Orbital Mechanics Calculator and Rich Purnell Maneuver

FURMAN COMPUTER SCIENCE

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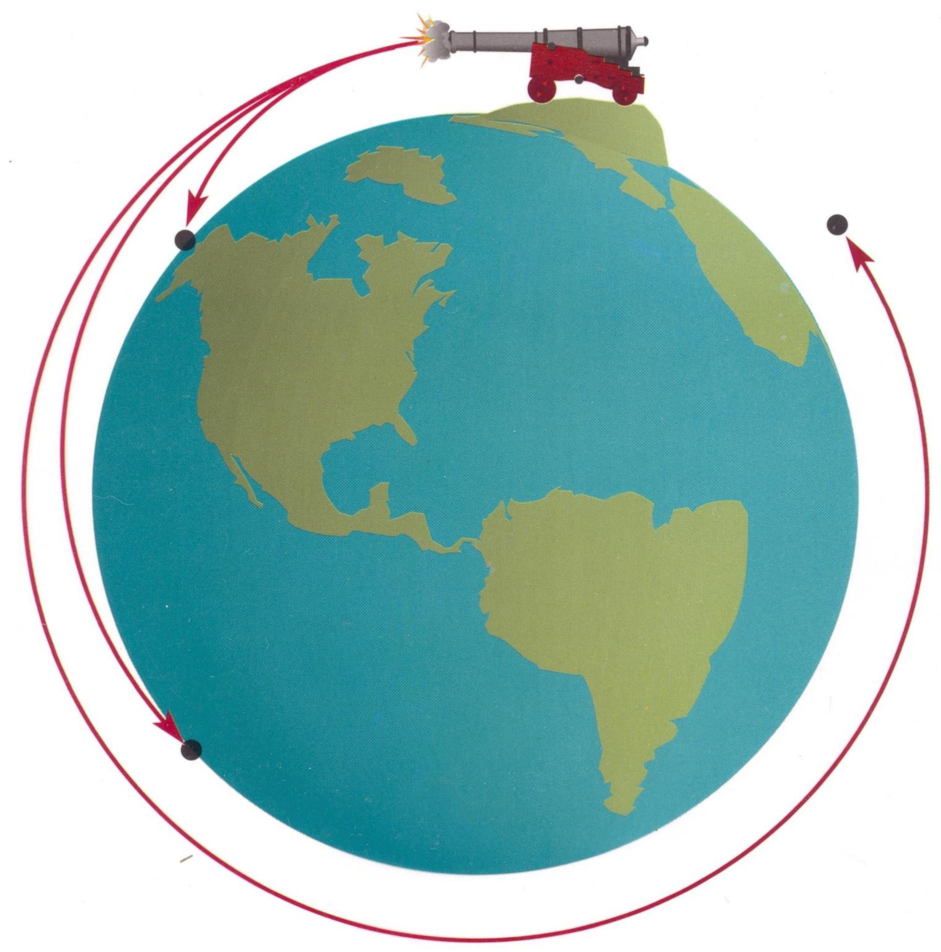
Introduction

Calculating orbital trajectories is an extremely complicated and time-consuming process. With the power of modern computing however, we can make the jobs of orbital dynamicists easier.

Orbits Explained

The figure below depicts Newton's Cannon. This thought experiment shows in simple terms the concept behind an earthly orbit. The faster and faster the cannon fires the ball, the closer the ball comes to continually missing the earth as it falls, otherwise known as orbiting.



Rocket Science Equations

In order to build a calculator for an orbital dynamicist, I had to become an orbital dynamicist. What follows are the most important equations that I implemented in my calculator.

$$\Delta V_A = \sqrt{GM\left(\frac{2}{r_A} - \frac{1}{a_{tx}}\right)}$$ velocity on transfer orbit at inital orbit (point A)

$$\Delta V_B = \sqrt{GM\left(\frac{2}{r_B} - \frac{1}{a_{tx}}\right)}$$ velocity on transfer orbit at final orbit (point B)

$$\Delta v = v_{bo} - v_o = u \ln \frac{m_o}{m_{bo}} - g t_{bo}, \text{ where}$$

$v_o =$ initial rocket velocity relative to stationary earth, S

$v_{bo} =$ burnout velocity; rocket velocity at moment of complete fuel expenditure

$\Delta v = v_{bo} - v_o =$ maximum vertical rocket velocity at burnout

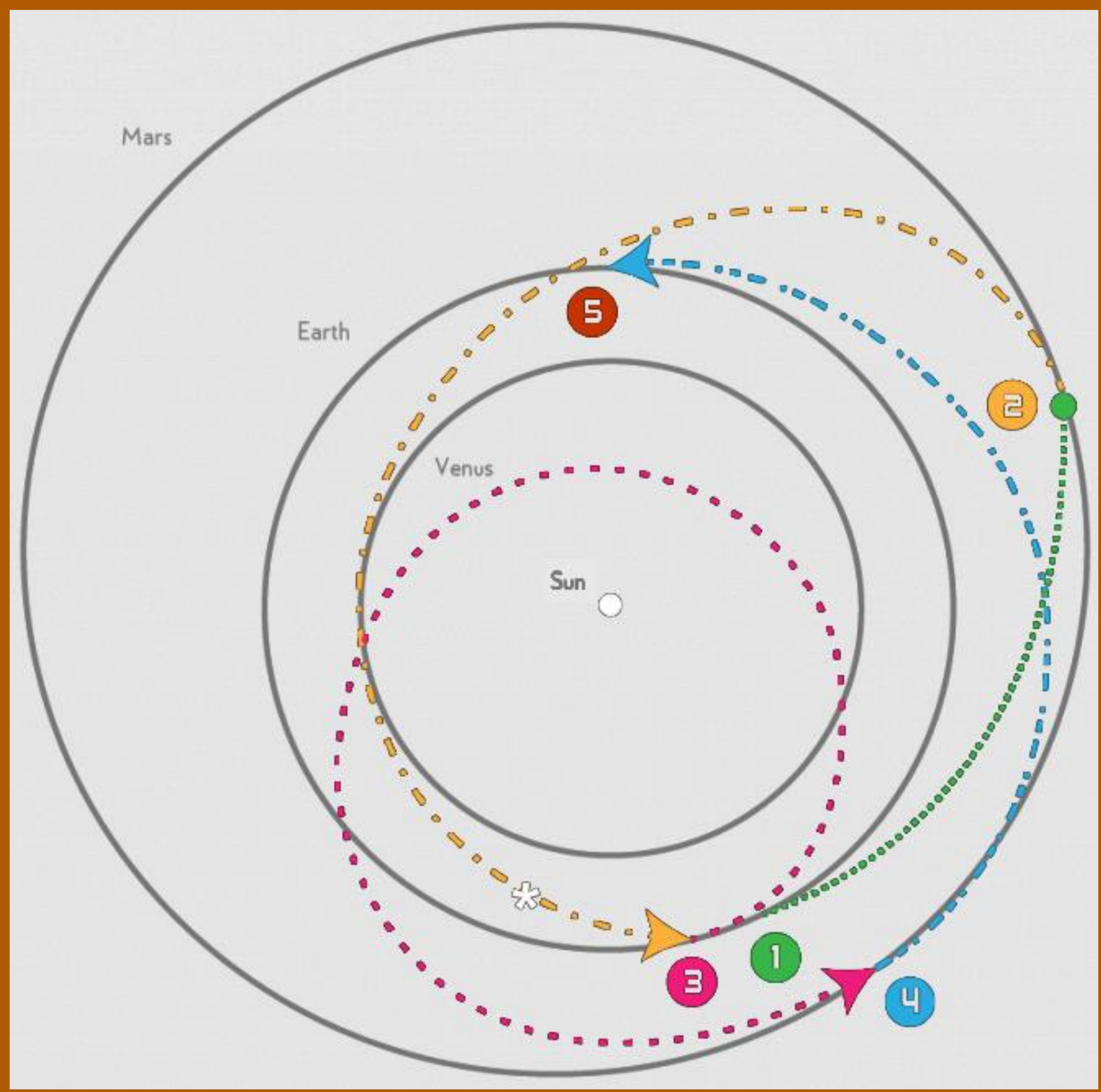
$u = -(v - v_o) =$ effective exhaust velocity relative to rocket nozzle, S'; hence, a constant

Trajectory Calculator

The computational tool I developed allows for the precise calculation of orbital trajectories with a wide range of possible data inputs. This tool is designed to give quick, accurate, answers to questions like, when should I leave, how much fuel do I need, and how long will the trip last. Perhaps you decide you want to leave for another planet a few months earlier than the optimal time, this tool can tell you how much more fuel you will have to bring along to complete your mission. The tool is also flexible enough that it can be used for any number of planets, solar systems, and galaxies, provided you have enough space on your computer.

My model of the solar system works off of the fictional Kerbol solar system, which is very similar to our own. I am using this system in my model, because I have extremely accurate data on where the planets are relative to each other at a given time, as well as 100% accurate values for each planets' attributes.

Although my calculator has been developed using a fictional solar system, the algorithms and techniques used in this simplified version translate easily to real world applications and can be easily modified to work both in a full three dimensions, but also with our real world planets.



The Rich Purnell Maneuver

The Rich Purnell Maneuver is a fictional orbital trajectory from the book and film "The Martian". The maneuver is one of the more complex orbital trajectories ever calculated and would surely be the most complex if it were ever attempted. The maneuver starts at Mars, and begins a return journey to Earth. Then, it accelerates towards Earth and slingshots back to Mars using the Earth's gravity. It then slingshots around Mars and returns to Earth.

The author of "The Martian" developed a virtual model of a our solar system to get a launch date for his fictional Mars mission. I wanted to do the same. I combined my new knowledge of orbital dynamics with my knowledge of computation to develop a simplified model of our solar system so as to determine for myself a similar trajectory while retaining the ability to plan other trajectories as well.

Hohmann Transfer

The Hohmann transfer technique was developed by Walter Hohmann in 1925, decades before humans launched their first satellite into orbit. The technique is designed to move a vessel from a lower orbit to a higher one. It also holds for the opposite direction. It calls for two engine burns, the first, to increase the altitude of the lower orbit to that of the higher one, and second, to match the rest of the current orbit to the higher one.