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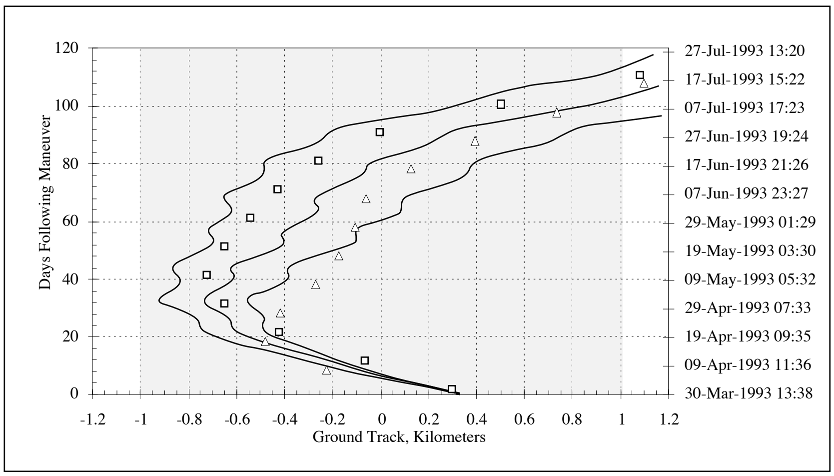
TOPEX/POSEIDON PROJECT

GTARG - The TOPEX/POSEIDON Ground Track Maintenance Maneuver Targeting Program - User's Reference Manual



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GTARG - The TOPEX/POSEIDON Ground Track Maintenance Maneuver Targeting Program - User's Reference Manual

Abstract

This document provides the basic background, inputs, and procedures necessary to use GTARG, the TOPEX/POSEIDON ground track maintenance maneuver targeting program. Maneuvers ensure that the ground track is kept within a ±1 km. control band of an ≈ 9.9 day exact repeat pattern. GTARG combines orbit prediction and targeting algorithms to design the maneuvers. The analytic mean-element propagation algorithm includes all perturbations that are known to cause significant variations in the satellite ground track. These include earth oblateness, luni-solar gravity, and drag, as well as the thrust due to impulsive maneuvers and unspecified along-track satellite fixed forces. Targeting strategies will either (a) maximize the time between maneuvers (*longitude targeting*) or (b) force control band exit to occur at specified intervals (*time targeting*). A runout mode allows for ground track propagation without targeting. Error models include uncertainties due to orbit determination, maneuver execution, drag unpredictability, and the knowledge of along-track satellite fixed forces.

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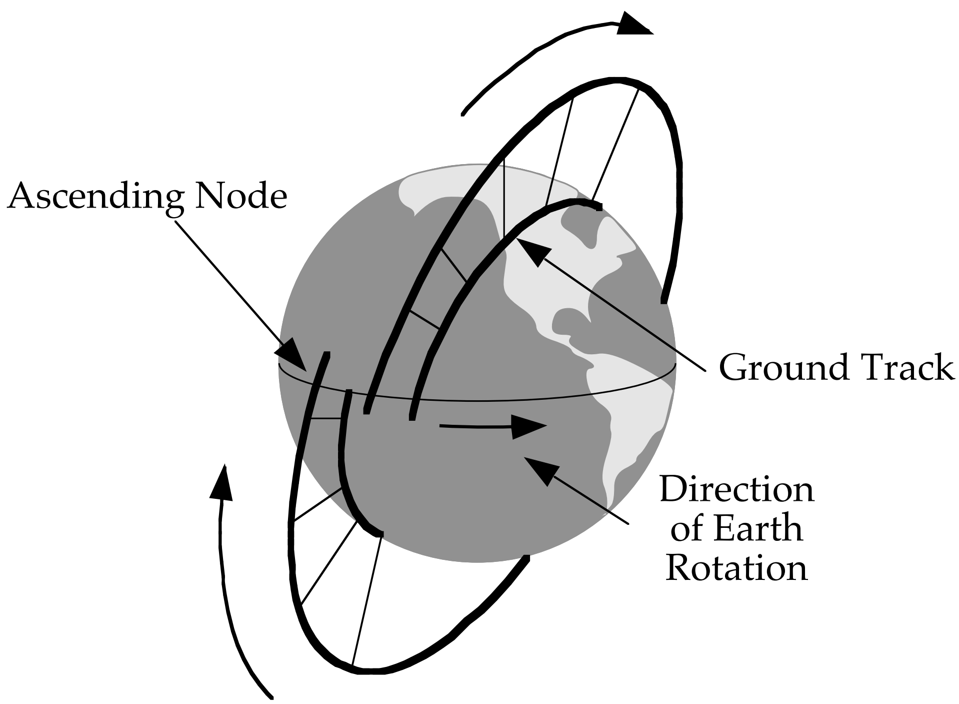
Introduction

1.1. Background

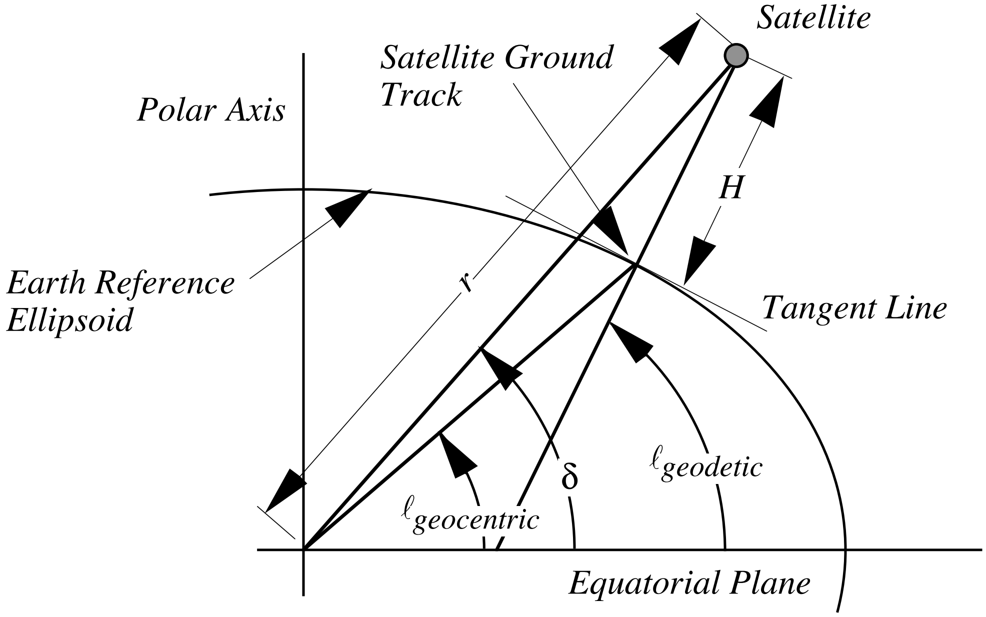
This document describes the inputs and procedures necessary to use GTARG, the TOPEX/POSEIDON ground track maintenance maneuver targeting program. This section summarizes some of the basic concepts needed to understand the use of a ground track targeting program. Section 1.2 provides an overview of the rest of this document. The references provide more details on the concepts of ground track, ground track maintenance, and the implementation of these concepts in GTARG.

Figure 1.1.
Definition of satellite ground track.



The *ground track* of the orbit is defined to be the locus of points traced out on the Earth's surface directly "beneath" the spacecraft orbit, as illustrated in figure 1.1. More precisely, the ground track is found by dropping a perpendicular line from the satellite to the reference ellipsoid representing the surface of the earth. The intersection of this line, which does not pass through the center of the Earth (except at the equator), with the reference ellipsoid, is the ground track (see figure 1.2). Typically, if the ground track repeats itself after some number of orbits, the satellite is said to be in an orbit with an *exact repeat ground track.* The desired ground track is referred to as the *reference ground track*, and the ascending node crossing longitudes of the reference ground track are called the *reference nodes* or *reference grid*.

Figure 1.2.
Definition of satellite ground track.[1] The ground track is found by dropping a perpendicular to the surface (defined by the reference ellipsoid) from the satellite. The geodetic altitude *H*, the declination δ, and the geodetic and geocentric latitudes $\ell_{geodetic}$ and $\ell_{geocentric}$ are shown.



There is a particular combination of the elements a, e, and i which will produce a given exact repeat orbit.[2] Due to the time varying nature of the perturbations on the orbit, however, it is impossible to exactly match the reference ground track for any significant duration of time. Deviations from the reference orbit lead to *ground track drift*. To see this, consider the orbit as it crosses the equator, as shown in figure 1.1. As the Earth rotates from one node crossing to the next the ground track moves westward. If the orbital period is exactly right, successive node crossings match successive reference nodes. If the period is too short, the Earth does not rotate quite far enough, and the true node falls to the east of the reference node. If the period is too long, the earth rotates too far, and the true node falls to the west (figure 1.3). After multiple orbits, the ground track moves further and further to one direction or another, and a ground track drift develops. Ground track maintenance maneuvers must be performed to ensure that the ground track remains within a permissible swath, surrounding the reference orbit. This swath is called the *control band*.

Figure 1.3.
Ground track drift, measured at the equator.

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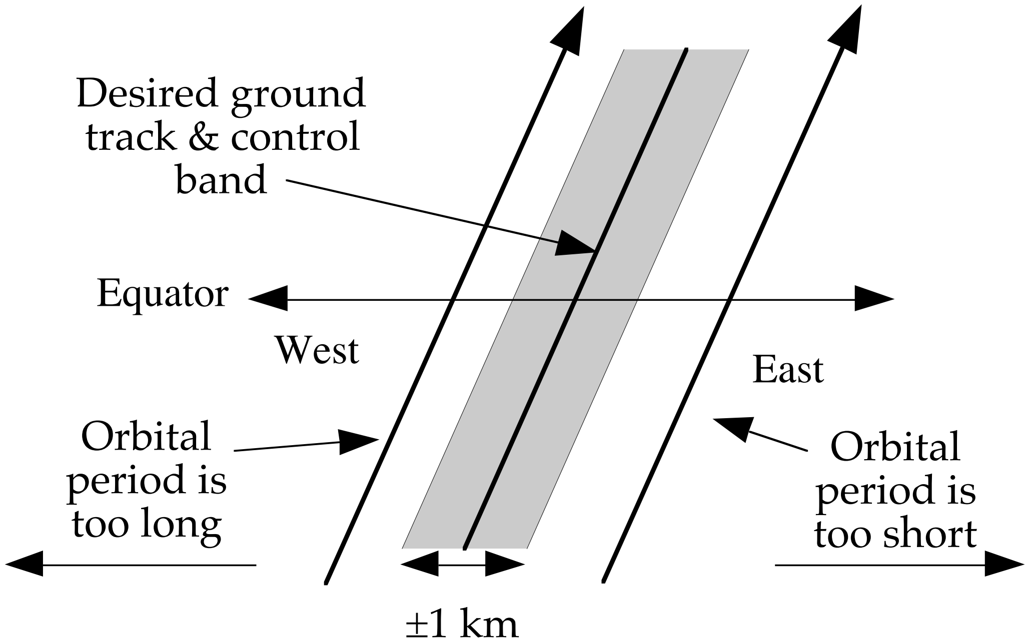
[1]Escobal, 1983. The calculation of latitude and longitude from the satellite position vector are given by transformation 3, pp. 398-399.
[2]Cutting, Born, & Frautnick, 1976.



Atmospheric drag is usually the dominant perturbation causing ground track drift. As a result of drag, the semi-major axis decays and hence the period decreases.[1] If the semi-major axis initially exceeds the semi-major axis of the reference orbit, the ground track drifts westward. This drift continues until the orbit matches the reference. As drag continues reducing the semi-major axis, the ground track turns around and begins moving eastward. The result is a somewhat lumpy parabola when plotted as a function of time (see figure 1-4). Various perturbations, such as solar and geomagnetic activity, luni-solar gravity, solar radiation pressure, tides, shadow entrance and exit effects, time-varying drag area, and other satellite fixed and external forces cause deviations from the basic parabola and produce the ripples shown in the curve of figure 1.4.

When the ground track approaches edge of the control band, a maneuver is performed to change the direction of the ground track drift. A *ground track maintenance maneuver* will increase (if the ground track is approaching the eastern edge of the control band) or decrease (approaching the western edge) the semi-major axis of the orbit. These maneuvers are along track (parallel or anti-parallel to the direction of motion) and are typically of very small magnitude (Δvs of millimeters per second). The process of determining the magnitude of the maneuver is called *maneuver targeting*. Various strategies can be used for maneuver targeting.[2,3] GTARG combines these targeting strategies with error models to plan maneuvers so that the ground track will remain within the control band for a known period of time with a high degree of confidence. The remaining sections of this document describe how to use GTARG to predict the ground track and perform maintenance maneuver targeting.

Figure 1.4.

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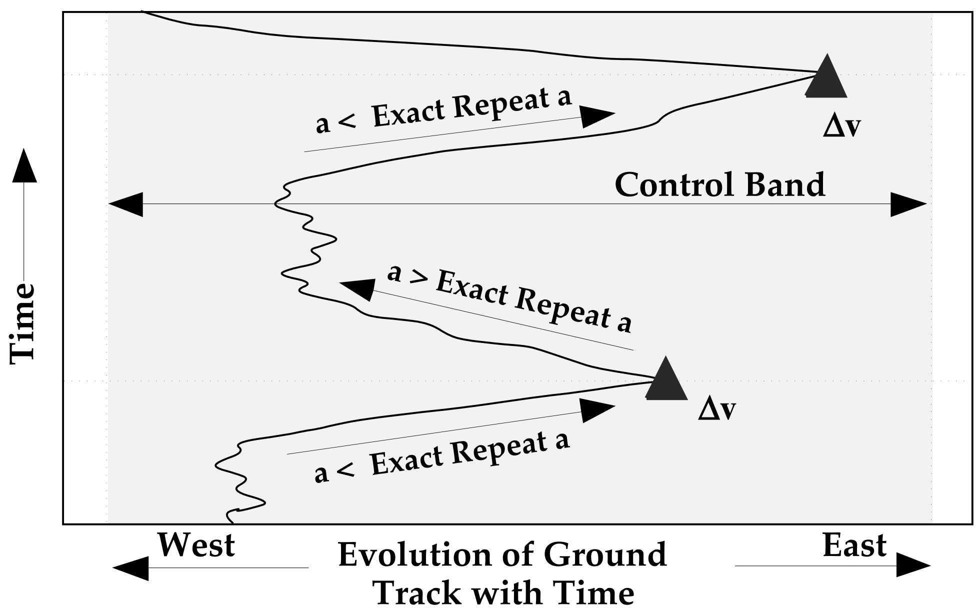
[1]Bhat, Frauenholz, & Cannell, 1989.
[2]Bhat, Frauenholz, & Cannell, 1989.
[3]Frauenholz & Shapiro, 1991.

Ground track drift as a function of time. The control band is shaded. Ground track maintenance maneuvers are indicated by Δv.



1.2. Scope of the User's Reference Manual

Section 2 describes the various models implemented in GTARG and cross-references the models to the available input parameters. The mathematical and algorithmic details are left to the references.[1] The purpose of section 2 is to provide the user with a basic understanding of the models which are available and the control which he or she has over those models.

GTARG was implemented on the VAX® VMS® operating system. It is assumed that the user is familiar with the use of VMS®. Section 3 describes how to execute GTARG in this environment.

All input to GTARG is provided through the use of standard FORTRAN namelists. Detailed descriptions of the input parameters available are given in section 4. The bulk of the reference material in this document is provided in this section. It has been assumed that the user has access to a standard text editor and is familiar with the editing of VAX® FORTRAN namelists.

Section 5 provides typical output files produced by GTARG.

Section 6 describes how to rebuild the source code on the standard host environment. This material will be useful if the user wishes to supply a user-defined density function, modify the source code, or transport GTARG to another platform.

[1]Shapiro & Bhat, 1993.

Appendix A summarizes the use of the EZPLOT plotting package. EZPLOT is not a part of GTARG. However, GTARG produces output files for plotting which are formatted as EZPLOT input namelists. This appendix provides the information necessary to understand the contents of the EZPLOT namelist files.[1,2]

Subjects left for the references include: the motivation[3] for creating GTARG, the importance and magnitude of the relative effects of the various orbital perturbations on the ground track,[4,5] the mathematical theories underlying the implementation,[6] how to define the reference orbit,[7,8,9] and strategies for performing maneuver targeting[10]. Pertinent references are given throughout the text.

1.3. Acknowledgments

The work described in this document was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. GTARG was developed under the direction of R. B. Frauenholz in his role as the TOPEX/POSEIDON Navigation Team leader. R. S. Bhat developed the perturbation equations and propagation algorithm into forms which were useful for direct implementation. P. E. Cannell coded the initial versions of GTARG.

[1]Cannell, 1990.
[2]Pearson, 1989.
[3]Bhat, 1991.
[4]Bhat, Frauenholz, & Cannell, 1989.
[5]Frauenholz & Shapiro, 1991.
[6]Shapiro & Bhat, 1993.
[7]Shapiro, 1992.
[8]Vincent, 1990.
[9]Carlisle, DiCicco, Harris, Salama, & Vincent, 1991.
[10]Bhat, Frauenholz, & Cannell, 1989.