PHYSICS

Hitchhiking in space

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 itineraries. 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 5% of its mass for fuel.

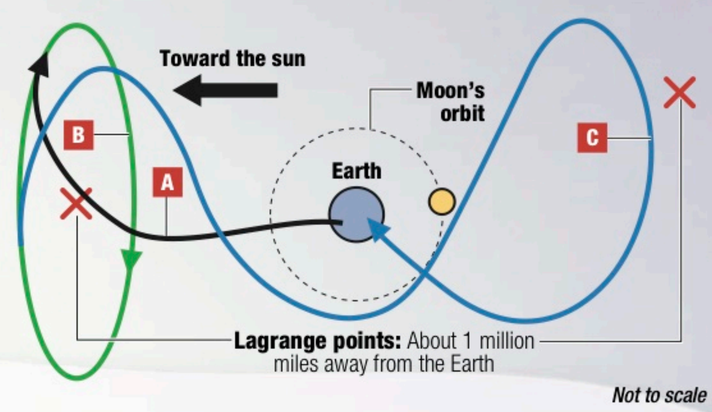
HOW THE GENESIS MISSION WORKED

Mission planners designed a low-energy trajectory, based on their calculations on how the spacecraft would act under the influence of gravitation from the sun and the Earth. There are points in space where those two forces cancel each other, creating areas of equilibrium called Lagrange points. The spacecraft was programmed to orbit around those points.

A Launched in 2001, Genesis traveled 900,000 miles toward the sun, which is four times greater than the moon's orbit around the Earth.

B It orbited around an equilibrium point for two and a half years, collecting solar particles.

C Genesis took a 3 million mile detour past Earth to loop past another equilibrium point before it headed back home in 2004.



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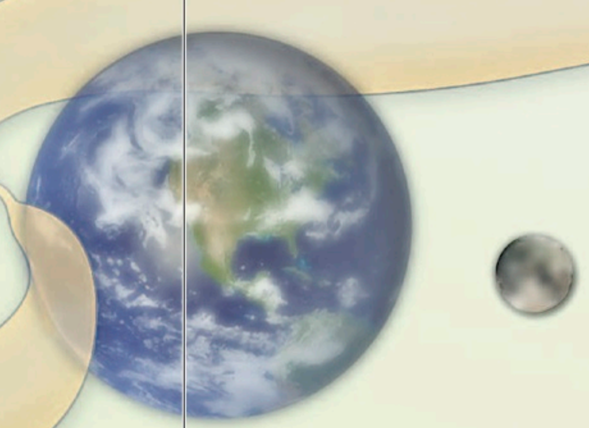


LAGRANGE POINTS

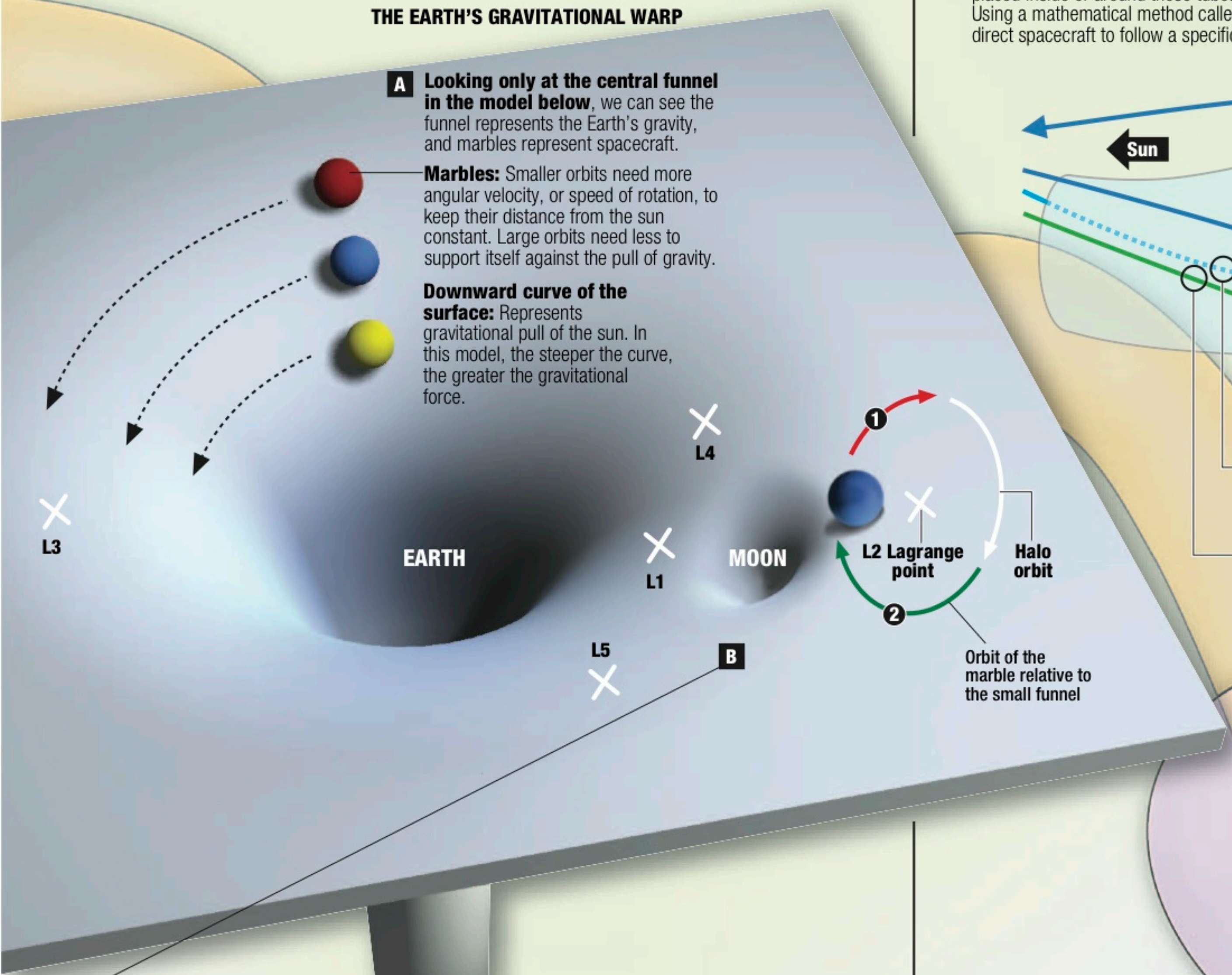
Lagrange points are positions of balance between two or more gravitational fields in space. In simple terms, for every pair of massive objects, such as the Earth and the moon or the sun and a planet, there are five Lagrange points, known as L1-L5 (shown below) where gravitational balance occurs. Small objects entering these areas of balance at just the right speed and angle can orbit these points.

THE EARTH'S GRAVITATIONAL WARP

A **Looking only at the central funnel in the model below**, we can see the funnel represents the Earth's gravity, and marbles represent spacecraft.

Marbles: Smaller orbits need more angular velocity, or speed of rotation, to keep their distance from the sun constant. Large orbits need less to support itself against the pull of gravity.

Downward curve of the surface: Represents gravitational pull of the sun. In this model, the steeper the curve, the greater the gravitational force.

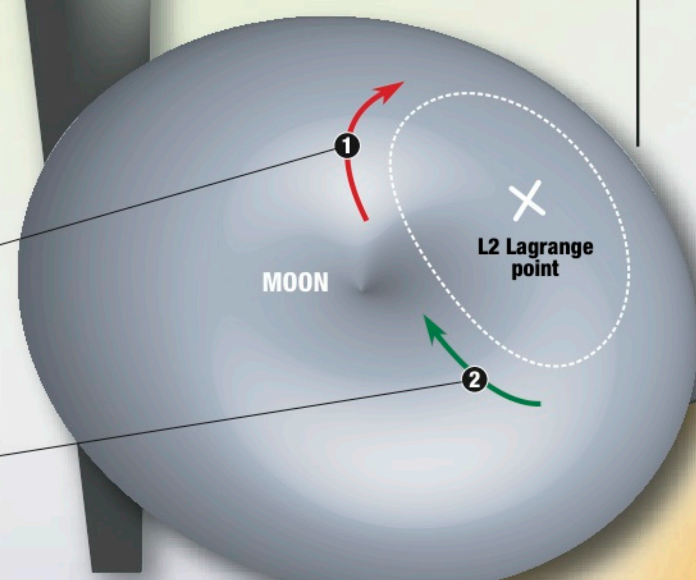


B **ORBITING LAGRANGE POINTS**

In this example, the smaller funnel to the right represents the moon.

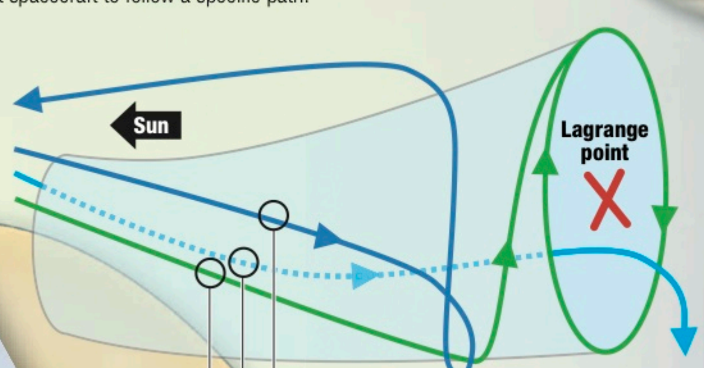
The description below and the **detail at right** further show how an object perpetuates its orbit around an L2 Lagrange point.

1. A marble circling the L2 Lagrange point between the point and the moon, with a speed a little faster than the moon's orbit will move ahead and outward. As it does, it's approaching a "rising" surface. The more steeply the surface rises, the more the marble slows down.
2. As L2 catches up with the marble, the marble momentum brings it around until it meets the "falling" surface of the funnel, and it moves inward. As a result, the marble has made a circle around L2.



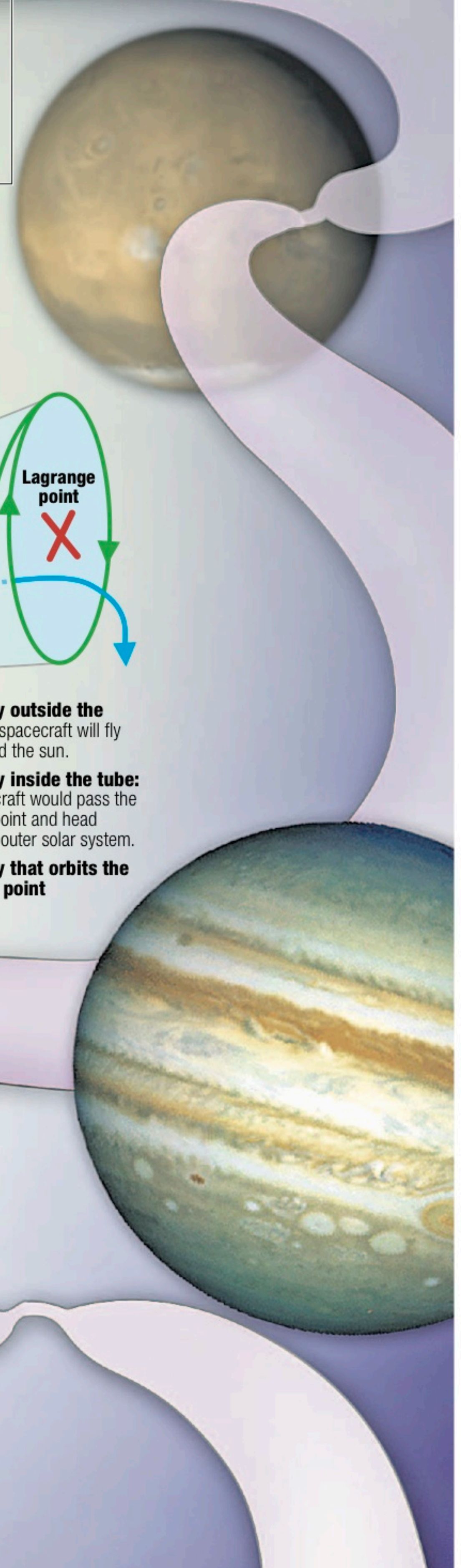
LOW-ENERGY TUBES

In space, there are many low-energy paths for spacecraft to follow, and many halo orbits around the Lagrange points are not on the plane of the Earth's orbit like they are in the funnel model. It is known that a number of similar paths make up a tube-like structure. Depending on initial velocities and positioning, an object placed inside or around those tubes follows various trajectories. Using a mathematical method called chaos theory, scientists can direct spacecraft to follow a specific path.



TUBE TRANSFER

Because the planets are orbiting around the sun, their Lagrange points and tubes are continuously moving. When two tubes intersect, 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; NASA

RIKA KANAOKA/rkanaoka@journalsentinel.com