For most spacecraft, flights follow fairly direct paths from starting points to destinations. It’s the quickest way to go, but the amount and cost of fuel needed often limits theineraries. For example, the Apollo lunar lander needed about 50% of its mass in fuel.

To make missions more efficient and affordable, scientists are studying “space tubes.” These complicated pathways are formed from the interaction of gravity fields and the resulting curvature of space. Simply stated, when forces from different celestial bodies interact, they produce areas where their gravitational fields cancel or greatly minimize each other’s force, creating energy-efficient pathways. Though fluid and dynamic, they are predictable enough to plan missions. Dubbed the Interplanetary Transport Network, this intricate web of pathways can lead spacecraft to and from destinations. Transfer points between connecting tubes even allow objects to change routes. The Genesis Discovery Mission traveled about 20 million miles during three years using only 3% of its mass for fuel.

**HOW THE GENESIS MISSION WORKED**

Genesis traveled toward the sun, which is four times farther than the Earth’s orbit before the Earth passed through.

- Launched in 2001, Genesis traveled 500,000 miles toward the sun, which is four times farther than the Earth’s orbit before the Earth passed through.
- It ended up at an equilibrium point for two and a half years, collecting solar particles.
- Genesis took a 3 million mile detour past Earth to keep past another equilibrium point before it headed back home in 2004.

**LAGRANGE POINTS**

Lagrange points are positions of balance between two or more gravitational fields in space. In simple terms, for every pair of massive objects, such as the Earth and the moon or the sun and a planet, there are five Lagrange points. Known as L1, L2, L3, L4, and L5, these points hold when gravitational balance occurs. Small objects utilizing these areas of balance are just the right speed and angle can orbit these points.

**THE EARTH’S GRAVITATIONAL MAP**

- Looking only at the central funnel in the nested image, we can see the funnel represents the Earth’s gravity, and children represent spacecraft.
- Mariner: Similar orbit: No more angular velocity, or speed of rotation, to keep their distance from the sun constant. Large orbit needed to support surf and set of pulling down on gravity.
- Downward curve of the surface: From the Earth’s gravity, the sun, to the moon, the deeper the curve, the greater the gravitational force.

**LOW-ENERGY TUBES**

In space, there are many low-energy paths for spacecraft to follow, and many paths orbit around the Earth. Lagrange points are not on the plane of the Earth’s orbit, but each point is on the funnel model. It’s known that a number of similar paths make up a funnel-like structure. Upon an initial injection and position, an object placed inside or around these paths follows various trajectories.

- Trajectory outside the tube: The spacecraft will fly back to the sun.
- Trajectory inside the tube: The spacecraft would pass the Lagrange point and head toward the opposite solar system.
- Trajectory that orbits the Lagrange point

**ORBITING LAGRANGE POINTS**

In this example, the smaller funnel is in the right represents the moon.

- A marble-circling the L2 Lagrange point, orbiting the point and the moon, with a speed a little faster than the Earth’s orbit (inner and outer), as it does, is approaching and flying around. The marble shadow the Earth and the moon, the more the marble moved down.
- As L2 catches up with the marble, the marble reaches around it and makes the “falling” surface of the funnel, and then moves around. As a result, the marble has made three circles around L2.

**TUBE TRANSFER**

Because the space is orbiting around the sun, the Earth’s Lagrange points and tubes are continuously moving. When two tubes intersect, a spacecraft can transfer from one tube to another.

**Sources:** Shane Ross, assistant professor of engineering science and mechanics at Virginia Polytechnic Institute and State University, S. V. Sagan, Lecturer, Space Science, Calvin College.