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DESIGN OF A SPACE MISSION FOR THE ACQUISITION OF TERRESTRIAL IMAGES FOR BOLIVIA

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RESUMEN

La importancia de adquirir un satélite de observación terrestre por parte del gobierno y de empresas privadas radica en la obtención de imágenes recientes, para usos como cartografía, plantaciones ilícitas, minería, depósitos de petróleo, desastres naturales, etc. Por esta razón obtener imágenes actualizadas del territorio nacional debe ser una prioridad. Este análisis y diseño de misión se enfoca en el diseño de la órbita del mismo; haciendo un estudio de la órbita apropiada para un futuro satélite de observación terrestre. La simulación de la órbita se realiza por medio del estudio de las perturbaciones que más afectan a los satélites de órbita baja, así como también el tiempo de revisita del satélite sobre una determinada área que será de interés potencial tanto para el gobierno como para empresas privadas radicadas en el país.

ABSTRACT

The importance of having a terrestrial observation satellite consists of the need of governments and private entities to have recent images of a specific area, for the use of cartography, illicit plantations, mining, petroleum deposits, natural disasters, etc. Therefore, having up-to-date images of the national territory should be a priority. This analysis and design of mission focuses on the design of the orbit of the satellite, studying what type of orbit is appropriate for a future Earth observation satellite. The simulation of the orbit is carried out in this work through the study of the perturbations that most affect low-altitude satellites. The calculation of the satellite's revisit time will be based on areas of potential study interest for both the government and private companies settled in the country.

Key Words: dynamics — Earth

1. INTRODUCTION

In this research, we determine and analyse a group of orbits that would be optimal for the collection of images of one region of Bolivia. For a terrestrial observation satellite mission, the criterion that must be fulfilled consists mainly in the minimisation of the revisit time, while maximising the resolution of the images collected. We set the following criteria for this specific mission:

- Revisit time less than 24 hours (time interval between satellite two consecutive passings through a specific location on Earth).
- Link time greater than 120 seconds (time on which the satellite passes over the ground station and communication between them takes place).
- Resolution of 50 Ground Sample Distance (for a commercial camera).

Having these goals in mind, we decided to take a practical approach in our analysis of the orbit by implementing a basic simulator. The result of this analysis gave us a better understanding of the relationship between the revisit and link time with the inclination of the orbit, showing us the optimal range for our purposes. Finally, these results were compared to the ones obtained by the software Satellite tool kit (STK 11.2) in order to validate them. Also, some possible launch sites that agree with our necessities were reviewed.

2. PROCEDURE

Our first step was to set up a simulator of the satellite movement, which was implemented in FORTRAN 90, using the Runge-Kutta-Fehlberg 78 integration method (Fehlberg 1968). The simulator considers the basic interaction between Earth and the satellite, as well as the J2 perturbation and the atmospheric drag (Bate et al. 1971, Soliz et al. 2018). It is important to notice that those models

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TABLE 1

SIMULATOR PARAMETERS

Parameter	Value	Unit
Altitude	300-800	km
Eccentricity	0.0009	-
Inclination	10 a 100	deg
LAN	0	deg
Arg. of perigee	0	deg
True anomaly	0	deg
Simulation time	30	days

were developed for the Earth-centered inertial frame (ECI). The equation of motion of a two-body problem with the effects of the mentioned perturbations is:

$$\ddot{\vec{r}} = -\frac{\mu}{r^3}\vec{r} + \vec{a}_{J_2} + \vec{a}_D \quad (1)$$

Once a simulation is finished, a transformation between reference frames is calculated, from the ECI reference system in which the simulation is executed, to the Azimuth-Elevation-Range (AER) reference frame placed at the origin of the ground station. Table 1 shows the input parameters that were used to configure this simulator, being these the initial orbital elements of the satellite, its physical attributes and the geographical location of the hypothetical ground station respectively.

The location of the ground station is Latitude=-17.399167°, Longitude=-66.218528°, Altitude=2556 km above sea level.

The results of the link and revisit time were introduced into an Index function, such that the larger the index, the larger the link time and the shorter the revisit time. In other words, a portion of the Index is proportional to the the link time, and the other one is inversely proportional to revisit time. For practical reasons this index is mapped between 0 and 10, and is shown in Figure 1. From our analysis, we conclude that the further the satellite is, the longer the link time gets. As for revisit time, it is significantly reduced at lower inclinations.

The index number defines a region of optimal performance within 20° to 30° of inclination. At this point no bound is defined for the altitude, reason for which we have make use of the lifetime and resolution criteria.

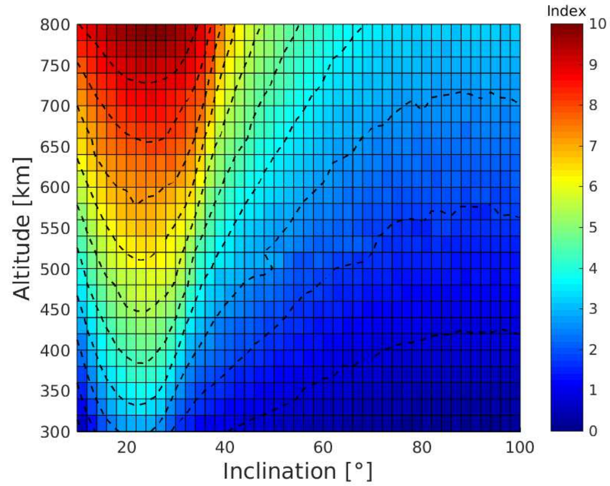

Fig. 1. Obtained Index function values (colorbar) for the range of inclinations and altitudes considered.

TABLE 2

ORBIT PRESELECTION

Parameter	Value	Unit
Min. altitude	350	km
Max. altitude	500	km
Min. inclination	20	deg
Max. inclination	30	deg
Eccentricity	0.0009	-

Finally, the optimal orbit for this satellite mission is summarised in Table 2.

3. VALIDATION AND RESULTS

As a final step and a way to validate our results, a satellite mission was configured in the STK simulator software with the parameters found. The comparison of results showed that the variation between our method and STK software is less than 5%.

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