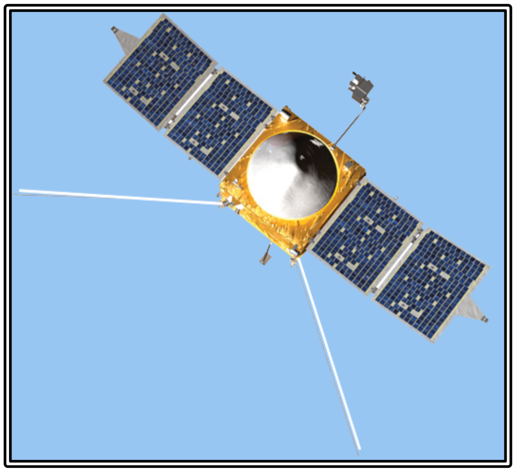
MAVEN = Mars Atmosphere and Volatile Evolution Mission

MAVEN spacecraft has just entered orbit around Mars. How fast does it need to travel?



On November 18, 2013 the MAVEN spacecraft was launched from Cape Canaveral for a mission to travel to Mars, establish an orbit around Mars, sample and test the atmosphere of that planet, and to try to understand what forces caused the demise of Mars' atmosphere. Last week, on September 22, 2014, the spacecraft MAVEN reached Mars and established an orbit around the planet.

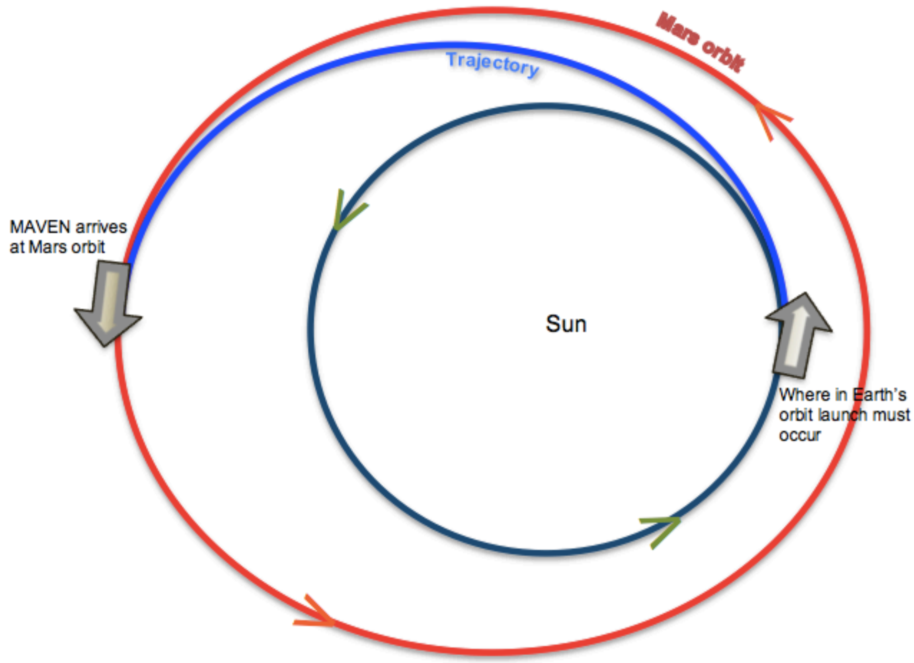
How did NASA scientists figure out when to launch this rocket and in what direction and at what speed they needed to accomplish a Mar's orbit? Oooooo. Orbital Mechanics!

1. First of all, can you explain why spacecraft can stay in orbit?

[If you have no clue or want to learn more, read this link. http://www2.jpl.nasa.gov/basics/bsf3-4.php and then go back and answer question #1.]

To stay in orbit around the Earth a rocket must be launched and reach a certain speed. That velocity has to be so great that the rocket will still be traveling forward while at the same time falling towards Earth (gravity) at just the right velocity = orbit. The International Space Station (ISS) is traveling at 17,100 mph (27,600 km/hr) in its orbit around the Earth.

Somehow the scientists at NASA knew to launch the rocket that carried MAVEN at the correct speed to get it to leave Earth orbit and travel on a trajectory away from the Sun far enough to match Mars' orbit.



The image above demonstrates the rocket (My rocket image is the fat arrow on the right.) at take off on November 18th last year, and that same rocket (fat arrow on the left) reaching a Mars obit on September 22nd of this year.

To create a trajectory path for a rocket to leave Earth's orbit and move into Mars' orbit it would be smart to figure out the least amount of energy required to make the trip.

2. What might be the benefits of finding a way to use the least energy required to get a spacecraft to Mars?

Earth is orbiting the Sun once every 365.2564 days. We orbit the Sun at an average distance of 150 million kilometers (93,000,000 miles). This number is actually an average, since we follow an elliptical path. At its closest point, the Earth gets to 147 million km (91 million miles), and at its most distant point, it's 152 million km (94.5 million miles). The mean radius of the sun is 432,450 miles (696,000 kilometers)

3. Draw a sketch of the Sun and our Earth. Mark the Sun's radius number and our average orbit height. This sketch doesn't have to be very precise or to scale. You will only use it to line up your measurements.

4. Using a circular circumference formula, calculate the number of miles in one orbit of the Earth around the Sun.

5. If Earth can complete it's orbit in 365.2564 days at what rate is the Earth moving in miles/hour.

The Earth is also rotating around its axis and our rocket will have the added force of that rotation. If our rocket launch site were on the Equator, I could figure out the distance that the Earth travels in one rotation.

6. If the Earth (with radius = about 3,959 miles (6,371 km) can rotate once in 24 hours, what is the velocity of the Earth's rotation on a rocket launched from the Equator?

But, in the United States, we launch rockets from Cape Canaveral (latitude 28.5^{o} North). The circumference of the Earth is surely smaller at the Cape than at the Equator. So the velocity that the spin of the Earth adds less to our rocket launch than if we launched at the Equator. So in 24 hours, Cape Canaveral will have traveled a smaller distance and the speed of the Earth (at Cape Canaveral) will be only about 915 mph (1,472 km/h).

7. What is the combined velocity of our rocket poised on the launch pad of Cape Canaveral from the Earth traveling around the Sun and also the Earth spinning on its axis?

Evidently the force required to leave Earth's atmosphere is its escape velocity = 11.2 km/s (approx. 40,320 km/h, or 25,000 mph). After leaving Earth's atmosphere our rocket will need to maintain a velocity that will bring it in line with Mars' orbit. So, let's calculate what velocity our orbiting spacecraft needs to maintain to reach Mars' orbit velocity.

Mars orbit is on average 141 million miles (225 million km) from the sun. The Sun has an approximate radius of 432,450 miles (696,000 kilometers). It takes Mars is 686.971 Earth days to circle the Sun.

8. What orbital velocity does Mars maintain?

9. Which planet, Earth or Mars has a greater orbital velocity?

10. Does your comparison of Earth's and Mars' calculated orbital velocities make sense as to where they are situated in orbit around the Sun? Please explain.

There is, of course, a lot more to these calculations than we have attempted to do here. We've just tried to point out that some of the motion required to get our MAVEN vehicle into orbit makes use of the Earth's orbit velocity and the Earth's axis velocity.

Calculating the proposed trajectory of our MAVEN space craft is another fascinating mathematical task dealing with the elliptical orbits of both the Earth and Mars and both of their periapsis (nearest to the Sun) point of their orbit and apoapsis (farthest from the Sun) point of their orbits. We will be covering those calculations in a future study of the Hohmann Transfer Orbits.

Math is everywhere!

Extension:

Below we've given you the mean distances from the Sun for a few of our Solar System's planets. Pick any other planet and use the data to help you determine the necessary velocity required to visit/orbit that planet.

Planet	*Mean distance from Sun*	*Time (in Earth months) for one rotation around the Sun*
Venus	108 million km / 67 million miles	7 Earth months
Jupiter	779 million km / 484 million miles	142 Earth months
Saturn	1.43 billion km / 889 million miles	354 Earth months

Source: http://www.foxnews.com/science/2014/09/22/nasa-says-maven-spacecraft-enters-orbit-around-mars/
http://en.wikipedia.org/wiki/Hohmann_transfer_orbit
http://www2.jpl.nasa.gov/basics/bsf4-1.php
http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970401c.html
http://www.aerospaceweb.org/question/spacecraft/q0080.shtml
http://www.universetoday.com/14841/how-long-does-it-take-to-get-to-mars/