SOURCE: NASA/JPL

Slated to launch in July 2020, the US$2.4-billion rover will be the first from any nation to collect Mars rocks and stash them for a future mission that would bring them back to Earth. The geology of the landing site has to be intriguing enough — and the potential for scientific discoveries there great enough — to make the mission worth the investment.

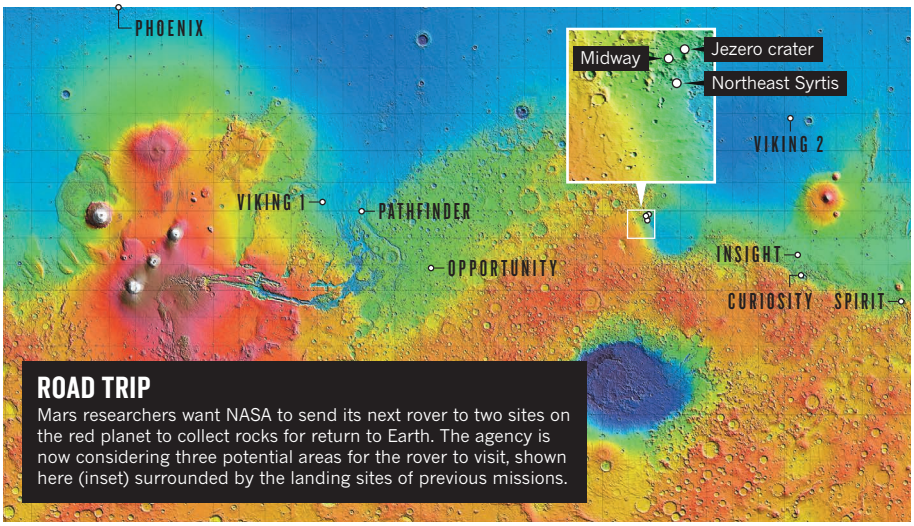
NASA has not planned how it would retrieve the rocks collected by the 2020 rover. But the agency gathered Mars experts in Glendale, California, from 16 to 18 October to hash out the merits of four finalists for the landing site.

Jezero, Northeast Syrtis and Midway came remarkably close to one another in votes by 169 scientists at the workshop. The researchers ranked the sites using several criteria, such as the potential of samples collected at each site to answer crucial scientific questions about Mars.

The idea of visiting Jezero and then Midway — or the other way around — emerged in the past year as mission scientists debated how to get the most out of the rover's journey. "It is ambitious as heck," says John Mustard, a planetary scientist at Brown University in Providence, Rhode Island. Midway's ancient rocks are similar to those at Northeast Syrtis and near the rivers-and-lake system at Jezero.

Sending a rover to Jezero and Midway would mean gambling that the vehicle would last long enough to reach both sites. Its primary mission is 1.25 Mars years (2.35 Earth years); during that time, it is expected to travel roughly 15 kilometres. That would get the rover around most of the Jezero site, if it started there, and possibly even to the crater's rim. But it would then face a trek across dunes to Midway.

NASA's Curiosity rover, the agency's biggest and most powerful so far, has travelled more than 19 kilometres since it landed on Mars in 2012. The engineers developing the 2020 rover expect it to be able to travel faster than Curiosity, in part because of new technology that improves its ability to navigate on its own.



ROAD TRIP
Mars researchers want NASA to send its next rover to two sites on the red planet to collect rocks for return to Earth. The agency is now considering three potential areas for the rover to visit, shown here (inset) surrounded by the landing sites of previous missions.

One major question is how many rock samples the rover will collect, and from where. The 2020 rover is equipped with 42 sample tubes, 5 of which will be reserved as spares. That leaves 37 tubes to be filled with the most precious extraterrestrial rocks ever collected.

"Sooner or later, somebody is going to have to decide whether these samples are worth bringing back," project scientist Ken Farley, of JPL, told the meeting. "I don't want to fail because we have not been ambitious enough."

At the workshop, project scientists laid out options for what might fill those 37 tubes. These include chunks of lake deposits from Jezero, fragments of enormous blocks of rock at the crater rim there and samples of the ancient rocks at Midway. The nuclear-powered rover has several possible paths by which to navigate the 28 kilometres of dune fields between Jezero and Midway. Driving that distance would take an estimated 401 Martian days, says deputy project scientist Katie Stack Morgan at JPL.

Still unknown is where the rover might stash its precious samples. One possibility is that it could collect two similar sets of samples at Jezero, depositing one there and carrying the other on to Midway, Farley told the meeting. That would leave open the possibility of retrieving the samples at Jezero if something went wrong with the rover on its way to Midway. Other researchers back a Midway-to-Jezero journey, to get the ancient rocks first.

NASA has not yet decided whether or how it might fetch the samples, although it has tentative plans for a mission in the late 2020s. "We're actually serious about bringing these samples back," Zurbuchen told the meeting. "That's what we're here for." ■

ETHICS

A moral map for AI cars

Survey reveals global variations in ethical rules of the road for autonomous vehicles.

BY AMY MAXMEN

When a driver slams on the brakes to avoid hitting a pedestrian crossing the road illegally, she is making a moral decision that shifts risk from the pedestrian to the people in the car. Self-driving cars might soon have to make such ethical judgements on their own — but settling on a universal moral code for the vehicles could be a thorny task, suggests a survey of 2.3 million people around the world.

The largest-ever survey of machine ethics[1], published this week in *Nature*, finds that many of the moral principles that guide a driver's decisions vary by country. For example, in a scenario in which some combination of pedestrians and passengers will die in a collision, people from relatively prosperous countries with strong institutions, such as law enforcement, were less likely to spare a pedestrian who stepped into traffic illegally.

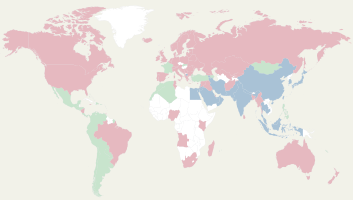
"People who think about machine ethics make it sound like you can come up with a perfect set of rules for robots, and what we show here with data is that there are no universal rules," says study co-author Iyad Rahwan, a computer scientist at the Massachusetts Institute of Technology in Cambridge.

The survey, called the Moral Machine, laid out 13 scenarios in which someone's death was inevitable. Respondents were asked to choose who to spare in situations that involved a mix of variables: young or old, rich or poor, more people or fewer.

People rarely encounter such stark moral dilemmas, and some critics ask whether the scenarios posed in the quiz are relevant to the ethical questions surrounding driverless cars. But the study's authors say that the scenarios stand in for the subtle moral decisions that drivers make every day. The findings reveal ▶

MORAL COMPASS

A survey of 2.3 million people worldwide reveals variations in the moral principles that guide drivers' decisions. Respondents were presented with 13 scenarios, in which a collision that killed some combination of passengers and pedestrians was unavoidable, and asked to decide who they would spare. Scientists used these data to group countries and territories into three groups based on their moral attitudes.



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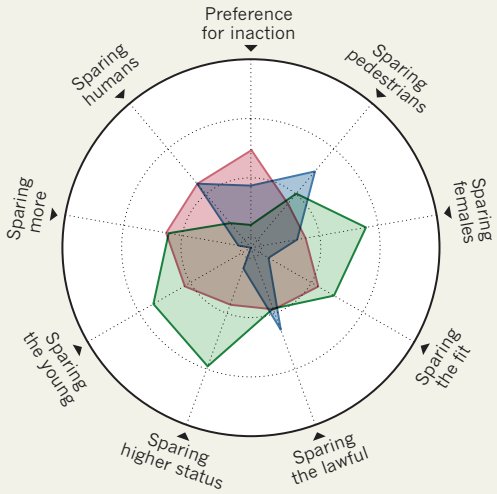

ADAPTED FROM REF.1

cultural nuances that governments and makers of self-driving cars must take into account if they want the vehicles to gain public acceptance, they say.

"It's a remarkable paper," says Nicholas Christakis, a social scientist at Yale University in New Haven, Connecticut. The debate about whether ethics are universal or vary between cultures is an old one, he says, and now the "twenty-first-century problem" of how to program self-driving cars has reinvigorated it.

Some of the world's biggest tech companies — including Google, Uber and Tesla — and carmakers now have self-driving-car programmes. Many of these companies argue that the vehicles could improve road safety and ease traffic, but social scientists say the cars raise complex ethical issues.

In 2016, Rahwan's team stumbled on a paradox about self-driving cars[2]: in surveys, people say they want an autonomous vehicle to protect pedestrians, even if it means sacrificing its passengers — but also that they wouldn't buy self-driving vehicles programmed to act in this way.

Curious to see whether the prospect of self-driving cars might raise other ethical conundrums, Rahwan gathered psychologists, anthropologists and economists to create the online Moral Machine quiz. Within 18 months, it had recorded 40 million decisions made by people from 233 countries and territories.

No matter their age, gender or country of residence, most people spared humans over pets, and groups of people over individuals. These responses are in line with rules proposed in what might be the only governmental guidance on self-driving cars: a 2017 report by the German Ethics Commission on Automated and Connected Driving.

But agreement ends there. When the authors analysed answers from people in the 130 countries with at least 100 respondents, they found that the nations could be divided into three groups (see 'Moral compass'). One contains North America and several European and other nations where Christianity has historically been the dominant religion; another includes countries such as Japan, Indonesia and Pakistan, which have strong Confucian or Islamic traditions. A third group consists of Central and South America, as well as France and former French colonies. The first group showed a stronger preference for sacrificing older lives to save younger ones than did the second group, for example.

Test versions of autonomous cars are cruising through several US cities. By 2021, at least five manufacturers hope to have self-driving cars and trucks in wide use.

Bryant Walker Smith, a law professor at the University of South Carolina in Columbia, says that the study is unrealistic because there are few instances in real life in which a vehicle would face a choice between striking two different types of person. "I might as well worry about how automated cars will deal with asteroid strikes," he says.

But Barbara Wege, who heads a group focused on autonomous-vehicle ethics at the car manufacturer Audi in Ingolstadt, Germany, says that such studies are valuable. Wege argues that self-driving cars would cause fewer accidents, proportionally, than human drivers do each year — but that events involving robots might receive more attention.

Surveys such as the Moral Machine can help to prompt public discussions about inevitable accidents, and so might foster trust. "We need to come up with a social consensus," she says, "about which risks we are willing to take." ■

1. Awad, E. *et al. Nature* https://doi.org/10.1038/s41586-018-0637-6 (2018).
2. Bonnefon, J. *et al. Science* **352**, 1573–1576 (2016).

DISASTER MANAGEMENT

Data hint at quake forecasts

Italian–earthquake analysis suggests possibility of predicting aftershocks of some quakes.

BY KATE RAVILIOUS

In 2016, three deadly earthquakes struck Italy between August and late October. Now, an analysis suggests the mechanism that might make such quakes unfold over a period of days or weeks, rather than as a single strike. The conclusion has stirred up excitement among earthquake researchers, because it raises the possibility that seismologists could make life-saving forecasts of the big quakes that follow the first, large quake in a sequence. But challenges remain, including how best to communicate the risk to people who might be affected.

Currently, seismologists can forecast earthquakes only in vague terms — say, estimating a 30% chance of one in a large region in the next 50 years. Most earthquakes take the form of a single large quake followed by aftershocks of decreasing size. But in 'sequence quakes', such as the 2016 Italy event, energy is released in a stop–start manner: several large quakes are interspersed with smaller aftershocks. Scientists aren't sure why this happens.

The latest research — which was published in August and will be presented at the American Geophysical Union Fall Meeting in December in Washington DC — suggests that the answer might lie in the interplay of faults and the movement of underground fluids (R. J. Walters *et al. Earth Planet. Sci. Lett.* **500**, 1–14; 2018). This knowledge could, in theory, be used to predict potentially deadly follow-up quakes.

Sequence quakes occur in all tectonically active areas of the world, but they are thought to be more prevalent in geologically young