

## **Volume 4 Project: The Slingshot Effect**

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The goal of our project is to model the slingshot effect whereby a spacecraft can gain velocity by coming close to a planet. We hope that given initial conditions (position and velocity) of a spacecraft, we will be able to model the trajectory of the spacecraft at successive times and determine which orbital parameters lead to optimal slingshots. We will start with Newton's equations of motion to get an idea of what the system looks like. For three bodies, Newton's equations describing gravitational motion don't have a general analytic solution, so we will have to employ a combination of simplification and numerical approximation to obtain a working model.

Some ways we hope to make the problem more tractable include making simplification to the equations (for example, eliminating small terms or restricting to a single plane of motion), using different coordinate systems, and using dimensional analysis and scaling. We hope that some or all of these methods might even make our numerical approximations more stable, especially if we can avoid some of the potential for floating point error with very large and very small numbers.

Once we have obtained the equations, we will try several different methods of numerical approximation to model the problem. We will try a combination of higher-stage Runge-Kutta methods and some higher-order methods of approximation. Then we will visualize our numerical solutions using phase portraits animated over time as well as trajectories animated over time. To test the stability and reliability of our model we will try slightly perturbing the initial conditions and seeing what effect that has on the solutions. We may also try implementing the model in a game engine like Unity to better visualize the model.

We will then try adding new elements to our model to see how structurally stable our model is, as well as how well it can handle more difficult situations. For example, we might try to model more accurate elliptical orbits (as opposed to circular orbits) and add more bodies to the problem (making it a 4 or 5 body problem as opposed to a 3 body problem). We might then try to find initial conditions that allow for a "double slingshot" wherein the satellite will slingshot past two planets due only to gravity (i.e. no thrust). We can also try to model the movement of a spacecraft through a slingshot trajectory, where we allow the spacecraft to use point thrusts to change its velocity as needed.