landscape. "Mount Sutro is part of a larger story," says Richard Hobbs, an ecologist at the University of Western Australia in Crawley. "What some people see as a weed-filled blot on the landscape, others see as something extremely valuable, worthy of managing in its own right. People are increasingly moving away from the belief that a native ecosystem is always best."

That idea grates with many restoration ecologists, says Hobbs. Yet studies increasingly suggest that altered ecosystems need not be bad for biodiversity or ecosystem function. Non-native pine trees provide habitat for threatened cockatoos in Western Australia, for example. And in Scotland, old industrial waste heaps — known as shale bings — are now home to rare and protected plants and animals.

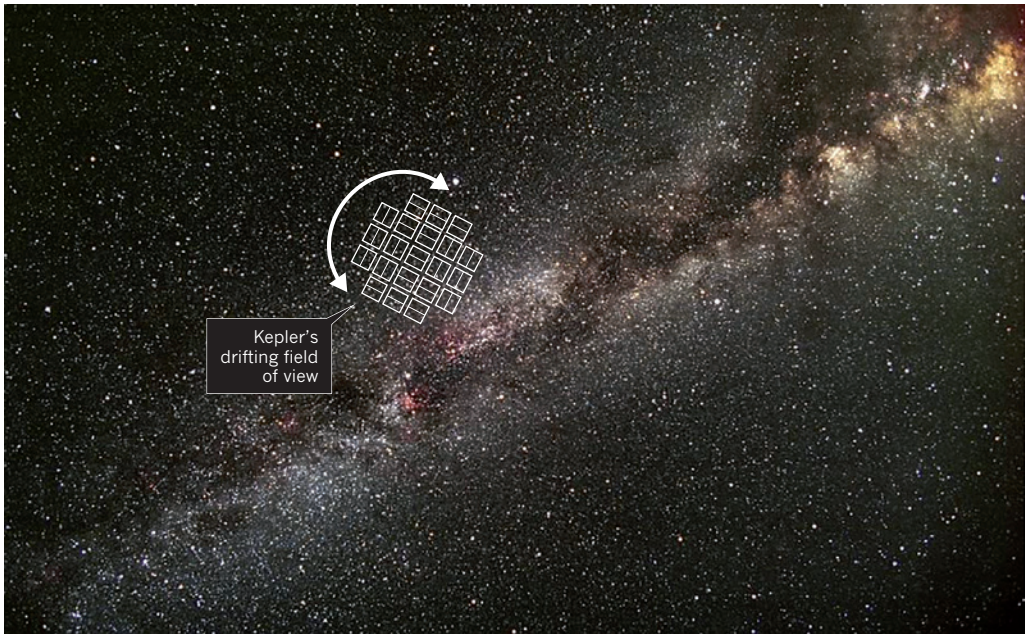
In the early 1990s, Patricia Kennedy of Oregon State University in Corvallis helped to develop management guidelines for northern goshawks. She found that the raptors do not strictly need old-growth forests; land used for timber harvesting can work, too. She says that, at the time, accepting the idea felt like a move to the "dark side". "The whole culture in wildlife biology and conservation circles has been that you can't approximate Mother Nature," she says.

But those ideas are changing today, with altered ecosystems such as Mount Sutro's providing a case in point. In the late 1880s, Adolph Sutro, a mayor of San Francisco, planted the tree-less hill with imported blue gum eucalyptus, as well as Monterey pine and cypress. The eucalyptus quickly took over, and today the forest feels like a primeval jungle — a tangle of almost exclusively introduced species. Joe Mascaro, an ecologist at Stanford University in California who has been publicly critical of UCSF's management plans, says that Mount Sutro has long since given way to a completely new ecosystem. "Restoring it to an original state would be borderline impossible, so why stop the succession that is already in place?"

Resistance to such a heretical idea runs deep among ecologists, but growing numbers are embracing altered ecosystems in the name of pragmatism. "You can reach more win–win situations if you don't insist on purity," says Katharine Suding, an ecologist at the University of California, Berkeley, who specializes in restoring human-affected areas. "It doesn't have to be a natural versus non-natural dichotomy."

For UCSF, finding a middle ground between native and non-native conservation ideals is proving difficult. But the university should get used to it, says Hobbs.

"There is a lot of tension about how to deal with situations like these right now," he says. "With so much non-native habitat, the old views — that everything must be natural — no longer apply." ■




Kepler's field of view is now drifting because of a failure of two of its four reaction wheels.

CARTER ROBERTS/NASA

ASTRONOMY

# NASA ponders Kepler's future

*Spacecraft could continue to hunt for planets — or take on alternative tasks, such as asteroid spotting.*

BY RON COWEN

NASA just can't quit Kepler.

On 15 August, the agency announced that it would stop trying to revive the failed reaction wheels that gave the planet-hunting telescope its precise pointing ability. That essentially brings an end to the main goal of the 4-year-old mission, which has found 3,548 candidate planets by looking for tiny dips in starlight that indicate a planet's passage, or transit, across that star.

But the agency left room for hope: two weeks earlier, it had asked astronomers to submit ideas by 3 September on how the hobbled spacecraft might still perform good science. *Nature* has learned about some of the options in the running, out of the dozens of proposals expected.

Ideas range from a survey of potentially hazardous near-Earth objects to a study of Jupiter-sized exoplanets in large orbits. Kepler scientists will sort through the proposals and decide by 1 November which ones, if any, to recommend to NASA headquarters for further review.

To secure funding from the space agency, the Kepler team will have to show that the studies could not be done by other telescopes. This will be no easy task — especially given that engineers are not sure how well Kepler can perform with just two of its four spinning reaction wheels, which act as stabilizing gyroscopes.

"We're in a real quandary," says Kepler principal investigator Bill Borucki at NASA's Ames Research Center in Moffett Field, California. "We just don't know what Kepler can do."

With three working wheels (a fourth was a spare), Kepler was able to exactly counterbalance the persistent push of sunlight, locking on to targets with such precision that light from a particular star always fell on the same tiny fraction of an individual pixel. But the wheels have a history of poor performance, and in July 2012 one failed — followed by another in May (see go.nature.com/4w1ufr). Although the craft's thrusters can still act as a crude version of a third wheel,

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go.nature.com/8pmjuf

they cannot replicate the pointing accuracy that three wheels provided, and the telescope's focus will drift. Over time, starlight will start to fall on different pixels with slightly different sensitivities. "Every single day, it's as if you're going to use a different detector, a different telescope," says Kepler scientist William Welsh of San Diego State University in California.

Kepler's drift could be minimized by keeping it pointed in the same plane in which the craft orbits the Sun. But that presents a complication. Some of the best science is expected to come from follow-up observations of the field of about 150,000 stars that Kepler has been focused on, and that star field does not lie in the plane.

In one proposal, offered up by Welsh and his colleagues, the craft would continue to stare at this original star field to search for Jupiter-sized planets. Such bodies are sufficiently large that when they pass in front of their parent star they produce a dip in light that can be detected by Kepler even in its compromised state.

Welsh's group would target Jupiters for which Kepler has recorded only a few transits — those that take more than a year to orbit their star. It usually takes a minimum of three transits to confirm the existence of a planet. Catching the third transit could make the difference between a possible and a definitive discovery.

The craft is too shaky to discover an Earth analogue from scratch, but Welsh suggests that it might also be possible for Kepler to add statistical significance to Earth-sized candidates for which transits have already been captured. And David Hogg, an astronomer at New York University, believes that, over the course of many months, Kepler's drift could be used to map out the different light responses of the pixels. That calibration, if detailed enough, could be enough for Kepler to resume its hunt for Earth analogues, says Hogg.

Daniel Fabrycky, an astronomer at the University of Chicago in Illinois, has an alternative follow-up study in mind. He and his colleagues have proposed looking at planetary systems in which densely packed planets are affected by one another's gravitational pulls — creating periodic cycles in which the timing of transits are first advanced and then delayed. The light dip during a transit reveals only the size of the eclipsing planet, but knowledge of transit-time variation yields the planet's mass, which is crucial for working out the density and composition of the bodies. Like Welsh, Fabrycky wants Kepler to zero in on planetary systems with long orbits, for which the full cycle of these transit-timing variations has not yet been seen.

But Andrew Gould, an astronomer at Ohio State University in Columbus, says that he is sceptical about using the craft to simply follow up on its original tasks when its pointing precision has been degraded by a factor of as much as 1,000. "People really have to break out and come up with new ideas," he says.

Perhaps taking such advice to heart, Fabrycky's team has a second proposal: putting Kepler to work not as a planet hunter, but as a sentinel for near-Earth objects, including asteroids several hundred metres in diameter that might be on a collision course with Earth. A survey of space rocks would take advantage of Kepler's large field of view. And at least part of the study could be completed with Kepler looking for targets within its orbital plane, so as to optimize its pointing.

***"We're in a real quandary. We just don't know what Kepler can do."***

Gould has proposed another scheme, in which Kepler would survey stars towards the Milky Way's central bulge for signs of planets, using a technique known as microlensing.

Microlensing relies on a prediction of Einstein's theory of general relativity: the gravity of any massive object bends light. Like a magnifying lens, a foreground star bends and brightens light from stars behind it. A single foreground star, or microlens, produces a characteristic brightening curve, but if that lensing star has a planet, the curve will have an additional wiggle.

Researchers have already used microlensing to reveal some 40 planets towards the centre of the Galaxy, but the observations typically do not reveal masses. By observing microlens planets using Kepler and ground-based telescopes at the same time, differences in transit duration and brightness emerge that can yield the planets' mass. However, the survey could be performed for only about five weeks of the year because of limited chances to view the Galactic Centre without interference from the Sun.

## COMPETING CHOICES

If any of the proposals recommended by the Kepler team seems worthwhile to NASA, they will be examined early next year by a review panel of external scientists. At that stage, a repurposed Kepler would face its biggest hurdle — a competition for the limited pot of funds against nine other astrophysics missions, including the Hubble Space Telescope and the Fermi Gamma-ray Space Telescope. On receiving recommendations from the review panel, NASA will make its final funding decisions next June.

Not everyone is rooting for Kepler. Doug Finkbeiner, an astronomer at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, wants NASA to support missions that are still healthy. He has used Fermi to discover two galaxy-sized bubbles of ionized gas blowing from the centre of the Milky Way, and is counting on continued funding for the γ-ray telescope. "My very biased and self-interested perspective is that I hope we let Kepler die," he says. ■