

MAE146: Astronautics – Design Project Description

Communication Relays at Mars

Assigned: Friday, January 19th, 2007

Due date: Monday, March 19th, 2007,
(by 5 : 00 pm in my office)

Project Overview

This design project aims at investigating the design trade-offs and requirements for an hypothetical mission supporting the human Mars exploration effort. The project requires that you write a report (typeset and due by the time and the date indicated above) based on the results of your analysis of the problem. This analysis should be backed by a sound reasoning and engineering estimates based on the dynamics we have learned in class, as well as numerical results obtained from computer modeling and simulations of the mission (suggested software: STK¹).

Mission Goal

The president vision for space exploration² redirected the space program in 2004 to promote the development of a Lunar base as an outpost to support human exploration of the solar system. In particular, human presence on Mars appears to be the next step once a lunar basis is (partially) completed. While the Mars astronaut crew will have to deal with many problems on their own, continuous communication between a Mars outpost and the control centers located on Earth appears desirable. The goal of this project is to explore some potential architectures to achieve such a continuous open communication channel. Assuming the first human Mars mission to be launched during the year 2030, the communication relay system should be operational by January 1st of that year.

Mission Concept

In a similar way as the Earth, Mars is rotating around its poles. Assuming that the line of sight between Earth and Mars is not obstructed by the sun, the first step is to investigate options for providing continuous communications as Mars rotates. To do so, we want to investigate the possibility of placing satellite relays in Mars orbit. At least one relay would face the Earth and the outpost on Mars (taken to be at 0° longitude and latitude) at all times. The relay(s) should be fully functional by the January 1st of 2030. The relays will be assumed to be 100kg in dry mass (needed for the communication systems).

Required Analysis

In order to provide technical advice on the feasibility/potentials of such an option, we need to provide:

- Relay(s) orbit(s) characteristics and maintenance cost at Mars
- Attitude requirements and possible antenna configurations
- Orbit transfer options starting from Earth.
- Overall fuel budget.

¹A professional software suite from Analytical Graphics Inc. (<http://www.agi.com>) installed on the computer labs ECT 123 and EG 3151.

²http://www.nasa.gov/mission_pages/exploration/main/index.html

Suggested Line of Investigation

In order to answer the above questions, the analysis can be split into two mostly independent problems: The relay configuration (orbit, attitude, architecture) around Mars, and the transfer from an Earth launch to the Mars orbit with insertion no later than January 1st of 2030. It is recommended to start the report at the same time as the analysis, laying out, for example an outline and writing down the project goals and settings. The project can then be filled in as the analysis progresses.

Preliminaries

- Become familiar with the Earth and Mars systems (Orbit characteristics, Physical parameters,...)
- Determine the time frame from which Mars is visible from the Earth and fix the initial insertion time at Mars to begin near the start of this period (within the previous time constraint of January 1st, 2030). What is the travel time for communications between Earth and Mars (signals move at the speed of light)?

Relay(s) configuration around Mars

- Model Earth and Mars as moving in circular orbits in the same plane, uniformly rotating about their polar axis which is assumed orthogonal to the orbital plane. Looking at the period of the circular orbits around Mars, can we achieve continuous pointing of the Earth and Mars with one satellite? Two, three?
- What is the effect of inclination, eccentricity and other orbital parameters? Discuss the advantages and drawback of your options and choose one of them (continuous communication in the event of spacecraft failure, minimization of costs are variables of interest in choosing a configuration)
- Implement a scenario in STK to represent your preliminary analysis and check that your configuration behaves as expected. Then, try to add more realism to your model using the options offered by the software (exact orbits/orientations for Earth and Mars, higher order gravity field...). Can you estimate correction maneuvers to insure that the perturbed trajectories meet the required objective?
- Assuming the spacecraft having two different antennas (one for communicating with the Mars outpost and the other for communicating with the Earth). What type of configuration are possible? Give the associated pointing requirements? What would be the attitude control strategy? Discuss the pros and cons of your options and pick one. Simulate it in STK.

Launch and insertion in the desired orbit

- Using a two body model, estimate the transfer time and fuel cost for a Hohmann type transfer between the Earth and Mars.
- Determine the launch windows in your simplified model.
- Before sending the spacecraft on its transfer course, a first step is to launch it into a parking orbit (Low Earth Orbit) in order to check if the system is functional after launch. What would be the trade-off between the launch vehicle and mass of the spacecraft based on your estimated transfer fuel cost? Choose a launch site, launch vehicle and launch windows to meet your previous transfer requirements.
- Implement a scenario corresponding to your analysis. Add more realism and evaluate the corrections from your initial two-body estimates.
- What is the arrival time and insertion ΔV ? Is the phasing at insertion correct?

Earth-Mars conjunctions (optional)

What options, consistent the previous strategy, would you propose for providing continuous communication when the Sun obstruct Mars from the Earth?

- Provide a schedule of when these events would occur.
- try to investigate your options along the lines of the previous analysis. Does it introduce additional delays in the communication times?