875498	777.64414122	0.16070675	-1.33222918	0.16088281	7.18150458
751	370513.97711901	-5313.63686903	860.48293264	0.16492630	-1.28428502	0.14977246	6.84007551
801	369657.62371941	-5808.05273482	947.19224402	0.17053205	-1.23947096	0.13947904	6.52936318
851	368764.43632584	-6323.73471692	1037.51258303	0.17743994	-1.19750665	0.12991730	6.24515476
901	367838.17003907	-6858.51480693	1131.13513392	0.18558502	-1.15814431	0.12100898	5.98392664
951	366883.29966825	-7409.80947257	1227.69707491	0.19491952	-1.12117039	0.11268369	5.74272031
1001	365905.04926888	-7974.60260399	1326.77588891	0.20541277	-1.08640683	0.10487966	5.51903483
1051	364909.41583551	-8549.43183476	1427.88268759	0.21702855	-1.05371980	0.09753382	5.31087119
1101	363903.18423268	-9130.37992151	1530.45465392	0.23693489	-1.02094507	0.09483289	5.07813352
1151	362893.92972377	-9713.07328391	1633.84682127	0.27179013	-0.99781841	0.13659676	4.78083547
1201	361890.00377903	-10292.69019837	1737.32355500	0.29684388	-1.03110594	0.21563299	4.51323946
1251	360900.49828642	-10863.98146089	1840.05029075	-0.18550643	-1.10889210	0.10078165	7.74895308

$Az = 5000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378302.52062981	-1414.94551936	161.40406879	0.66056740	-2.38320908	0.40815786	18.41240872
51	378086.54021698	-1630.92593213	198.95016005	0.60283324	-2.25246985	0.38481310	16.65473091
101	377840.34870235	-1877.11744682	241.22744384	0.55396261	-2.13119320	0.36116611	15.06204268
151	377561.71195128	-2155.75419784	288.45979090	0.51248650	-2.01912654	0.33769634	13.65672230
201	377248.54168722	-2468.92446190	340.82192159	0.47722875	-1.91571091	0.31473881	12.43557019
251	376898.95323306	-2818.51291610	398.43430296	0.44728162	-1.82027067	0.29254160	11.38217504
301	376511.32270718	-3206.14344195	461.35895312	0.42194508	-1.73211616	0.27129477	10.47514091
351	376084.34251474	-3633.12363439	529.59619640	0.40066903	-1.65059561	0.25114102	9.69268680
401	375617.07415857	-4100.39199056	603.08233828	0.38300675	-1.57511806	0.23217711	9.01487091
451	375108.99761779	-4608.46853137	681.68816044	0.36858210	-1.50515719	0.21445346	8.42443048
501	374560.05678447	-5157.40936466	765.21807850	0.35706983	-1.44024387	0.19797669	7.90688088
551	373970.70066870	-5746.76548044	853.40976439	0.34818596	-1.37995531	0.18271616	7.45026687
601	373341.92025630	-6375.54589286	945.93401274	0.34168366	-1.32390589	0.16861314	7.04479059
651	372675.28099824	-7042.18515090	1042.39463069	0.33735165	-1.27174180	0.15559055	6.68243101
701	371972.95091215	-7744.51523701	1142.32815026	0.33501303	-1.22313931	0.14356189	6.35660381
751	371237.72416504	-8479.74198413	1245.20320463	0.33452422	-1.17780559	0.13243836	6.06187609
801	370473.03978822	-9244.42636094	1350.41947104	0.33577400	-1.13548109	0.12213425	5.79373447
851	369682.99484784	-10034.47130131	1457.30616450	0.33868299	-1.09594259	0.11257055	5.54839938
901	368872.35098303	-10845.11516612	1565.12016679	0.34320399	-1.05900638	0.10367708	5.32267680
951	368046.53274480	-11670.93340435	1673.04399438	0.34932367	-1.02453070	0.09539321	5.11383940
1001	367211.61566893	-12505.85048022	1780.18394546	0.35706651	-0.99241634	0.08766720	4.91952620
1051	366374.30153317	-13343.16461599	1885.56892027	0.36656209	-0.96258040	0.08048246	4.73734160
1101	365541.87785419	-14175.58829496	1988.15057305	0.37923013	-0.93455128	0.07449731	4.55907858
1151	364722.15844235	-14995.30770680	2086.80562101	0.40498443	-0.90631114	0.07773047	4.33902618
1201	363923.40184794	-15794.06430121	2180.34128728	0.44843082	-0.89513908	0.12991606	4.05899195
1251	363154.20489682	-16563.26125233	2267.50496562	-0.02209790	-1.06986787	0.10050058	6.86859753

$Az = 5000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4901	378845.88412320	-1509.62435193	178.29946624	1.15206494	-2.32232401	0.41992879	16.43521857
4951	378709.08053075	-1746.57512463	220.84347487	1.07104883	-2.18653260	0.39746244	14.79328636
1	378550.52769222	-2021.19669673	269.04101472	0.95121065	-2.09545368	0.37676836	14.67513995
51	378368.21558710	-2336.97052563	323.21405202	0.83701632	-2.01425808	0.35643212	14.64758527
101	378160.19608086	-2697.27087934	383.61381357	0.77843230	-1.90604228	0.33390689	13.21884324
151	377924.64044297	-3105.26521219	450.41006172	0.72764899	-1.80566116	0.31161506	11.97477607
201	377659.89900791	-3563.81082860	523.68163538	0.68363541	-1.71271623	0.28978345	10.90278242
251	377364.56124829	-4075.35083364	603.40860415	0.64553032	-1.62671504	0.26858881	9.98297450
301	377037.51451625	-4641.81239004	689.46626490	0.61261586	-1.54712779	0.24818319	9.19377456
351	376677.99982240	-5264.51010581	781.62107367	0.58429557	-1.47342557	0.22870035	8.51470163
401	376285.66323633	-5944.05700655	879.52847085	0.56007304	-1.40510843	0.21025009	7.92757630
451	375860.60177122	-6680.28506051	982.73243842	0.53953181	-1.34172136	0.19290877	7.41688231
501	375403.40292571	-7472.17669005	1090.66653879	0.52231961	-1.28285824	0.17671313	6.96968783
551	374915.17733920	-8317.80821148	1202.65613645	0.50813834	-1.22815813	0.16166089	6.57535543
601	374397.58423744	-9214.30576134	1317.92150186	0.49673919	-1.17729998	0.14771749	6.22517786
651	373852.84946269	-10157.81406787	1435.58154497	0.48792123	-1.12999941	0.13482624	5.91201658
701	373283.77587667	-11143.47843213	1554.65802055	0.48153222	-1.08600910	0.12291922	5.62997953
751	372693.74578599	-12165.44052715	1674.08018483	0.47747157	-1.04512196	0.11192716	5.37414925
801	372086.71478103	-13216.84906951	1792.69005428	0.47569569	-1.00717613	0.10178733	5.14035867
851	371467.19602147	-14289.88703731	1909.24861197	0.47622709	-0.97205990	0.09244899	4.92500525
901	370840.23359456	-15375.81781517	2022.44351116	0.47916895	-0.93971465	0.08387626	4.72489109
951	370211.36316516	-16465.05335026	2130.89902122	0.48472679	-0.91013485	0.07604780	4.53708431
1001	369586.55781648	-17547.24795902	2233.18912250	0.49322637	-0.88336946	0.06894666	4.35886117
1051	368972.15683022	-18611.42168345	2327.85475251	0.50505788	-0.85954189	0.06250051	4.18803954
1101	368374.77529474	-19646.11685439	2413.42619246	0.52029941	-0.83890296	0.05634727	4.02458179
1151	367801.19297089	-20639.59058162	2488.45141338	0.53739754	-0.82188243	0.04927281	3.87514536
1201	367258.22190710	-21580.04405114	2551.53082385	0.54929029	-0.80928908	0.03865413	3.76477132
1251	366752.55395127	-22455.88664243	2601.35824194	0.52965645	-0.80491357	0.02178362	3.78351775

$Az = 5000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4801	379717.46614913	-2000.90635120	274.48822787	1.66920747	-1.77697751	0.36327621	14.66775566
4851	379717.46614914	-2327.97983332	338.86649868	1.54922892	-1.68299570	0.34687549	13.50495128
4901	379717.46614917	-2715.48871215	412.27942105	1.44016507	-1.59122689	0.32774494	12.33741595
4951	379717.46614914	-3170.46529866	495.30636170	1.34300944	-1.50155238	0.30635141	11.19059689
1	379717.46614914	-3699.90872834	588.36250693	1.25235987	-1.42162588	0.28518240	10.24780596
51	379717.46614915	-4310.52950512	691.66213443	1.11796411	-1.41886600	0.28216976	10.90873997
101	379717.46614917	-5008.46590023	805.18428750	1.04846094	-1.34255219	0.26428657	9.88162227
151	379717.46614915	-5798.98289642	928.64286350	0.98723679	-1.27110778	0.24627067	8.98903212
201	379717.46614915	-6686.16619003	1061.46288277	0.93355146	-1.20459426	0.22817933	8.21563075
251	379717.46614915	-7672.62425621	1202.76425393	0.88666575	-1.14297765	0.21009659	7.54590306
301	379717.46614915	-8759.21070863	1351.35380219	0.84586618	-1.08612792	0.19213626	6.96560009
351	379717.46614915	-9944.77726966	1505.72577390	0.81050087	-1.03382512	0.17443699	6.46203118
401	379717.46614915	-11225.96511274	1664.07060045	0.78002109	-0.98578058	0.15715359	6.02386879
451	379717.46614915	-12597.03982919	1824.29150697	0.75402171	-0.94167724	0.14044730	5.64085315
501	379717.46614916	-14049.77353701	1984.02865868	0.73227901	-0.90122268	0.12447870	5.30354599
551	379717.46614916	-15573.37740885	2140.69097551	0.71479884	-0.86419788	0.10940943	5.00307765
601	379717.46614916	-17154.48962459	2291.49646411	0.70193254	-0.83046644	0.09542151	4.73051827
651	379717.46614916	-18777.22764069	2433.52279466	0.69419978	-0.80034795	0.08285478	4.47914925
701	379717.46614916	-20423.31937835	2563.77066462	0.62635542	-0.82687799	0.08678675	4.75214022
751	379717.46614916	-22072.33448641	2679.24292159	0.62457630	-0.79953308	0.06920677	4.50660143
801	379717.46614916	-23702.04228695	2777.04202983	0.62459511	-0.77772624	0.05294562	4.30028432
851	379717.46614916	-25288.92438269	2854.48678002	0.62140765	-0.76391168	0.03909668	4.15721612
901	379717.46614916	-26808.86328370	2909.24576757	0.59061414	-0.76730701	0.03187614	4.21078350
951	379717.46614916	-28238.00996641	2939.48007447	0.58864626	-0.75796492	0.01856574	4.10287283
1001	379717.46614916	-29553.80117659	2943.98146872	0.58553379	-0.75223691	0.00789715	4.02518404
1051	379717.46614916	-30736.05456861	2922.28694212	0.58204039	-0.74882740	-0.00050644	3.96830157
1101	379717.46614916	-31768.02646411	2874.74799730	0.57797031	-0.74698166	-0.00718357	3.92958836
1151	379717.46614916	-32637.28933856	2802.53615121	0.57197028	-0.74629263	-0.01252929	3.91285965
1201	379717.46614916	-33336.29066246	2707.57552266	0.56151654	-0.74664558	-0.01669168	3.92833945
1251	379717.46614916	-33862.49896018	2592.40729815	0.54084671	-0.74898041	-0.01940487	4.00549206

Table C.6 Initial conditions for long transfers to a 6000 km Az halo orbit

$Az = 6000$ km

$\phi = 30^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378186.29612643	-884.02142480	86.26403840	0.37693121	-2.57429092	0.51414989	20.68660921
51	377955.75426419	-1017.12483102	114.73403855	0.33210307	-2.43256761	0.48626330	18.78246351
101	377693.23346926	-1168.69128260	147.35747571	0.29581901	-2.30217989	0.45768460	17.01344530
151	377396.31181421	-1340.11908008	184.41478094	0.26627261	-2.18284638	0.42910890	15.42754683
201	377062.66590997	-1532.74963274	226.15847551	0.24193258	-2.07372221	0.40099508	14.03887376
251	376690.12015627	-1747.83902389	272.80939812	0.22168703	-1.97367486	0.37368258	12.83929208
301	376276.69570883	-1986.52973995	324.55347071	0.20484864	-1.88150904	0.34746716	11.80858375
351	375820.65848927	-2249.82295142	381.53904603	0.19106117	-1.79616346	0.32261729	10.92197161
401	375320.56574092	-2538.55163430	443.87482817	0.18013401	-1.71683579	0.29933538	10.15530179
451	374775.31083419	-2853.35470145	511.62830524	0.17190400	-1.64297143	0.27771822	9.48766199
501	374184.16623180	-3194.65219675	584.82458747	0.16618221	-1.57416551	0.25776100	8.90193693
551	373546.82470990	-3562.62149601	663.44550508	0.16275852	-1.51007347	0.23939030	8.38437756
601	372863.43908384	-3957.17437118	747.42879124	0.16142180	-1.45036584	0.22249597	7.92394108
651	372134.66077881	-4377.93472179	836.66715579	0.16197595	-1.39471566	0.20695211	7.51169913
701	371361.67760496	-4824.21676527	931.00704601	0.16424829	-1.34280065	0.19262965	7.14037475
751	370546.25103176	-5295.00351683	1030.24689082	0.16809230	-1.29430975	0.17940363	6.80399277
801	369690.75309462	-5788.92548111	1134.13463329	0.17338715	-1.24894963	0.16715713	6.49761502
851	368798.20280476	-6304.23963124	1242.36437483	0.18003574	-1.20645015	0.15578323	6.21713727
901	367872.30157014	-6838.80895828	1354.57198148	0.18796241	-1.16656859	0.14518591	5.95913057
951	366917.46666909	-7390.08314543	1470.32954190	0.19710919	-1.12909364	0.13527946	5.72072692
1001	365938.86125821	-7955.08124285	1589.13861984	0.20750887	-1.09382673	0.12602519	5.49906987
1051	364942.41875511	-8530.37759024	1710.42231655	0.22296825	-1.05969868	0.11977042	5.27039310
1101	363934.85873850	-9112.09263705	1833.51625644	0.25337324	-1.02989383	0.13803233	4.97814544
1151	362923.69078758	-9695.89072572	1957.65874046	0.28107447	-1.03939125	0.20057605	4.69222274
1201	361917.20200244	-10276.98729674	2081.98048302	0.30456778	-1.06461275	0.22524204	4.45506937
1251	360924.42338377	-10850.16829948	2205.49456818	-0.19169041	-1.11807336	0.12069201	7.80084213

$Az = 6000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378317.74093912	-1399.72521005	192.33336599	0.66892858	-2.38066938	0.49217129	18.50972256
51	378102.46149379	-1615.00465537	237.33730705	0.61263577	-2.25017274	0.46407205	16.66343860
101	377857.06572431	-1860.40042486	288.02012066	0.56527377	-2.13005995	0.43564896	14.99684308
151	377579.32343977	-2138.14270939	344.64581636	0.52511370	-2.01995317	0.40739945	13.53598532
201	377267.14712006	-2450.31902910	407.42030174	0.49070298	-1.91907287	0.37964228	12.27956178
251	376918.64930408	-2798.81684509	476.48540129	0.46091857	-1.82639412	0.35262447	11.21097004
301	376532.19947052	-3185.26667861	551.91390208	0.43504077	-1.74076915	0.32659989	10.30543077
351	376106.47926183	-3610.98688730	633.70569535	0.41272768	-1.66114761	0.30184785	9.53524086
401	375640.53508154	-4076.93106759	721.78499063	0.39381865	-1.58679415	0.27860859	8.87460683
451	375133.82731834	-4583.63883080	815.99849375	0.37815002	-1.51728581	0.25700885	8.30227962
501	374586.27568841	-5131.19046073	916.11436873	0.36550322	-1.45235420	0.23705728	7.80171060
551	373998.30040624	-5719.16574291	1021.82175244	0.35562849	-1.39176045	0.21868533	7.36014283
601	373370.85906885	-6346.60708032	1132.73056271	0.34827707	-1.33525010	0.20178491	6.96763620
651	372705.47923481	-7011.98691435	1248.37133766	0.34322160	-1.28255204	0.18623147	6.61631620
701	372004.28668253	-7713.17946661	1368.19486674	0.34026566	-1.23339088	0.17189752	6.29984368
751	371270.02922854	-8447.43692060	1491.57142166	0.33924708	-1.18750025	0.15866069	6.01304331
801	370506.09577273	-9211.37037642	1617.78946672	0.34003846	-1.14463375	0.14640850	5.75163757
851	369716.52991833	-10000.93623081	1746.05382315	0.34254674	-1.10457336	0.13504075	5.51205086
901	368906.03711039	-10811.42903876	1875.48337886	0.34671321	-1.06713578	0.12447050	5.29126118
951	368079.98376519	-11637.48238396	2005.10857456	0.35251508	-1.03217652	0.11462388	5.08668249
1001	367244.38636709	-12473.07978206	2133.86905799	0.35998674	-0.99958501	0.10544805	4.89597110
1051	366405.88803026	-13311.57811889	2260.61207841	0.36952264	-0.96918970	0.09708916	4.71542276
1101	365571.71962507	-14145.74652408	2384.09238855	0.38432698	-0.94021890	0.09175467	4.52828863
1151	364749.64232075	-14967.82382840	2502.97462003	0.41437633	-0.91398843	0.10373122	4.28940991
1201	363947.86839272	-15769.59775645	2615.83928220	0.45417074	-0.91573366	0.15810720	4.02315190
1251	363174.95747833	-16542.50867082	2721.19367243	-0.02717867	-1.08024913	0.12083631	6.89818825

$Az = 6000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4951	378721.45091551	-1725.14898973	262.80289702	1.07066346	-2.18970110	0.47986783	15.15488304
1	378563.59132161	-1998.56982690	320.56460314	0.98852583	-2.07114693	0.45204225	13.88320148
51	378382.06242059	-2312.98710644	385.49933277	0.84799770	-2.01044592	0.43023891	14.59032227
101	378174.91957104	-2671.76904630	457.90311118	0.79102903	-1.90361701	0.40347264	13.09200199
151	377940.33448123	-3078.08234054	537.97562320	0.74177141	-1.80537389	0.37697827	11.79606178
201	377676.65444442	-3534.78956125	625.80907709	0.69891068	-1.71516717	0.35090573	10.69152770
251	377382.46202961	-4044.34577096	721.37890447	0.66128387	-1.63222594	0.32534716	9.75952966
301	377056.63350297	-4608.69733361	824.53659423	0.62803708	-1.55554558	0.30042847	8.97644456
351	376698.39436483	-5229.18572213	935.00479130	0.59873972	-1.48407536	0.27638515	8.31584952
401	376307.37059562	-5906.45875740	1052.37462461	0.57321832	-1.41707496	0.25353182	7.75268222
451	375883.63448144	-6640.39123614	1176.10508325	0.55131830	-1.35420388	0.23212226	7.26650825
501	375427.74419440	-7430.01637597	1305.52414933	0.53282646	-1.29531579	0.21226671	6.84188249
551	374940.77658483	-8273.46901738	1439.83133516	0.51749704	-1.24028152	0.19395546	6.46727120
601	374424.35286490	-9167.94113854	1578.10126700	0.50508922	-1.18893599	0.17711033	6.13389992
651	373880.65698253	-10109.65003067	1719.28801096	0.49539126	-1.14108647	0.16162268	5.83490846
701	373312.44648364	-11093.81948417	1862.22994667	0.48823399	-1.09653436	0.14737690	5.56478594
751	372723.05553019	-12114.67456104	2005.65515442	0.48349925	-1.05509540	0.13426475	5.31899240
801	372116.38948962	-13165.45096654	2148.18748235	0.48112727	-1.01661549	0.12219398	5.09369498
851	371496.91016160	-14238.42063691	2288.35369076	0.48112619	-0.98098218	0.11109278	4.88557286
901	370869.61030549	-15324.93585927	2424.59231209	0.48358579	-0.94813194	0.10091106	4.69166342
951	370239.97572676	-16415.49493983	2555.26510004	0.48869512	-0.91805382	0.09161693	4.50924784
1001	369613.93285218	-17499.83300633	2678.67213786	0.49674687	-0.89079446	0.08317544	4.33585785
1051	368997.77955971	-18567.04181413	2793.07179883	0.50805380	-0.86647210	0.07545849	4.16970935
1101	368398.09713784	-19605.72223722	2896.70675044	0.52255920	-0.84529049	0.06796627	4.01127304
1151	367821.64174574	-20604.17226463	2987.83701221	0.53861033	-0.82752869	0.05925719	3.86734593
1201	367275.21474671	-21550.61158958	3064.78065439	0.54929505	-0.81379437	0.04640333	3.76207482
1251	366765.51287202	-22433.44113326	3125.96201560	0.52840182	-0.80807206	0.02620927	3.78509442

$Az = 6000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4801	379717.46614913	-1965.55693439	324.52617966	1.67607152	-1.77755050	0.43830309	14.92663798
4851	379717.46614914	-2289.86298357	401.45180329	1.55566458	-1.68202793	0.41858390	13.69021355
4901	379717.46614914	-2674.24182962	489.22728492	1.44638255	-1.59035996	0.39584645	12.46567593
4951	379717.46614914	-3125.70840397	588.54228137	1.35246082	-1.49834087	0.36927670	11.17380797
1	379717.46614917	-3651.25702951	699.89200520	1.24969228	-1.43554061	0.35094463	10.54344741
51	379717.46614917	-4257.60883089	823.53396993	1.12627533	-1.41584195	0.34312392	10.84285009
101	379717.46614917	-4950.93089001	959.44732748	1.05743284	-1.34051859	0.32259987	9.78216455
151	379717.46614915	-5736.53764137	1107.29723401	0.99711242	-1.27028940	0.30180691	8.86270370
201	379717.46614915	-6618.58684088	1266.40639018	0.94460716	-1.20525017	0.28069306	8.06722720
251	379717.46614917	-7599.78295759	1435.73536099	0.89912047	-1.14545694	0.25925749	7.38025613
301	379717.46614915	-8681.10011520	1613.87262037	0.85975015	-1.09085440	0.23756214	6.78925398
351	379717.46614915	-9861.53483486	1799.03459783	0.82555683	-1.04115476	0.21574069	6.28360655
401	379717.46614915	-11137.89630133	1989.07547894	0.79572785	-0.99576858	0.19401508	5.85262869
451	379717.46614916	-12504.63934874	2181.50625970	0.76974567	-0.95393980	0.17272537	5.48445022
501	379717.46614916	-13953.74357478	2373.52266542	0.74745417	-0.91504789	0.15231625	5.16657035
551	379717.46614916	-15474.64165369	2562.04205045	0.72903376	-0.87881413	0.13322969	4.88705271
601	379717.46614916	-17054.20151764	2743.75024359	0.71500438	-0.84526072	0.11581901	4.63497189
651	379717.46614916	-18676.77083702	2915.16035751	0.70563415	-0.81519968	0.10046864	4.40523126
701	379717.46614916	-20324.29787850	3072.68658733	0.63871638	-0.83808473	0.10263116	4.65734476
751	379717.46614916	-21976.54943740	3212.73660616	0.63465170	-0.81114450	0.08145935	4.43720954
801	379717.46614916	-23611.45231706	3331.82582102	0.63253719	-0.78872194	0.06217916	4.25029142
851	379717.46614916	-25205.58686372	3426.71490121	0.62796774	-0.77350239	0.04577628	4.11770397
901	379717.46614916	-26734.85550440	3494.56813648	0.59592971	-0.77613093	0.03700708	4.17557742
951	379717.46614916	-28175.33212580	3533.12422719	0.59287091	-0.76533924	0.02147307	4.07423417
1001	379717.46614916	-29504.26726416	3540.86377119	0.58915851	-0.75825905	0.00896982	3.99964661
1051	379717.46614916	-30701.18182705	3517.15087150	0.58528351	-0.75375077	-0.00092711	3.94453050
1101	379717.46614916	-31748.93775897	3462.32285038	0.58085148	-0.75107283	-0.00881970	3.90735272
1151	379717.46614916	-32634.64358929	3377.70498450	0.57435533	-0.74979014	-0.01515405	3.89252679
1201	379717.46614917	-33350.25327094	3265.53780252	0.56302635	-0.74978708	-0.02008952	3.91124880
1251	379717.46614916	-33892.75715920	3128.82096617	0.54026579	-0.75224912	-0.02323700	3.99713806

Table C.7 Initial conditions for long transfers to a 7000 km Az halo orbit

$Az = 7000$ km

$\phi = 30^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378205.93988062	-872.68009803	99.69124325	0.38645054	-2.57470272	0.60352390	20.83522339
51	377976.11477102	-1005.36968688	132.81198541	0.34474881	-2.43368280	0.57073745	18.78821957
101	377714.41012881	-1156.46493251	170.78444322	0.31329518	-2.30587346	0.53700290	16.85036770
151	377418.41102236	-1327.36009630	213.93031874	0.29264741	-2.19210133	0.50213207	15.02198936
201	377085.79769730	-1519.39448906	262.53917565	0.26398408	-2.09926160	0.46034876	13.73625980
251	376714.39450304	-1733.82422328	316.86425730	0.24208132	-2.00230455	0.41183316	12.54338244
301	376302.21856518	-1971.79411196	377.11885905	0.22133876	-1.91589094	0.37606252	11.56203991
351	375847.52753301	-2234.31010175	443.47332408	0.20543164	-1.82998784	0.34785182	10.70023907
401	375348.86590531	-2522.21252677	516.05266823	0.19261696	-1.75006437	0.32556673	9.95743415
451	374805.10963903	-2836.15035348	594.93477661	0.18216861	-1.67461469	0.30673784	9.32191086
501	374215.50894764	-3176.55647137	680.14905882	0.17456678	-1.60262058	0.28875886	8.76744344
551	373579.72938491	-3543.62397306	771.67540167	0.16971689	-1.53510497	0.27094687	8.27556355
601	372897.89145853	-3937.28328338	869.44322319	0.16730501	-1.47239737	0.25363738	7.83510108
651	372170.60911394	-4357.17994082	973.33040697	0.16703724	-1.41425172	0.23714557	7.43828567
701	371399.02745137	-4802.65282141	1083.16188392	0.16867119	-1.36026828	0.22160149	7.07898742
751	370584.85997651	-5272.71263217	1198.70762699	0.17201151	-1.31004505	0.20702299	6.75211114
801	369730.42553281	-5766.02058826	1319.67983331	0.17690268	-1.26321407	0.19337347	6.45335454
851	368838.68480717	-6280.86733625	1445.72908781	0.18322416	-1.21944775	0.18059276	6.17905809
901	367913.27594799	-6815.15239021	1576.43933230	0.19101129	-1.17843248	0.16867822	5.92524402
951	366958.54837864	-7366.36460938	1711.32150675	0.20282623	-1.13947275	0.15924587	5.67242922
1001	365979.59333779	-7931.56456573	1849.80578907	0.22647964	-1.10447630	0.16476731	5.36971299
1051	364982.26905065	-8507.37001139	1991.23243950	0.25137635	-1.09588181	0.20181894	5.06236306
1101	363973.21774118	-9089.94605653	2134.84136542	0.27223334	-1.10897961	0.22419046	4.79518229
1151	362959.87098360	-9675.00207981	2279.76066801	0.29174975	-1.11056047	0.22599133	4.58199527
1201	361950.43920631	-10257.79778814	2424.99462540	0.31126771	-1.10071167	0.22409669	4.40299422
1251	360953.88058998	-10833.16117355	2569.41181405	-0.19953402	-1.13012645	0.13996420	7.86625741

$Az = 7000$ km	continued						
$\phi = 45\,^{\circ}$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378335.73005384	-1381.73609532	222.52036828	0.68188697	-2.37761829	0.57781479	18.53555789
51	378121.29860314	-1596.16754603	274.95213201	0.62929078	-2.24841959	0.54515188	16.53607526
101	377876.86332150	-1840.60282766	334.01122320	0.59835004	-2.12808481	0.51152159	14.40208151
151	377600.19878588	-2117.26736324	399.99919213	0.55258343	-2.04452807	0.45502239	13.11275262
201	377289.21848721	-2428.24766191	473.15103262	0.50966153	-1.95514808	0.37049392	12.01611248
251	376942.03181115	-2775.43433798	553.62839603	0.47793070	-1.86655171	0.32551149	10.94553559
301	376557.00055290	-3160.46559627	641.51391675	0.44937127	-1.78034242	0.29956979	10.06885086
351	376132.79382871	-3584.67232045	736.80675388	0.42514155	-1.69893288	0.28363207	9.32311954
401	375668.44042253	-4049.02572663	839.41934184	0.41134607	-1.61921789	0.27271310	8.60106469
451	375163.37782698	-4554.08832219	949.17523848	0.39485764	-1.55314952	0.26645515	8.03697649
501	374617.49747117	-5099.96867799	1065.80787307	0.37893176	-1.48602280	0.25822862	7.58979623
551	374031.18584805	-5686.28030109	1188.95993370	0.36673261	-1.41958385	0.24486943	7.19618703
601	373405.36142454	-6312.10472460	1318.18309842	0.35768265	-1.35839190	0.22902195	6.83881007
651	372741.50731888	-6975.95883028	1452.93780834	0.35132120	-1.30231006	0.21300728	6.51306684
701	372041.69973605	-7675.76641311	1592.59280468	0.34733355	-1.25062720	0.19761604	6.21571041
751	371308.63205282	-8408.83409634	1736.42420441	0.34548122	-1.20278053	0.18307655	5.94358317
801	370545.63423936	-9171.83190981	1883.61396908	0.34558475	-1.15834366	0.16943018	5.69369980
851	369756.68699281	-9960.77915634	2033.24772825	0.34751455	-1.11698554	0.15665170	5.46333716
901	368946.42956321	-10771.03658594	2184.31205108	0.35118640	-1.07844765	0.14469341	5.25004981
951	368120.15979032	-11597.30635883	2335.69141760	0.35657531	-1.04252773	0.13351234	5.05156013
1001	367283.82437794	-12433.64177121	2486.16532407	0.36388443	-1.00903117	0.12319295	4.86481712
1051	366443.99695986	-13273.46918929	2634.40616207	0.37467998	-0.97758372	0.11488291	4.68027724
1101	365607.84110743	-14109.62504172	2778.97873519	0.39480982	-0.94843472	0.11535712	4.46892668
1151	364783.05517398	-14934.41097518	2918.34250648	0.42729192	-0.93233073	0.14213575	4.21770584
1201	363977.79584308	-15739.67030609	3050.85788686	0.46205759	-0.94570822	0.18373354	3.97518061
1251	363200.57755024	-16516.88859892	3174.79804269	-0.03378329	-1.09436845	0.14075230	6.93528035

$Az = 7000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4951	378736.05299538	-1699.85744557	303.54808822	1.08107917	-2.18661168	0.56328826	15.27031706
1	378579.02808760	-1971.83256384	370.82917795	0.98255952	-2.08250288	0.53334793	14.42596348
51	378398.44053400	-2284.61938189	446.48223529	0.96234529	-1.98671356	0.50447015	11.92474107
101	378192.34984226	-2641.57893101	530.84503044	0.88138538	-1.84929585	0.54279043	11.08285225
151	377958.92828827	-3045.87692210	624.14490923	0.75533004	-1.79640503	0.54149928	11.49134796
201	377696.51966198	-3500.38199514	726.48608890	0.57728584	-1.76286262	0.54002361	13.62039915
251	377403.69851309	-4007.56310255	837.83895833	0.69012308	-1.71217549	-0.15117730	8.17748832
301	377079.32819686	-4569.38897072	958.03176313	0.69067895	-1.57723066	0.10113090	7.88430256
351	376722.61612423	-5187.23240420	1086.74485473	0.67437085	-1.48966562	0.16748004	7.27264031
401	376333.16482227	-5861.78184630	1223.50748397	0.65238630	-1.41961517	0.19672079	6.78147297
451	375911.01768447	-6592.96213724	1367.69694390	0.63450139	-1.34837589	0.21294187	6.35236848
501	375456.69858825	-7379.86589472	1518.53973487	0.51425948	-1.36504263	0.20626891	6.93530815
551	374971.24484022	-8220.69645103	1675.11434885	0.53338938	-1.27352818	0.21485746	6.25623335
601	374456.23312891	-9112.72290152	1836.35525948	0.51812434	-1.21421653	0.20091546	5.97737260
651	373913.79829006	-10052.24760223	2001.05776157	0.50638637	-1.16175903	0.18507628	5.71390202
701	373346.64469434	-11034.58644568	2167.88342590	0.49768505	-1.11419026	0.16968430	5.46879191
751	372758.04994367	-12054.06245891	2335.36611652	0.49173238	-1.07058701	0.15518679	5.24154551
801	372151.86032094	-13104.01368450	2501.91874584	0.48836865	-1.03045326	0.14167682	5.03050374
851	371532.47709683	-14176.81689803	2665.84120606	0.48753842	-0.99349362	0.12916119	4.83363996
901	370904.83240054	-15263.92940112	2825.33019415	0.48928636	-0.95953599	0.11762786	4.64882882
951	370274.35295911	-16355.95182679	2978.49191990	0.49375965	-0.92850120	0.10706003	4.47396117
1001	369646.90967325	-17442.71547676	3123.35892053	0.50119010	-0.90039004	0.09740770	4.30712474
1051	369028.75081841	-18513.39802048	3257.91235795	0.51178270	-0.87527217	0.08847073	4.14716091
1101	368426.41673365	-19556.67125843	3380.11119296	0.52532992	-0.85325292	0.07960393	3.99514318
1151	367846.63430920	-20560.88387492	3487.92944715	0.54009275	-0.83442817	0.06918854	3.85795587
1201	367296.19051356	-21514.28049567	3579.40231041	0.54933240	-0.81922278	0.05409638	3.75878710
1251	366781.78570269	-22405.25576377	3652.68107182	0.52691879	-0.81186511	0.03063857	3.78698808

$Az = 7000$ km continued

$\phi = 90^\circ$

manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4801	379717.46614913	-1924.05668773	371.92529679	1.68455791	-1.77807560	0.51468777	15.23990833
4851	379717.46614914	-2245.06352112	461.21011810	1.56361929	-1.68094535	0.49171297	13.91527920
4901	379717.46614914	-2625.71288168	563.16486116	1.45581605	-1.58785447	0.46530163	12.56108777
4951	379717.46614917	-3072.99905628	678.58631446	1.36469523	-1.49792741	0.43432352	11.15221613
1	379717.46614917	-3593.91038990	808.04794029	1.24622997	-1.45302401	0.42309634	10.92655186
51	379717.46614917	-4195.17999037	951.85053665	1.13829132	-1.41204035	0.40974011	10.69915464
101	379717.46614915	-4883.00807066	1109.97551611	1.07091077	-1.33791982	0.38923781	9.58432100
151	379717.46614915	-5662.76623451	1282.04369031	1.01286890	-1.26901075	0.36915443	8.61098005
201	379717.46614915	-6538.69577085	1467.28209100	0.96365398	-1.20577362	0.35000159	7.76049960
251	379717.46614915	-7513.61265197	1664.50074432	0.92188127	-1.14889914	0.33298550	7.02877171
301	379717.46614915	-8588.63122604	1872.08053450	0.88471573	-1.09901765	0.31872541	6.42945988
351	379717.46614915	-9762.91677873	2087.97250893	0.85570803	-1.04790708	0.30907199	5.87885352
401	379717.46614915	-11033.47464160	2309.70835261	0.82023239	-1.01975569	0.29503873	5.55450974
451	379717.46614916	-12394.98098073	2534.42144497	0.79983016	-0.94953567	0.30939620	5.11664934
501	379717.46614916	-13839.65855822	2758.87801792	0.76550158	-0.96049774	0.25147320	5.00232878
551	379717.46614917	-15357.20029672	2979.51849434	0.75723804	-0.91819666	0.15777594	4.66566661
601	379717.46614916	-16934.74493592	3192.51005763	0.73657528	-0.87433837	0.13533939	4.48271352
651	379717.46614916	-18556.91267214	3393.81272877	0.72360092	-0.83884807	0.11722252	4.29195162
701	379717.46614916	-20205.91422496	3579.26243526	0.65624121	-0.85742463	0.11586080	4.52811041
751	379717.46614916	-21861.75345861	3744.67532446	0.64791349	-0.82817691	0.09161054	4.34834065
801	379717.46614916	-23502.54979068	3885.97732965	0.64252830	-0.80332517	0.06995418	4.18853541
851	379717.46614916	-25105.00939981	3999.36106766	0.63607675	-0.78550577	0.05145401	4.06960901
901	379717.46614916	-26645.06989554	4081.46792086	0.60240343	-0.78703062	0.04120010	4.13311098
951	379717.46614916	-28098.72757355	4129.58643466	0.59792877	-0.77419418	0.02383281	4.04031272
1001	379717.46614916	-29443.02704163	4141.84964358	0.59342920	-0.76536519	0.00973632	3.96993612
1051	379717.46614916	-30657.15146835	4117.40565862	0.58906622	-0.75948966	-0.00151225	3.91718748
1101	379717.46614916	-31723.50645779	4056.53111978	0.58420776	-0.75580148	-0.01053927	3.88185372
1151	379717.46614916	-32628.65697077	3960.65952098	0.57715711	-0.75381414	-0.01781846	3.86910142
1201	379717.46614916	-33363.97245480	3832.30786462	0.56484941	-0.75340255	-0.02350655	3.89127366
1251	379717.46614916	-33925.87109982	3674.90392232	0.53962326	-0.75608510	-0.02705280	3.98711964

Table C.8 Initial conditions for long transfers to a 8000 km Az halo orbit

$Az = 8000$ km

$\phi = 30^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
51	377999.62969450	-991.79333948	150.40789878	0.37105697	-2.44811720	0.65577111	18.57429984
101	377738.89589291	-1142.32807006	193.68715906	0.32699490	-2.33806358	0.55518509	16.95972344
151	377443.99119648	-1312.59137589	242.87958284	0.28535698	-2.23046856	0.47567698	15.55342574
201	377112.60034781	-1503.91997157	298.30937485	0.25124813	-2.12989563	0.41498081	14.24464519
251	376742.54793367	-1717.56983250	360.26009282	0.21680930	-2.03394853	0.37087589	13.21506392
301	376331.84672624	-1954.68828517	428.97069239	0.20250409	-1.93408856	0.33575708	12.01270914
351	375878.74513411	-2216.28661139	504.63220878	0.19509181	-1.84840300	0.31149953	10.93137840
401	375381.77326795	-2503.21345209	587.38510453	0.18531982	-1.76661329	0.29312832	10.10576797
451	374839.78732435	-2816.12918250	677.31723703	0.17595541	-1.69096775	0.27879974	9.42947439
501	374252.01219365	-3155.48131243	774.46233085	0.17278926	-1.61911210	0.26691807	8.79852869
551	373618.08238350	-3521.48085898	878.79878365	0.17210340	-1.55716409	0.25920520	8.23338853
601	372938.08150097	-3914.07955157	990.24859093	0.17137955	-1.50035376	0.25271209	7.75683143
651	372212.58063216	-4332.94767346	1108.67614481	0.17144223	-1.44358735	0.24539777	7.35354432
701	371442.67598543	-4777.45232850	1233.88664675	0.17297427	-1.38773231	0.23632964	7.00082445
751	370630.02610615	-5246.63595508	1365.62387055	0.17612723	-1.33453137	0.22550962	6.68377703
801	369776.88882624	-5739.19499329	1503.56702048	0.18115008	-1.28475063	0.21382505	6.39184407
851	368886.15786570	-6253.45875314	1647.32644962	0.19008272	-1.23851657	0.20339538	6.10461617
901	367961.39865860	-6787.36873029	1796.43803513	0.20709233	-1.19851986	0.20128223	5.78817056
951	367006.88253224	-7338.45887277	1950.35605362	0.22661835	-1.17762267	0.21452536	5.46766867
1001	366027.61783317	-7903.83761039	2108.44446230	0.24404177	-1.17509120	0.22434870	5.17882634
1051	365029.37597040	-8480.17281859	2269.96657929	0.26112520	-1.17114017	0.22340567	4.93265649
1101	364018.70966760	-9063.68128057	2434.07327384	0.27869372	-1.16071455	0.21989829	4.72116412
1151	363002.96000901	-9650.12461938	2599.78993582	0.29686741	-1.14484450	0.21733389	4.53580407
1201	361990.24817659	-10234.81406845	2766.00270456	0.31564784	-1.12480639	0.21625495	4.37081107
1251	360989.44719655	-10812.62678367	2931.44470790	0.33515474	-1.10212898	0.21607208	4.22139801
1251	360953.88058998	-10833.16117355	2569.41181405	-0.19953402	-1.13012645	0.13996420	7.86625741

$Az = 8000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
1	378356.48554021	-1360.98060896	251.83761567	0.77159850	-2.34536187	0.66342737	16.07226112
51	378143.05862281	-1574.40752630	311.66056583	0.67184934	-2.29566488	0.45717623	15.89059505
101	377899.75829363	-1817.70785553	379.06020113	0.61399171	-2.20009284	0.27288679	14.22556820
151	377624.36477130	-2093.10137787	454.37252100	0.47294482	-2.14803935	0.14841804	15.05461959
201	377314.79286884	-2402.67328032	537.85910939	0.40592434	-2.05604679	0.10714667	14.15882948
251	376969.14851756	-2748.31763161	629.69962617	0.36182397	-1.96718627	0.10602724	13.06664824
301	376585.78486829	-3131.68128088	729.98545223	0.42216025	-1.81456879	0.16767987	10.42959700
351	376163.35684705	-3554.10930212	838.71464255	0.40900157	-1.72500586	0.18092368	9.50454314
401	375700.87321407	-4016.59293507	955.78820579	0.39034879	-1.64886874	0.19043453	8.83033257
451	375197.74539190	-4519.72075724	1081.00760418	0.38222019	-1.57272862	0.19878837	8.16800016
501	374653.83255874	-5063.63359040	1214.07326389	0.37501915	-1.50037563	0.20269064	7.62233115
551	374069.48271946	-5647.98342967	1354.58381060	0.37245770	-1.43745032	0.20809730	7.11427522
601	373445.56963888	-6271.89651029	1502.03570091	0.36736602	-1.38651422	0.21317815	6.69910354
651	372783.52562326	-6933.94052590	1655.82291034	0.36091983	-1.33407981	0.21346990	6.37418138
701	372085.37014831	-7632.09600085	1815.23636184	0.35603632	-1.27948560	0.20838487	6.09788559
751	371353.73423717	-8363.73191198	1979.46283574	0.35324456	-1.22738846	0.19891408	5.84754640
801	370591.88029736	-9125.58585178	2147.58318836	0.35249751	-1.17928686	0.18730321	5.61557582
851	369803.71682410	-9913.74932505	2318.56982401	0.35368748	-1.13505514	0.17505040	5.39926893
901	368993.80699081	-10723.65915834	2491.28351074	0.35672010	-1.09426841	0.16286995	5.19702561
951	368167.36969612	-11550.09645303	2664.46980454	0.36153327	-1.05655513	0.15107613	5.00744769
1001	367330.27115554	-12387.19499362	2836.75554852	0.36810283	-1.02164311	0.13979838	4.82920180
1051	366489.00465173	-13228.46149743	3006.64614334	0.37643644	-0.98934741	0.12906729	4.66106567
1101	365650.65565520	-14066.81049397	3172.52453457	0.38653337	-0.95955045	0.11881182	4.50213940
1151	364822.84926023	-14894.61688892	3332.65312270	0.39820919	-0.93217703	0.10870748	4.35261277
1201	364013.67682898	-15703.78932017	3485.18005033	0.41034054	-0.90717352	0.09756232	4.21678333
1251	363231.59900230	-16485.86714685	3628.15152194	0.41665904	-0.88500343	0.08095530	4.11922092

$Az = 8000$ km continued

$\phi = 60\,^{\circ}$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4951	378752.87551231	-1670.71999147	342.86966296	1.09816242	-2.18363112	0.64887437	15.29154532
1	378596.83419983	-1940.99147283	419.61486951	0.97736701	-2.10653846	0.62355158	15.13211373
51	378417.35375488	-2251.86072239	505.93273556	0.90937026	-1.92150850	0.75869148	12.89395322
101	378212.49849400	-2606.68044249	602.19914321	0.78407693	-1.84044515	0.80275606	12.87348676
151	377980.44141279	-3008.61509735	708.66640519	0.64666954	-1.82869376	0.69560716	14.33881878
201	377719.52238127	-3460.54011661	825.44911495	0.57438464	-1.72249288	0.72714649	13.27924430
251	377428.30688466	-3964.94015275	952.51210391	0.49017399	-1.66574543	0.70399385	13.19765264
301	377105.64363927	-4523.80928748	1089.66098735	0.43650003	-1.53885064	0.77586193	11.75746188
351	376750.71951018	-5138.55591190	1236.53554061	0.37046441	-1.50296672	0.73908164	11.67953801
401	376363.11035318	-5809.91466528	1392.60591134	0.60948760	-1.47046523	0.03166082	6.96542251
451	375942.82667004	-6537.86735809	1557.17146709	0.61753409	-1.39159412	0.10312351	6.38011824
501	375490.35325956	-7321.57429412	1729.36192038	0.54020009	-1.36752146	0.10508009	6.55755766
551	375006.68232585	-8159.31692542	1908.14028184	0.54108494	-1.29751279	0.14426421	6.11600832
601	374493.33972630	-9048.45238953	2092.30717354	0.53448381	-1.24256358	0.16581571	5.77809737
651	373952.40416944	-9985.38025765	2280.50609391	0.52189840	-1.19795681	0.17808123	5.53063294
701	373386.51918547	-10965.52180112	2471.22935756	0.51083325	-1.14529714	0.17770981	5.32653764
751	372798.89757665	-11983.31228324	2662.82463312	0.50284776	-1.09570928	0.16891177	5.13260256
801	372193.31782457	-13032.20718186	2853.50225475	0.49788694	-1.05124977	0.15718231	4.94549000
851	371574.11160096	-14104.70382151	3041.34377674	0.49579327	-1.01122606	0.14491966	4.76609793
901	370946.14113805	-15192.38056893	3224.31255420	0.49651026	-0.97500341	0.13299861	4.59450926
951	370314.76481534	-16285.95643855	3400.26744241	0.50009405	-0.94221148	0.12175034	4.43008673
1001	369685.78897962	-17375.37454277	3566.98097783	0.50667111	-0.91266465	0.11124256	4.27202502
1051	369065.40381271	-18449.91317211	3722.16359172	0.51630566	-0.88627934	0.10125710	4.12010958
1101	368460.10110384	-19498.32821783	3863.49545028	0.52863479	-0.86298483	0.09105543	3.97610517
1151	367876.57217584	-20509.02996882	3988.66734224	0.54185519	-0.84267088	0.07893357	3.84694142
1201	367321.58506735	-21470.29583826	4095.43156784	0.54941294	-0.82561253	0.06166464	3.75487333
1251	366801.84148214	-22370.51813477	4181.66295265	0.52520626	-0.81631758	0.03504391	3.78921189

$Az = 8000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4801	379717.46614916	-1876.55010722	416.25718585	1.69480836	-1.77856415	0.59272248	15.61460049
4851	379717.46614914	-2193.71262118	517.67411964	1.57383185	-1.67913189	0.56658125	14.16069460
4901	379717.46614914	-2570.01889033	633.58702298	1.47191140	-1.58237218	0.53584911	12.52651574
4951	379717.46614914	-3012.43926563	764.89603706	1.37954580	-1.50609988	0.51310281	11.14323521
1	379717.46614917	-3527.95481882	912.25068540	1.24106562	-1.47277555	0.50726294	11.41640868
51	379717.46614915	-4123.31172735	1075.99496933	1.14978737	-1.40841828	0.49427120	10.55397448
101	379717.46614917	-4804.74722609	1256.11491206	1.07899425	-1.33333701	0.48147245	9.45619215
151	379717.46614915	-5577.69718523	1452.19191724	1.01335394	-1.26682337	0.46776894	8.60144917
201	379717.46614915	-6446.49710628	1663.36488558	0.96134485	-1.19271425	0.45635452	7.73008640
251	379717.46614915	-7414.08902165	1888.30333311	0.90539233	-1.14622658	0.44213110	7.21787375
301	379717.46614915	-8481.74613528	2125.19285501	0.86477875	-1.06877213	0.43590084	6.57257639
351	379717.46614915	-9648.82529043	2371.73337541	0.82618329	-1.02781246	0.43662502	6.08970058
401	379717.46614915	-10912.55488811	2625.14989398	0.78497807	-0.99671381	0.43503494	5.77202085
451	379717.46614916	-12267.86333057	2882.21505659	0.74295951	-0.96837394	0.41997998	5.58719652
501	379717.46614916	-13707.25115093	3139.28296308	0.87217966	-0.97792694	0.03634632	4.09206617
551	379717.46614916	-15220.70940620	3392.33423181	0.81487620	-0.99550121	0.04113529	4.16123734
601	379717.46614916	-16795.68819150	3637.03341983	0.77745524	-0.92740968	0.10161573	4.18841681
651	379717.46614917	-18417.12255523	3868.80129274	0.75456207	-0.88092052	0.12094107	4.10335787
701	379717.46614916	-20067.52852090	4082.90585534	0.68290642	-0.89431977	0.11677423	4.33869478
751	379717.46614916	-21727.18864198	4274.57703859	0.66537493	-0.85324968	0.09632440	4.23406358
801	379717.46614916	-23374.45295309	4439.14985592	0.65484993	-0.82233148	0.07491184	4.11349364
851	379717.46614916	-24986.18474955	4572.23893293	0.64584224	-0.80011250	0.05553912	4.01255127
901	379717.46614916	-26538.37761887	4669.94284315	0.61009587	-0.80010132	0.04402471	4.08306478
951	379717.46614916	-28006.95640797	4729.06932044	0.60382444	-0.78451530	0.02545731	4.00118989
1001	379717.46614916	-29368.74729798	4747.36278428	0.59832056	-0.77350819	0.01012427	3.93636135
1051	379717.46614917	-30602.56168465	4723.70582407	0.59335072	-0.76598813	-0.00227816	3.88668505
1101	379717.46614916	-31690.29252039	4658.25999707	0.58800375	-0.76111101	-0.01233335	3.85351128
1151	379717.46614916	-32617.88491638	4552.51271957	0.58035557	-0.75831060	-0.02050624	3.84293118
1201	379717.46614916	-33376.03318270	4409.20880427	0.56699473	-0.75744161	-0.02693164	3.86859042
1251	379717.46614916	-33960.48660962	4232.16603870	0.53893976	-0.76046590	-0.03085706	3.97538160

Table C.9 Initial conditions for long transfers to a 9000 km Az halo orbit

$Az = 9000$ km

$\phi = 30^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
51	378026.30272258	-976.39365958	167.45362768	0.35238868	-2.49246287	0.61202948	20.03620034
101	377766.70643443	-1126.27164643	215.99048575	0.31526732	-2.37337080	0.50311221	17.81148756
151	377473.08029087	-1295.79677945	271.18043603	0.24639725	-2.26768412	0.42797786	17.06990045
201	377143.11452041	-1486.30260581	333.37952457	0.20481584	-2.16111220	0.36693244	15.70895786
251	376774.63435949	-1699.04472595	402.89919134	0.19749262	-2.06043989	0.32276725	13.78767085
301	376365.64802988	-1935.17309344	480.00206121	0.15549580	-1.96871045	0.29321021	13.06690063
351	375914.39386306	-2195.70480813	564.89835184	0.15808576	-1.87322824	0.27166682	11.63753578
401	375419.38607679	-2481.49768676	657.74296210	0.14694504	-1.79300991	0.25759780	10.73514468
451	374879.45890815	-2793.22478292	758.63321413	0.14943283	-1.71210624	0.24738482	9.81604703
501	374293.80900613	-3131.34991152	867.60713991	0.15236403	-1.64162387	0.24098733	9.05240932
551	373662.03617267	-3496.10412699	984.64213538	0.15511983	-1.57390933	0.23536991	8.42976757
601	372984.18269275	-3887.46301607	1109.65375276	0.16329219	-1.50941926	0.23067274	7.85329455
651	372260.77159007	-4305.12461094	1242.49436608	0.16856588	-1.45795776	0.22879638	7.37537777
701	371492.84417798	-4748.48770904	1382.95142435	0.17284270	-1.40798526	0.22615491	6.98050254
751	370681.99722269	-5216.63041694	1530.74500145	0.17755967	-1.35814516	0.22261183	6.64245133
801	369830.41989757	-5708.28881485	1685.52435918	0.18314986	-1.30928963	0.21765547	6.34514590
851	368940.93047272	-6221.83577371	1846.86325955	0.19004987	-1.26211008	0.21100130	6.07644749
901	368017.01235132	-6755.26014983	2014.25379605	0.19929100	-1.21758632	0.20351899	5.82240581
951	367062.84863323	-7306.14682930	2187.09856069	0.21292114	-1.17776610	0.19842612	5.56435293
1001	366083.35386357	-7871.65839823	2364.70103067	0.23114983	-1.14816400	0.20093739	5.29575732
1051	365084.20101685	-8448.51956325	2546.25414913	0.25089725	-1.13397938	0.20929878	5.03308009
1101	364071.84109988	-9033.00583383	2730.82719916	0.27094857	-1.12856098	0.21412017	4.79295246
1151	363053.51205131	-9620.93838416	2917.35123861	0.29142971	-1.12245725	0.21430435	4.58128277
1201	362037.23293953	-10207.68740291	3104.60358640	0.31240464	-1.11227909	0.21302061	4.39535238
1251	361031.77885954	-10788.18658666	3291.19214310	0.33382695	-1.09768809	0.21206682	4.23084237
1251	360953.88058998	-10833.16117355	2569.41181405	-0.19953402	-1.13012645	0.13996420	7.86625741

$Az = 9000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
251	377000.05086234	-2717.41528683	704.53072181	0.27488034	-1.97023537	-0.19893306	13.59713495
301	376618.61638956	-3098.84975957	817.14939159	0.45620612	-1.80674967	0.07303673	9.72782729
351	376198.24545119	-3519.22069797	939.23811233	0.35572912	-1.77649236	0.05671737	10.02555970
401	375737.92451586	-3979.54163327	1070.68683331	0.33422959	-1.69332723	0.08500320	9.41084627
451	375237.03591793	-4480.43023124	1211.27608420	0.35815649	-1.59969154	0.12603076	8.35813735
501	374695.40279330	-5022.06335584	1360.67521741	0.36305688	-1.53006609	0.14952425	7.66669092
551	374113.33007981	-5604.13606933	1518.44146138	0.35476811	-1.46915956	0.16304624	7.22050940
601	373491.64146750	-6225.82468164	1684.01942480	0.36143016	-1.39911261	0.17415230	6.73174505
651	372831.71228627	-6885.75386290	1856.74067736	0.36244732	-1.34971943	0.18351057	6.33512119
701	372135.49833636	-7581.96781278	2035.82305360	0.36116094	-1.30198918	0.18910416	6.02058348
751	371405.56058021	-8311.90556896	2220.36938617	0.35986591	-1.25351784	0.19132413	5.75852412
801	370645.08542664	-9072.38072250	2409.36546645	0.35943667	-1.20532704	0.18948903	5.53064228
851	369857.90004978	-9859.56609937	2601.67715710	0.36040350	-1.15883703	0.18364805	5.32476116
901	369048.48180938	-10668.98433978	2796.04673703	0.36300005	-1.11525789	0.17501809	5.13380798
951	368221.96039920	-11495.50574995	2991.08874882	0.36730816	-1.07495934	0.16493007	4.95439631
1001	367384.11087590	-12333.35527325	3185.28583741	0.37334647	-1.03783684	0.15426235	4.78490043
1051	366541.33525426	-13176.13089489	3376.98531880	0.38108547	-1.00366342	0.14344538	4.62452386
1101	365700.62995022	-14016.83619894	3564.39749113	0.39035659	-0.97220625	0.13248974	4.47340571
1151	364869.53607069	-14847.93007846	3745.59698972	0.40044816	-0.94320957	0.12069906	4.33421975
1201	364056.06948156	-15661.39666761	3918.52876627	0.40820640	-0.91644733	0.10535577	4.21972517
1251	363268.62780115	-16448.83834800	4081.02050940	0.38832992	-0.89686607	0.07505774	4.23326420

$Az = 9000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4951	378771.90353409	-1637.76249105	380.55567832	1.09673905	-2.19010607	0.78763685	15.93338368
1	378617.00318135	-1906.05777204	466.69790806	0.96072591	-2.04702058	0.86475748	15.37744472
51	378438.80421519	-2214.70743529	563.61562763	0.82474250	-1.94441420	0.88204555	15.46207874
101	378235.37642389	-2567.05470555	671.71858108	0.57491467	-1.97370812	0.99633254	21.06255699
151	378004.89369965	-2966.26249415	791.28089293	0.62611568	-1.61382016	1.05740349	12.42407626
201	377745.69162761	-3415.21365240	922.42560456	0.51190848	-1.71298118	0.84558054	15.06722641
251	377456.32566549	-3916.41020073	1065.11134378	0.42281697	-1.67329473	0.79943981	15.39325958
301	377135.62827563	-4471.87437386	1219.12173471	0.35639553	-1.61117502	0.78125256	14.82350770
351	376782.76346351	-5083.05415663	1384.05786785	0.25635049	-1.63081715	0.69375368	16.86071421
401	376397.27736556	-5750.73566389	1559.33387427	0.49912341	-1.52019268	-0.19389696	7.33514196
451	375979.14378682	-6474.96426662	1744.17540499	0.57532091	-1.40232667	-0.02160934	6.55513728
501	375528.80387655	-7254.97587191	1937.62063386	0.49010594	-1.40111466	-0.02716203	6.73579308
551	375047.19940499	-8089.13928578	2138.52329150	0.53489166	-1.30133026	0.06536692	6.07440396
601	374535.79932631	-8974.91020504	2345.55721036	0.53547938	-1.26102356	0.10977129	5.69758499
651	373996.61944269	-9908.79715793	2557.22191926	0.52962630	-1.21714760	0.13445864	5.41975737
701	373432.23500568	-10886.33967783	2771.84896539	0.52223265	-1.17182322	0.15083299	5.19720305
751	372845.78598580	-11902.09917629	2987.60885626	0.51484458	-1.12543029	0.15938218	5.01059206
801	372240.97452138	-12949.66336167	3202.51878917	0.50901772	-1.07877313	0.15952009	4.84325277
851	371622.05373997	-14021.66560093	3414.45165648	0.50570664	-1.03497289	0.15343403	4.68373953
901	370993.80676460	-15109.82128198	3621.14716132	0.50524360	-0.99535422	0.14432154	4.52855646
951	370361.51432123	-16204.98391915	3820.22622321	0.50773228	-0.95984244	0.13414718	4.37735577
1001	369730.90901765	-17297.22434445	4009.21016218	0.51321725	-0.92809502	0.12375320	4.23041717
1051	369108.11414535	-18375.93670597	4185.54637390	0.52162699	-0.89979774	0.11322955	4.08855915
1101	368499.56486107	-19429.97498526	4346.64228418	0.53246580	-0.87464538	0.10194951	3.95421386
1151	367911.90993607	-20447.82317269	4489.90922132	0.54389545	-0.85232327	0.08828295	3.83431947
1201	367351.89303801	-21417.80089322	4612.81737859	0.54954426	-0.83299272	0.06900913	3.75030836
1251	366826.21380915	-22328.30402608	4712.96218338	0.52326207	-0.82145351	0.03938503	3.79178052

$Az = 9000$ km continued

$\phi = 90^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4801	379717.46614913	-1823.20877591	457.10035249	1.70688732	-1.77919330	0.67274671	16.06580335
4851	379717.46614914	-2135.96722318	570.37987593	1.58914980	-1.67377261	0.64317530	14.31955167
4901	379717.46614917	-2507.30122706	699.98871136	1.48246718	-1.58938409	0.61920579	12.79742602
4951	379717.46614914	-2944.15387483	846.92590096	1.37523482	-1.50287812	0.62143192	11.50212637
1	379717.46614914	-3453.49754485	1011.91437571	1.25809253	-1.43519868	0.61220098	10.93274037
51	379717.46614915	-4042.09227378	1195.34106403	1.14552226	-1.39573046	0.59476581	10.71424548
101	379717.46614917	-4716.21572033	1397.19906928	1.06696157	-1.32317126	0.58091903	9.72086863
151	379717.46614917	-5481.37442113	1617.03577305	0.99958557	-1.24484147	0.56522256	8.78457559
201	379717.46614915	-6342.00786999	1853.91026661	0.93693815	-1.18051919	0.54896691	8.08066117
251	379717.46614915	-7301.19763286	2106.36269457	0.88575601	-1.10686537	0.53951639	7.34710195
301	379717.46614915	-8360.39316550	2372.39708328	0.84069292	-1.05529692	0.53820947	6.73063394
351	379717.46614915	-9519.16431541	2649.47819731	0.79485560	-1.01257933	0.54013130	6.27776571
401	379717.46614915	-10774.98807600	2934.54212728	0.74516911	-0.98606260	0.51471516	6.11547996
451	379717.46614915	-12123.07460356	3224.01984937	0.69477722	-0.90153178	0.55805494	5.66439373
501	379717.46614916	-13556.23552865	3513.87305313	0.87757749	-0.87989669	-0.02308009	3.98049397
551	379717.46614916	-15064.79686781	3799.64216895	0.84851105	-1.12003874	-0.13623243	3.71959510
601	379717.46614916	-16636.55992634	4076.50770141	0.78664983	-0.92648287	0.03395706	4.05957269
651	379717.46614916	-18256.81679576	4339.36753140	0.78112020	-0.91470272	0.08323364	3.92917622
701	379717.46614916	-19908.43230835	4582.93448035	0.71616078	-0.92754063	0.08145666	4.09707179
751	379717.46614916	-21572.01103057	4801.85965898	0.68746342	-0.88489085	0.08749896	4.08916007
801	379717.46614916	-23226.17463370	4990.88726660	0.66959774	-0.84561329	0.07461033	4.02397727
851	379717.46614916	-24847.97935461	5145.04472115	0.65723316	-0.81720260	0.05720238	3.94678317
901	379717.46614917	-26413.50168510	5259.86742715	0.61901344	-0.81519828	0.04491154	4.02534977
951	379717.46614916	-27898.60869223	5331.64963942	0.61053438	-0.79618965	0.02612544	3.95709333
1001	379717.46614916	-29279.90402476	5357.70223517	0.60379064	-0.78259955	0.01005915	3.89932588
1051	379717.46614916	-30535.80160989	5336.58686845	0.59808722	-0.77317329	-0.00323307	3.85350648
1101	379717.46614916	-31647.63252118	5268.28786888	0.59219347	-0.76693773	-0.01418200	3.82281059
1151	379717.46614916	-32600.65033941	5154.28319772	0.58392077	-0.76322135	-0.02318997	3.81443306
1201	379717.46614916	-33384.78480656	4997.48727192	0.56946431	-0.76184818	-0.03034441	3.84344590
1251	379717.46614916	-33995.01709774	4802.06088017	0.53823752	-0.76535894	-0.03465645	3.96187821

Table C.10 Initial conditions for long transfers to a 10000 km Az halo orbit

$Az = 10000$ km

$\phi = 30\,^{\circ}$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
51	378056.13421285	-959.17044064	183.88197070	0.31634859	-2.54754142	0.55502787	22.63150801
101	377797.85539065	-1108.28778817	237.61996427	0.23862376	-2.43968937	0.45003419	21.68831641
151	377505.70552716	-1276.96059046	298.75113713	0.22484089	-2.30776789	0.36748171	18.18478474
201	377177.38146660	-1466.51857520	367.66015406	0.12941484	-2.21695628	0.31186563	18.55425537
251	376810.70964656	-1678.21664921	444.68354402	0.07084724	-2.11924135	0.26742503	17.74259381
301	376403.69368436	-1913.20742456	530.10531874	0.16385475	-1.97897439	0.24347577	12.94173905
351	375954.56114749	-2172.51421562	624.15314762	0.09243776	-1.91215893	0.22440713	13.00033886
401	375461.80901534	-2457.00479177	726.99520182	0.13327422	-1.80968187	0.21865360	10.98262705
451	374924.24753621	-2767.36605647	838.73767037	0.12382346	-1.73351896	0.21276869	10.19859596
501	374341.04238017	-3104.07971031	959.42285308	0.14036875	-1.65334132	0.21084260	9.21994848
551	373711.75517546	-3467.39884735	1089.02765324	0.13986801	-1.59289610	0.21019206	8.59853755
601	373036.38266312	-3857.32534915	1227.46223110	0.14990440	-1.52428577	0.20873684	7.99087001
651	372315.39480810	-4273.58788131	1374.56853548	0.16001907	-1.46775601	0.20898339	7.46117898
701	371549.77223684	-4715.62027892	1530.11840581	0.16684186	-1.41847843	0.20924333	7.03281529
751	370741.04332807	-5182.54013212	1693.81092800	0.17352691	-1.37045611	0.20876901	6.66912387
801	369891.32115432	-5673.12745785	1865.26873284	0.18097920	-1.32404666	0.20763954	6.34955947
851	369003.34024546	-6185.80347464	2044.03294574	0.18921273	-1.27950122	0.20565628	6.06528730
901	368080.49282924	-6718.60967880	2229.55652856	0.19816570	-1.23649121	0.20244718	5.81088221
951	367126.86378424	-7269.18766464	2421.19580445	0.20787549	-1.19479881	0.19765155	5.58123504
1001	366147.26303613	-7834.76042027	2618.20002300	0.21845458	-1.15463891	0.19122633	5.37127804
1051	365147.25353475	-8412.11617507	2819.69891780	0.23008668	-1.11643730	0.18355351	5.17639808
1101	364133.17229406	-8997.59625236	3024.68833668	0.24310455	-1.08062269	0.17539354	4.99223699
1151	363112.14128464	-9587.08878050	3232.01419902	0.25816365	-1.04773867	0.16801414	4.81373641
1201	362092.06428979	-10176.03050808	3440.35526832	0.27636908	-1.01889929	0.16359403	4.63452664
1251	361081.60522605	-10759.41932054	3648.20553475	0.29878950	-0.99641665	0.16506519	4.44948968

$Az = 10000$ km continued

$\phi = 45^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
451	375281.36291679	-4436.10323237	1339.75215956	0.31047233	-1.62798114	0.03521915	8.75151159
501	374742.33921566	-4975.12693351	1505.36800648	0.33202839	-1.54346133	0.08037193	7.91664218
551	374162.87793022	-5554.58821895	1680.26900323	0.34112613	-1.47378008	0.11009835	7.31382068
601	373543.74753321	-6173.71861593	1863.85161026	0.35157746	-1.41286485	0.13390793	6.77757738
651	372886.26045303	-6831.20569614	2055.38944495	0.35701468	-1.36073799	0.15029977	6.35322420
701	372192.30211196	-7525.16403720	2254.03244278	0.35837394	-1.31345025	0.16150297	6.02027729
751	371464.35594498	-8253.11020416	2458.80540299	0.35984266	-1.26701929	0.16940608	5.73716315
801	370705.52415553	-9011.94199364	2668.60568531	0.36200748	-1.22232868	0.17449239	5.48908962
851	369919.54368592	-9797.92246322	2882.19995766	0.36477380	-1.17908033	0.17660999	5.27082840
901	369110.79652108	-10606.66962807	3098.22006014	0.36830974	-1.13674533	0.17533650	5.07678483
951	368284.31301171	-11433.15313744	3315.15825173	0.37291339	-1.09579702	0.17073849	4.90055425
1001	367445.76644372	-12271.69970543	3531.36233934	0.37882143	-1.05702808	0.16352964	4.73721295
1051	366601.45661708	-13116.00953207	3745.03145677	0.38612158	-1.02086682	0.15452593	4.58414981
1101	365758.27979167	-13959.18635750	3954.21355631	0.39464557	-0.98732871	0.14412070	4.44099895
1151	364923.68206781	-14793.78408135	4156.80599019	0.40357348	-0.95613166	0.13181101	4.31069495
1201	364105.59317267	-15611.87297648	4350.56086874	0.40953193	-0.92687067	0.11490696	4.20667634
1251	363312.33779894	-16405.12835021	4533.09715490	0.38618882	-0.90447504	0.08171087	4.23611212

$Az = 10000$ km continued

$\phi = 60^\circ$							
manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4951	378793.11762256	-1601.01861191	416.39175454	1.06161162	-2.15568007	0.98601063	17.13331370
1	378639.52498132	-1867.04887028	511.85058530	0.89842466	-2.05130540	0.99943072	17.88241206
51	378462.79140092	-2173.16041088	619.29034648	0.76872618	-1.93890612	1.01039654	17.61243602
101	378260.99280585	-2522.68583050	739.14973161	0.66122502	-1.82363068	1.01898474	16.72723338
151	378032.30418651	-2918.78613825	871.72102691	0.53013812	-1.80554887	0.94041351	18.77782133
201	377775.05653609	-3364.35213891	1017.13347002	0.46311953	-1.69104122	0.95006282	16.71021036
251	377487.79441541	-3861.90472703	1175.33868221	0.34604227	-1.71097097	0.85885804	19.55077943
301	377169.33254713	-4413.49686320	1346.09893498	0.27545900	-1.26497853	1.16229630	11.56622124
351	376818.80992682	-5020.61985078	1528.97866969	0.26281070	-1.49786670	0.87408391	14.81301112
401	376435.74011778	-5684.11622288	1723.33936439	0.60502165	-1.52403111	-0.34664918	5.79512369
451	376020.05664448	-6404.10111846	1928.33756088	0.56217881	-1.40883458	-0.09902252	6.42368629
501	375572.15267867	-7179.89354417	2142.92565292	0.42620403	-1.49092354	-0.23460859	6.45411863
551	375092.91448488	-8009.95844474	2365.85490381	0.53559993	-1.32326068	0.01272253	5.91673166
601	374583.74831025	-8891.86012869	2595.68012427	0.53345993	-1.27758983	0.05711616	5.61384309
651	374046.60054104	-9822.22735614	2830.76549468	0.52763960	-1.22897248	0.08962177	5.37380607
701	373483.97097371	-10796.73035263	3069.29116140	0.52299342	-1.18304620	0.11396106	5.15158542
751	372898.91895602	-11810.07017230	3309.26046318	0.51973087	-1.14016143	0.13156237	4.94657541
801	372295.06194741	-12855.98119175	3548.50793667	0.51694363	-1.09941020	0.14302088	4.76515102
851	371676.56574034	-13927.24804667	3784.70859632	0.51486368	-1.05847483	0.14797507	4.60540943
901	371048.12521769	-15015.73896143	4015.38935868	0.51436576	-1.01830955	0.14682782	4.45881059
951	370414.93412712	-16112.45810123	4237.94386096	0.51615830	-0.98073256	0.14131608	4.31903631
1001	369782.64200621	-17207.62017985	4449.65226929	0.52057632	-0.94656624	0.13319154	4.18376736
1051	369157.29615408	-18290.75096804	4647.70793634	0.52761240	-0.91584228	0.12335570	4.05322832
1101	368545.26651279	-19350.81740249	4829.25288279	0.53675411	-0.88825068	0.11170171	3.92980555
1151	367953.15159622	-20376.39052190	4991.42395948	0.54618960	-0.86339077	0.09693855	3.82019657
1201	367387.66429084	-21355.84326585	5131.41110315	0.54972842	-0.84137271	0.07599664	3.74508626
1251	366855.49754273	-22277.58311168	5246.52823791	0.52108248	-0.82729369	0.04360797	3.79471092

$Az = 10000$ km continued

$\phi = 90^\circ$

manifold	x (km)	y (km)	x (km)	$\dot{x}$ (km/s)	$\dot{y}$ (km/s)	$\dot{z}$ (km/s)	TOF (days)
4801	379717.46614913	-1764.23343337	494.04238967	1.72233318	-1.77798640	0.75503714	16.52859345
4851	379717.46614917	-2072.01238729	618.86851275	1.60459262	-1.67302302	0.72432224	14.64204695
4901	379717.46614917	-2437.72824892	761.86612657	1.48296038	-1.59382429	0.72315976	13.35375660
4951	379717.46614914	-2868.29350695	924.12799774	1.36413121	-1.48719103	0.72454516	11.98683930
1	379717.46614917	-3370.67028818	1106.44727432	1.24049003	-1.42257924	0.70954487	11.51447891
51	379717.46614917	-3951.63297279	1309.25326701	1.13373985	-1.37922869	0.69099296	11.04981490
101	379717.46614917	-4617.50250539	1532.54865616	1.04953891	-1.30556443	0.67145622	10.09571929
151	379717.46614917	-5373.86172229	1775.85253289	0.97769252	-1.22192734	0.65191527	9.13378263
201	379717.46614917	-6225.26289242	2038.15316561	0.91633408	-1.15255087	0.63657268	8.29387732
251	379717.46614915	-7174.93938260	2317.87344522	0.86408616	-1.09046776	0.62882340	7.51973812
301	379717.46614915	-8224.53291367	2612.85083076	0.80814345	-1.05184211	0.61087121	7.11013819
351	379717.46614915	-9373.84627137	2920.33245768	0.76029918	-0.96665535	0.62388184	6.45174001
401	379717.46614917	-10620.62897751	3236.98511464	0.71272278	-0.97428670	0.58817340	6.36397371
451	379717.46614917	-11960.40087273	3558.91924366	0.60243731	-0.80485476	0.73387798	5.56569653
501	379717.46614916	-13386.31651635	3881.72613110	0.89388315	-0.92721592	-0.03816013	3.85376661
551	379717.46614916	-14889.07242545	4200.52810284	0.85045737	-0.98359100	-0.02426128	3.85035101
601	379717.46614916	-16456.86005823	4510.04279272	0.77634061	-0.89051988	-0.04448639	3.99771374
651	379717.46614916	-18075.37040082	4804.66425622	0.78204710	-0.92179619	0.03609399	3.87245078
701	379717.46614916	-19727.86108342	5078.56554933	0.73527761	-0.92722801	0.04539510	3.94580343
751	379717.46614916	-21395.30361653	5325.82888918	0.70949430	-0.90921926	0.06587236	3.94142565
801	379717.46614916	-23056.63536968	5540.60994136	0.68600054	-0.86988677	0.06686434	3.92320782
851	379717.46614916	-24689.14609441	5717.34122635	0.66988282	-0.83597658	0.05558894	3.87414536
901	379717.46614916	-26269.02870359	5850.97511611	0.62902508	-0.83169302	0.04328863	3.96063466
951	379717.46614916	-27772.11446943	5937.25873922	0.61798600	-0.80894876	0.02561914	3.90852273
1001	379717.46614916	-29174.78993212	5973.02160436	0.60977675	-0.79249792	0.00947491	3.85934544
1051	379717.46614916	-30455.05564169	5956.44388162	0.60321438	-0.78095607	-0.00437460	3.81819253
1101	379717.46614916	-31593.64027727	5887.26312184	0.59672121	-0.77321473	-0.01605378	3.79028412
1151	379717.46614916	-32575.04037183	5766.87515765	0.58781232	-0.76848823	-0.02583055	3.78408229
1201	379717.46614916	-33388.33408413	5598.29545492	0.57224980	-0.76656428	-0.03371333	3.81616571
1251	379717.46614916	-34027.63338648	5385.97056224	0.53753927	-0.77071925	-0.03845814	3.94658479

LIST OF REFERENCES

LIST OF REFERENCES

[1] Victor Szebehely and Hans Mark. *Adventures in Celestial Mechanics.* John Wiley and Sons, Inc., New York, New York, second edition, 1998.

[2] William E. Wiesel. *Spaceflight Dynamics.* McGraw Hill, New York, New York, second edition, 1997.

[3] Victor Szebehely. *Theory of Orbits: The Restricted Problem of Three Bodies.* Academic Press, Inc., New York, New York, 1967.

[4] Gerhard Beutler. *Methods of Celestial Mechanics, Volume 1.* Springer, Heidelberg, Germany, 2005.

[5] Henri Poincaré and Daniel L. Goroff (editor). *New Methods of Celestial Mechanics (English Translation).* Vol. 13, History of Modern Physics and Astronomy, American Institute of Physics, Woodbury, New York, 1993.

[6] Kathleen C. Howell. Families of Orbits in the Vicinity of the Collinear Libration Points. *Journal of the Astronautical Sciences*, Vol. 49, No. 1, January-March 2001, pp. 107-125.

[7] Kathleen C. Howell. Three-Dimensional, Periodic, 'Halo' Orbits. *Celestial Mechanics*, Vol. 32, 1984, pp. 53-71.

[8] Michel Hénon. *Generating Families in the Restricted Three-Body Problem.* Springer, Heidelberg, Germany, 1997.

[9] G. Gómez, J. J. Masdemont, and J. M. Mondelo. Libration Point Orbits: A Survey from the Dynamical Point of View. Proceedings of the Conference Libration Point Orbits and Applications, Aiguablava, Spain, Gerard Gómez, Martin W. Lo and Josep J. Masdemont (editors), June 10-14, 2002, pp. 311-372.

[10] Robert W. Farquhar. Utilization of Multi-Body Trajectories in the Sun-Earth-Moon System. *NASA, Goddard Space Flight Center Technical Memorandum*, Report No. 80740, August 1980.

[11] D. W. Dunham and R. W. Farquhar. Libration Point Missions, 1978-2002. Proceedings of the Conference Libration Point Orbits and Applications, Aiguablava, Spain, Gerard Gómez and Martin W. Lo and Josep J. Masdemont (editors), June 10-14, 2002, pp. 45-73.

[12] Robert W. Farquhar, David W. Dunham, Yanping Guo, and James V. McAdams. Utilization of Libration Points for Human Exploration in the Sun-Earth-Moon System and Beyond. *Acta Astronautica*, Vol. 55, 2004, pp. 687-700.

[13] Robert W. Farquhar. The Utilization of Halo Orbits in Advanced Lunar Operations. *NASA, Goddard Space Flight Center*, Report No. X-551-70-449, December 1970.

[14] Louis A. DAmario and Theodore N. Edelbaum. Minimum Impulse Three-Body Trajectories. *AIAA Journal*, Vol. 12, NO. 4, April 1974, pp. 455-462.

[15] Raoul R. Rausch. Earth to Halo Orbit Transfer Trajectories. M.S. Thesis, School of Aeronautics and Astronautics, Purdue University, West Lafayette, Indiana, 2005.

[16] B. T. Barden, K. C. Howell, and M. W. Lo. Application of Dynamical Systems Theory to Trajectory Design for a Libration Point Mission. *Journal of the Astronautical Sciences*, Vol. 45, No. 2 April-June 1997, pp. 161-178.

[17] Jeffrey S. Parker and George H. Born. Direct Lunar Halo Orbit Transfers. AAS Paper 07-229, AAS/AIAA Space Flight Mechanics Conference, Sedona, Arizona, January 28-February 1, 2007.

[18] Archie E. Roy. *The Foundations of Astrodynamics.* The Macmillian Company, New York, New York, 1967.

[19] Roger R. Bate, Donald D. Mueller, and Jerry E. White. *Fundamentals of Astrodynamics.* Dover Publications, Inc., Mineola, New York, 1971.

[20] Kathleen C. Howell. AAE 632 - Advanced Orbital Dynamics. Class notes, 2006.

[21] Brian T. Barden. Using Stable Manifolds to Generate Transfers in the Circular Restricted Problem of Three Bodies. M.S. Thesis, School of Aeronautics and Astronautics, Purdue University, West Lafayette, Indiana, 1994.

[22] Belinda A. Marchand. Temporary Satellite Capture of Short-Period Jupiter Family Comets from the Perspective of Dynamical Systems. M.S. Thesis, School of Aeronautics and Astronautics, Purdue University, West Lafayette, Indiana, 2000.

[23] Katsuhiko Ogata. *Modern Control Engineering.* Prentice Hall, Inc., Upper Saddle River, New Jersey, fourth edition, 2002.

[24] A. E. Roy and W. M. Ovenden. On the Occurrence of Commensurable Mean Motions in the Solar System, II. The Mirror Theorem. *Monthly Notices of the Royal Astronomical Society*, Vol. 115, January 1955, pp. 296-309.

[25] Germàn P. Alonso. The Design of System-to-System Transfer Arcs Using Invariant Manifolds in the Multi-Body Problem. Ph.D. Thesis, School of Aeronautics and Astronautics, Purdue University, West Lafayette, Indiana, 2006.

[26] Christopher E. Patterson. Representations of Invariant Manifolds for Applications in System-to-System Transfer Design. M.S. Thesis, School of Aeronautics and Astronautics, Purdue University, West Lafayette, Indiana, 2005.

[27] Kathleen C. Howell and Robert W. Farquhar. John Breakwell, the Restricted Problem, and Halo Orbits. *Acta Astronautica*, Vol. 29, No. 6, 1993, pp. 485-488.

[28] K. C. Howell, M. Beckman, C. Patterson, and D. Folta. Representations of Invariant Manifolds for Applications in Three-Body Systems. *Journal of the Astronautical Sciences*, Vol. 54, No. 1, January-March 2006, pp. 69-93.

[29] D. R. Cooke, B. K. Joosten, M. W. Lo, K. M. Ford, and R. J. Hansen. Innovations in Mission Architectures for Exploration Beyond Low Earth Orbit. *Acta Astronautica*, Vol. 53, 2003, pp. 387-397.

[30] P. J. Message. On the Existence of Periodic Solutions of Poincaré's Second Sort in the General Problem of Three Bodies Moving in Plane. *Celestial Mechanics*, Vol. 21, January 1980, pp. 55-61.