# Combination of satellite missions help detect Earth candidates

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Artist's rendition of Kepler spacecraft. Image: NASA/Kepler mission/Wendy Stenzel

The possibility of discovering a planet that is small, cool, rocky, orbiting a sunlike star and able to host life — an Earth twin, in other words — has made the search for planets outside of our solar system, or exoplanets, one of the hottest research areas in physical science. This three-part series explores MIT researchers' roles in the quest to find an Earth twin and the effort to make sense of the 500 exoplanets that have been discovered since 1995.

In September, researchers announced the discovery of Gliese 581g, a rocky planet with a mass that is just three to four times that of Earth. If the discovery is confirmed with independent data, it could be the closest that planetary scientists have come to finding a planet outside the solar system that resembles our own. Although other planets with nearly the same mass as Earth have been discovered, Gliese 581g is the smallest planet that is also in the "Goldilocks zone," or at a distance from its host star to make the planet's temperature cool enough for liquid water to exist on its surface. Astronomers discovered Gliese 581g using two Earth-based telescopes to observe the movements of the planet's host star that are caused by gravitational tugs from orbiting bodies. Based on these slight tugs, the researchers were able to estimate the planet's mass.

In the future, planetary scientists will increasingly rely on telescopes based in space to locate even tinier Earth candidates. That's because observations made by a space-based telescope are unaffected by transparency variations, or the changes in the amount of starlight that make it through Earth's atmosphere. Having a clearer image helps astronomers detect even the slightest change in starlight that occurs when a faraway, small planet passes in front of its host star — a process known as transiting — and causes a drop in the star's brightness. Although astronomers can detect planets and glean details about a planet's atmosphere and mass during a transit, the majority of planets, including Gliese 581g, are located at an angle that makes it impossible to view their transits from Earth.

It's highly likely that a planet that is smaller and even more Earthlike than Gliese 581g will be discovered by Kepler, a NASA satellite that is observing 150,000 stars with the goal of detecting Earth-sized planets located in or near the Goldilocks zone. But although Kepler has delivered promising data to date — data that several MIT researchers are analyzing — the satellite is looking at only a narrow field of the sky. MIT faculty, researchers and students are working on several satellites to complement Kepler's efforts and scan much more of the sky.

## Learning from curves

Launched in 2009, Kepler is in its own orbit around the sun, meaning it can observe continuously without Earth getting in its way. Kepler's greatest advantage is its ability to detect and measure tiny changes in starlight. Every six seconds, the telescope records the light emanating from the 150,000 stars it is observing, and this provides data points that are used to create a light curve, or graph, of a star's change in brightness over time. Any sudden dip in brightness could be caused by a transiting exoplanet, and researchers analyze the patterns of these curves to learn details about a planet, such as its size.

To date, the Kepler team has found about 750 stars that may be hosting exoplanets. Half of these may be real planets, while the other half are likely "false positives," or something other than a planet that is causing the light dip, such as another star.

Ruling out these false positives from Kepler's list of planet candidates is crucial, and as a participating scientist for the mission, Sara Seager, the Ellen Swallow Richards Professor of Planetary Science in the Department of Earth, Atmospheric and Planetary Sciences and professor of physics, and several of her students have studied the Kepler data to help identify anything that may be masquerading as an Earth. They are now analyzing Kepler's light curves to learn new details about the uninhabitable massive planets that Kepler detects because characterizing these "hot Jupiters" and Neptune-sized planets (planets less than four times the diameter of Earth) is considered great practice for eventually studying small planets.

## Observing many more nearby stars

But Kepler's major drawback is that because the telescope is only focused on a narrow field of the sky, it is observing faraway, faint stars and may be missing closer stars — the kind that will enable the best follow-up observations from the ground.

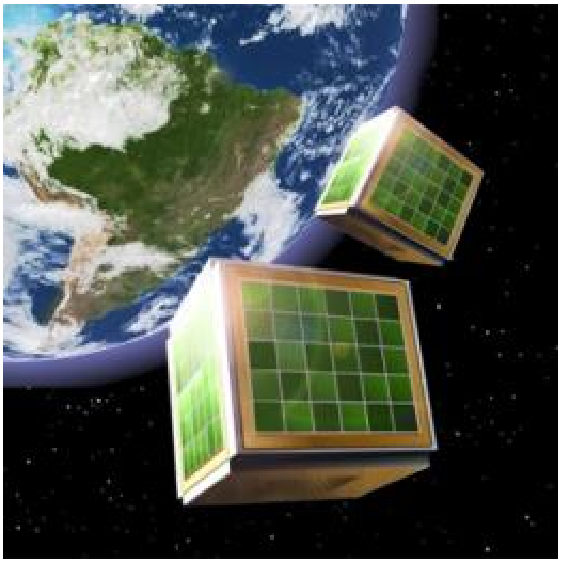
A team of MIT researchers led by Kavli Senior Research Scientist George Ricker is currently designing a satellite that would use six wide-angled, high-precision cameras to observe a wider region of the sky — one 400 times larger than revealed by Kepler's scope. By surveying some 2.5 million stars, the Transiting Exoplanet Survey Satellite (TESS) could potentially detect between 1,600 and 2,700 planets within two years, including between 100 and 300 small planets, several of which could be Earth candidates.

TESS has been in development since 2007, when NASA selected Ricker's team to develop a mission as part of its Small Explorer satellite program to provide funding for missions using small- to midsized spacecraft. Although NASA elected not to proceed with TESS in 2009, the agency is accepting new proposals later this year and has increased the budget from $105 million to $200 million.

This fall, the TESS team has been finalizing a new proposal that reflects the budget increase. "The higher cost cap means we can use bigger cameras and bigger lenses to get more data," says Seager, who is the deputy mission scientist for TESS. The group is also refining its estimates of the number and type of exoplanets that TESS could find.

## Utilizing CubeSats

Another satellite effort currently underway at MIT is ExoplanetSat, a research project inspired by the increasing use of cube satellites, or "CubeSats," by research universities as a way to conduct observations in space. The Rubik's Cube-sized satellites are popular because they can piggyback on a variety of launch vehicles for a fraction of what it costs to put larger satellites in space. There are about a dozen CubeSats currently orbiting Earth.



Artist's rendition of CubeSats in orbit. Image: Christine Daniloff

Last spring, Seager and David Miller of MIT's Department of Aeronautics and Astronautics began a three-semester class to explore using CubeSats as a way to search for exoplanets transiting very bright stars. Seager's idea is that the odds of detecting a transiting planet orbiting a bright star increase significantly if there is just one telescope dedicated to observing a star that neither Kepler nor TESS can observe.

The concept eventually developed into ExoplanetSat, a research program that is designed to launch a fleet of about one dozen "triple CubeSats" (three cubes stuck together), and about another two dozen six-unit CubeSats into low-Earth orbit. Each satellite would have its own computer, processor and tiny camera and would be pointed at an individual star. Although the program doesn't have funding yet, MIT students will try to build two prototypes within the next two years and then hopefully secure funding for a formal mission to send dozens of the tiny cubes into space.

But detecting Earthlike planets may only be half the battle, according to Joshua Winn, an assistant professor in MIT's Department of Physics, who says "it remains to be seen" if current telescope technology will enable researchers to study Earthlike planets with enough detail to confirm whether they can host life. For now, researchers await the 2014 launch of the James Webb Space Telescope, an instrument whose size will make it easier to obtain higher-quality data of exoplanet atmospheres.

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