**ABSTRACT**

This project is the design and implementation of a computer program which simulates various aspects of a spacecraft mission to the planet Mars and its return to Earth. This program is PC-based and it provides a graphical simulation of the mission. The program computes a spacecraft trajectory of minimum energy, the fuel consumption of the spacecraft associated with the trajectory, and the launch window during which the mission may commence. The user is required to enter the date after which the first available launch window is to be computed, the initial mass of the spacecraft, the specific impulse of the rocket fuel, and the burn rate of the fuel.

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## BACKGROUND AND RATIONALE

It has been more than twenty years since the last American astronaut set foot on the moon. During that time there has been growing interest in future space missions back to the moon and to other planets in our solar system. In particular, proposed missions to the planet Mars have received a great deal of attention. This is due to the fact that Mars is the closest planet that exhibits similar features to those on Earth. For example, Mars has polar caps, an atmosphere, dust storms, volcanoes, and evidence of ancient rivers. Also, the possibility of microbial life on Mars is still a great allure to many scientists.

The Viking spacecraft was launched by the National Aeronautics and Space Administration (NASA) to the planet Mars in 1975. This mission involved both a lander, which successfully touched down on the surface, and an orbiter, which remained in orbit and took hundreds of high-resolution photographs of the Martian surface. A future mission to Mars that is under consideration involves an unmanned spacecraft which lands on the surface, retrieves a soil sample, and successfully returns the soil sample to Earth. Any manned mission to Mars would, of course, involve a two-way trip also.

For the most part, computations of the trajectories involved in Mars missions have been performed by NASA on high-speed supercomputers or workstations. Such calculations are extremely detailed because they must model precisely an existent spacecraft. Consequently, the computer programs that perform these calculations tend to be huge, and they require years of development effort in order to implement them. But, if only the crucial aspects of the spacecraft are modeled, then it becomes possible to develop a simpler computer program which can run on a small computer such as a PC. The development of such a PC-based program is the goal of this project.

In order to implement this program two very different types of physics equations must be solved. The first type involves solving for the position of a body which is under the influence of a gravitational field. This includes the use of Kepler's laws of planetary motion. The second type involves solving for the effects on the trajectory of a rocket due to the burning of its fuel. These two different types of equations are solved together. Thus, this project provides an excellent opportunity to demonstrate the principles involved in two different branches of physics. Because physics is my application area, the project is an appropriate one for this area.

In addition, because both the orbit of Earth and the orbit of Mars are ellipses with their respective semi-major axes intersecting at an oblique angle, the symmetry of the problem is lost. What this means is that no simple analytical solution of the spacecraft orbit is possible. Instead, an iterative technique must be used in which successively better approximations to the orbit are made until some tolerance value is reached. This allows for several principles of computer science such as state-space search to be applied. Thus, this project demonstrates both principles in physics and in computer science.

Timing is of critical importance in the simulated Mars mission. In fact, the mission may not begin until Earth and Mars are in the correct position relative to one another. The time during which this correct relative position occurs is known as the launch window. The calculation of when the launch window occurs is one of the primary calculations of the program. The user is prompted to enter a date (e.g., September 15, 1996) and the program computes the next launch window after this date. The simulated mission begins on that date according to the simulated mission calendar. In addition to the launch window for the outbound journey to Mars, there is one for the return journey as well. In other words, once the spacecraft arrives at Mars, it must wait until the next available returning launch window before leaving Mars.

In addition to the pure orbital calculations, the program produces a graphical simulation of the mission as it unfolds. This involves producing a display of Earth, Mars, and the spacecraft on the monitor screen. The display evolves over time in accordance with how the mission evolves over time. The only difference is that many months of mission time are compressed into only a few short minutes of user time. This provides the user with some intuitive feeling for how the mission is progressing.

The simulated Mars mission program has a variety of educational uses. It demonstrates basic principles of astronomy and celestial mechanics, such as Kepler's three laws of planetary motion. The basic orbital parameters of Earth and Mars can be changed by editing an input file. This allows students to get an intuitive feeling for how parameters such as the orbital eccentricity affect the various trajectories involved. Students can experiment with the model in various ways, and thus gain a better grasp of the physical concepts involved. Thus, the program can serve as a valuable tool in the area of simulation and modeling.