Gravitational Slingshot

Kai Levy and Keenan Zucker -- Olin College of Engineering Fall 2014

Abstract

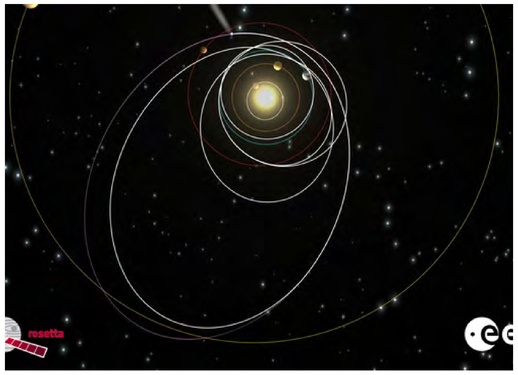
After the recent excitement over the Rosetta spacecraft landing on a comet over a 12 year long journey in space, we wanted to explore how Rosetta used gravity assist to slingshot out to a comet using the gravity of planets. To validate our model, we showed energy conservation, as the total energy in the system stayed constant. We also used a stationary planet and compared to data from Rosetta's first swing-by of Earth as referenced from Earth. Our results show the output velocities of the spacecraft with differing initial velocities of the spacecraft and planet.

I. Introduction: What Is A Gravity Assist, and Why Is It Used?

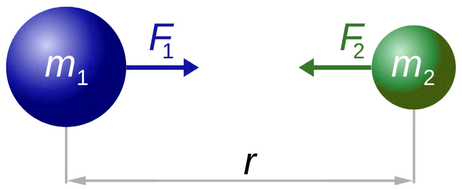
- Technique used to change the direction or velocity of a spacecraft by using the gravity of a celestial body
- Can be used to accelerate the spacecraft, go further with less fuel

Limitations:

- Treat both spacecraft and planet as point particles
- Planet's motion is linear
- No boosters are used during the simulation, gravity is only force



II. Physical System: Universal Law of Gravitation

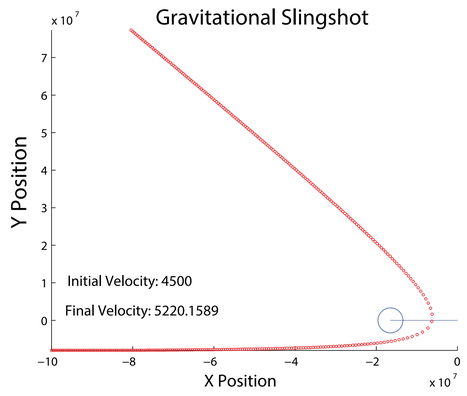


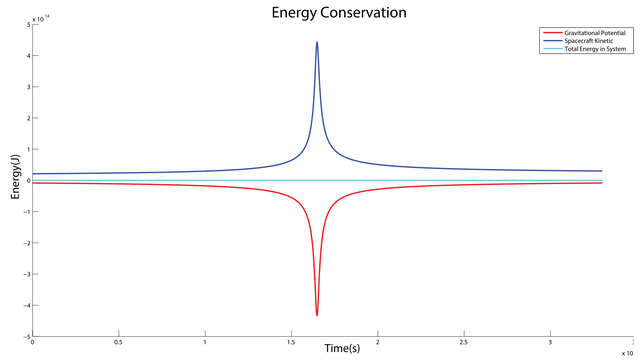
$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

- Universal Law of Gravitation between two bodies
- Force on planet is basically negligible
- Both planet and spacecraft given initial velocities

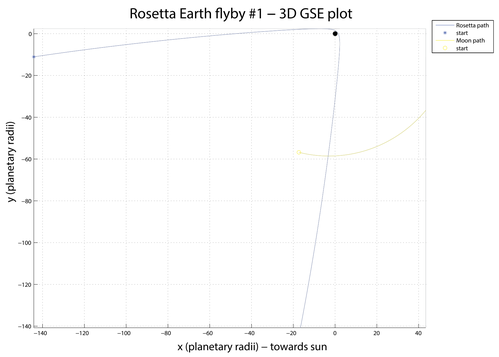
III. Our Model and Validation : Energy Conservation and NASA Data

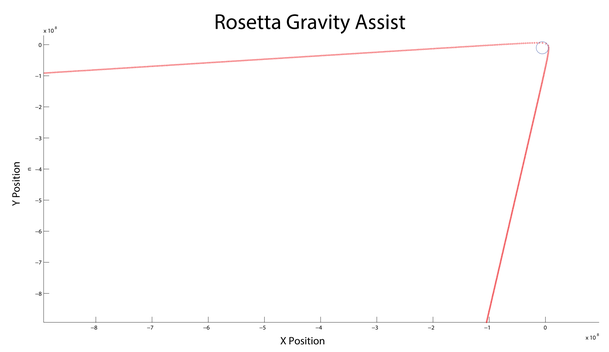
- Investigated conservation of energy
- Gravitational potential energy and spacecraft kinetic energy essentially equal and opposite
- MATLAB not precise enough to detect change in planet kinetic energy





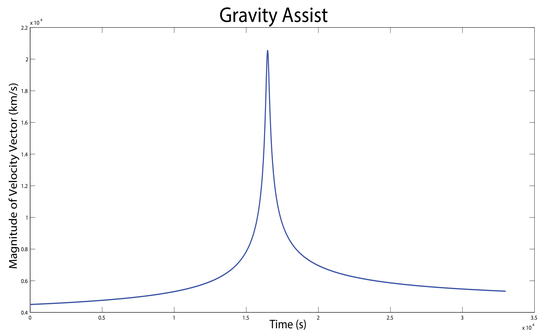
- Examined real world data from Rosetta Space Probe
- Used Earth as frame of reference (Earth is stationary)
- We set up similar scenario and achieved matching behavior



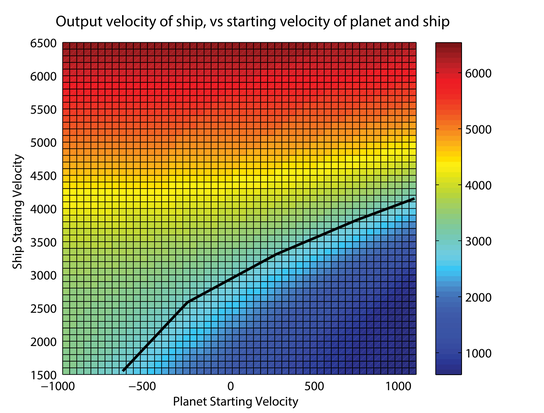


IV. Results: Examining Output Velocity of Spacecraft

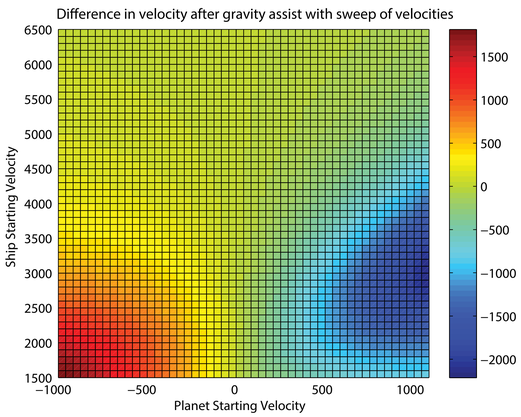
- Velocity of spacecraft is higher after encounter with planet



- Output velocity of spacecraft when swept through starting velocities of planet and spacecraft
- Escape velocity of spacecraft is about 2600 m/s



- Difference in velocity, that is:
  Output Velocity – Starting Velocity of spacecraft



V. Future Work: Where Can Gravity Assist Take Us Next?

For future iterations, we would like to:

- Have planet move in elliptical orbit around sun
- Investigate MATLAB error in scale
- Add more planets to model