SPECIAL REPORT

The planetary police

Planetary scientists are looking for new ways to sterilize their spacecraft, so that they won't be excluded from exploring interesting places. **Eric Hand** reports.

In 1975, the twin Viking landers sped off to Mars as the most sparkingly clean things ever put into space. If either was to have any chance of detecting microbial life in its scoops of Martian soil, it couldn't risk carrying stow-aways from its launchpad at Cape Canaveral. "Going to Mars to study Florida is not a very good idea," says John Rummel, NASA's former planetary protection officer.

All the cleaning ended up being overkill. Viking found Mars to be cold, dry and dead. The rules for planetary protection — the endeavour of keeping Earth bugs off Mars, and Mars bugs off Earth — were relaxed. The Mars landers that followed were built in clean rooms and wiped down with alcohol, but did not have to be fully baked and sterilized.

But now engineers are looking at ways to make the rigour of Viking-type sterilization de rigueur. This year, scientists at the Jet Propulsion Laboratory in Pasadena, California — where many NASA spacecraft are built — will submit documentation to NASA arguing for the adoption of a second method of sterilization, which uses lower-temperature vaporization of hydrogen peroxide rather than high-temperature baking. If adopted, the protocol could make it easier for engineers to design and manage fully sterilized spacecraft. "We're trying to make it easier to do upfront," says NASA's acting planetary protection officer Catharine Conley.

Tough microbes

Sterilization is crucial, because in recent decades ever more hardy microbes have been discovered on Earth (see 'Extremophiles on Earth'), even as water ice has been found in ever more places on Mars. That raises the potential for similarly tough microbes to live in places on Mars, probably underground, that may yet be wet. Last week, the US National Research Council released a report reaffirming that, if and when researchers manage to bring back a rock sample from Mars, it will need to be kept in a state-of-the-art, maximum-security biocontainment laboratory — just to avoid the possibility of anything escaping.

Planetary protection efforts have mostly focused on the possibility of Earth microbes forward-contaminating other Solar System bodies. International guidelines for sterilizing spacecraft are set by the Committee on Space Research (COSPAR), which divides

missions into five broad categories ranging from flybys of bodies not of interest to astrobiologists, to a sample return from another world. Within these categories — and subdivisions for various targets of interest, such as Mars, or Jupiter's moon Europa with its ice-covered ocean — are strict rules for the number of spores that may be cultivated off the spacecraft after it has been heat-shocked at 80 °C for 15 minutes.

For the most part, scientists haven't minded such restrictions, because extra-clean instruments make for more precise measurements. But engineers balk at the cost and complexity of full sterilization; baking both Vikings, for instance, cost 10% of the US\$800-million mission, or about \$320 million in today's dollars. And so they prioritize, choosing to clean just the instrument that will potentially come in contact with the extraterrestrial surface.

For example, Phoenix, the NASA spacecraft that landed last summer near the planet's northern polar plains, had its sterilized robotic arm and scoop entombed in a 'biobag' during transit, so as to minimize the chance of passing on Earth microbes when it scraped through a thin layer of soil to find ice. But the lander set down in millimetres of ice exposed by retrorockets during landing. Now, some claim¹, Phoenix's legs may have become covered in droplets of briny water created when deliquescent salt lying above the subsurface ice was kicked up during landing. Any microbes that might have clung to the lander could

thus find a relatively comfortable home.

"I would have wanted the lander legs to be sterilized," says Conley. Phoenix had qualified as being clean, though, because only its arm needed sterilizing.

Full sterilization through heat baking is the rule for any spacecraft destined for 'special regions' on Mars — areas where ice or water could be near the surface, with temperatures warm enough for organisms from Earth to replicate. A 2006 National Research Council report argued that, given the potential for transient water to be in many

places on Mars, the entire planet should be treated as 'special' until scientists can show otherwise. That suggestion, however, didn't go down very well. "Certainly, the community didn't want all of Mars to be considered a special region," says Conley.

Later that year, Mars researchers, using models

and data from orbiters, did their best to identify the likely zones of near-surface ice and gullies that could indicate transient water in the near past. These are the designated 'special regions'. The regions between 30° north and 30° south qualified as not-so-special² (see map). But since then, there have been mid-latitude discoveries of buried glaciers³ and tiny pools of ice excavated by recent asteroid impacts⁴ — suggesting that the non-special zone might be even smaller than currently designated.

The \$2.3-billion Mars Science Laboratory (MSL) super-rover, due to launch in 2011, has a radioactive heat source that could melt ice

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EXTREMOPHILES ON EARTH

Life has been found everywhere, from boiling hot springs to Himalayan glaciers to nuclear reactors. These extremophiles on Earth make life on Mars more of a possibility — and also make planetary protection more of a challenge.

Parameter	Example
High temperature (thermophile)	Archaeal strain 121 (121 °C)
Low temperature (psychrophile)	Himalayan midge (−18 °C)
High pH (alkaliphile)	<i>Alkaliphilus transvaalensis</i> (pH 12.5)
Low pH (acidophile)	<i>Ferroplasma acidimanus</i> (pH 0)
Salt-tolerant (halophile)	Halobacteriaceae (saturated solutions 10 times saltier than sea water)
Lack of oxygen (anaerobe)	Methanogens
Desiccation (xerophile)	Lichens, cyanobacteria
Radiation (radiophile)	<i>Deinococcus radiodurans</i> (withstands radiation 1,000 times the lethal dose for a human)
Pressure (piezophile)	Obligate bacterial strain MT41 (1,000 times atmospheric pressure)
Vacuum-tolerant	Tardigrades ('water bears'), insects, seeds
Longevity	Bacteria isolated from 250-million-year old salt crystal

CAMBRIAN CHEMISTRY
Animals on the sea floor may have stoked global sulphate levels.
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J.L. AMOS

for many years — complicating things if there were a crash or mishap above thinly covered ice. Mission managers elected to avoid special regions altogether, figuring that there would be less chance of contamination if the ice were deep. Although the MSL is capable of detecting organic molecules such as methane, it is not technically considered a life-detection mission — because that, too, would bump it up to a level that requires full-baking sterilization for those instruments. (One of the reasons that mission managers for Phoenix and the MSL have said their probes are exploring 'habitability' rather than searching for life, Conley says, is to avoid stiffer requirements.)

Engineers steering the probe's descent have other reasons to avoid higher latitudes, and the shortlist of the four places where the MSL may end up are all in equatorial regions. But it is possible that the rover could stumble on a surprise — a hydrothermal vent, say, or a pond of buried ice not too far below the surface. In one of these scenarios, the rules could force scientists to throw the rover into reverse. Scientists would be told to pull out, "even though it was scientifically meaningful, and even though it would be desirable", says Karen Buxbaum, planetary protection manager for the Mars programme at the Jet Propulsion Lab.

Would scientists have the patience to leave the area in a pristine state, being forced to wait

years for another, cleaner probe to come along? "I don't think people would have a big problem with it," says John Mustard, a geologist at Brown University in Providence, Rhode Island, and chair of a NASA Mars exploration advisory committee. "If you're going in with a blunt tool, and you really need a scalpel, there's no point in going in there until you get the right equipment."

Getting cleaner

ExoMars, a Mars astrobiology rover proposed for launch in 2016 by the European Space Agency (ESA), will be the cleanest Martian mission since Viking. But last year, ESA decided that ExoMars would also avoid special regions, so that only the life-detection instruments rather than the whole spacecraft would need to be heat-baked, according to ESA planetary protection officer Gerhard Kmínek. Areas containing features such as gullies, although interesting, would have been difficult to land near anyway, he says. "It saves money, but it also was a practical issue."

Rummel says that scientists have already shown restraint about exploring sensitive regions. In 2003, mission controllers sent Galileo, a mission to the Jupiter system, plummeting early into Jupiter rather than risk losing control of it and having it hit Europa and its ice-capped ocean. "We knew that to

protect Europa we had to kill the spacecraft," says Rummel, now director of the Institute for Coastal Science and Policy at East Carolina University in Greenville, North Carolina.

For now, Conley and her colleagues are working to ensure that, whatever craft leaves this planet, they know what is on it. As part of modernizing and updating the planetary protection techniques, she hopes to replace the decades-old diagnostic for measuring spacecraft contamination, which relies on counting the numbers of bacteria as a proxy for overall microbial life. By adding approaches involving biochemistry and the polymerase chain reaction, she says, scientists can generate a more specific inventory of exactly what types of microbes, if any, are present. Recent studies along these lines have shown how several species of archaeal bacteria still cling to surfaces in spacecraft-assembly clean rooms⁵.

Even with existing technology, she notes, scientific exploration and planetary protection should not be in conflict. "There is nothing that is off limits," she says. "You just have to be clean enough."

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3. Holt, J. W. *et al.* *Science* **322**, 1235-1238 (2008).
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5. Moissel, C. *et al.* *ISME J.* **2**, 115-119 (2008).