NEWS IN FOCUS

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Launched in 2010, the Swedish satellite PRISMA has been testing a greener alternative to the toxic propellant hydrazine.

SPACE SCIENCE

Green fuels blast off

Propellants offer satellites greater efficiency and lower toxicity than liquid hydrazine.

BY ALEXANDRA WITZE

It looks like chardonnay, smells like glass cleaner and packs enough punch to shift a satellite. It is a Swedish-made 'green propellant', one that is fast becoming a viable fuel for manoeuvring craft in orbit. Along with a US-made propellant, it is providing an attractive alternative to hydrazine, the toxic chemical that has dominated this corner of the space industry for decades.

The Swedish propellant is currently nudging a satellite around in space, and may be used in a constellation of small commercial Earth-imaging satellites. The US-made fuel will take centre stage in a NASA test mission launching in 2015.

Both fuels offer higher efficiency, lower toxicity and are easier to handle than hydrazine, which means that they can be loaded into spacecraft faster and more cheaply because launch-pad workers don't have to wear cumbersome full-body protection. Such a propellant "isn't green in the sense that it's totally environmentally friendly", says James Reuther, deputy associate administrator of NASA's space technology mission directorate. "But it's a heck of a lot easier to work with."

Green propellants probably won't completely replace hydrazine, the workhorse of many research satellites and interplanetary missions. Nor will they replace the powerful fuels typically used to launch rockets. But the new fuels, some of which are more tolerant of low temperatures, could enable cheaper and more flexible mission designs.

Hydrazine (N_2H_4) has been powering rocket engines since the Second World War. It tends not to be burned like petrol; instead, a catalyst is used to trigger hydrazine's decomposition into ammonia, nitrogen and hydrogen, a process that releases chemical energy. The fuel is valued for being a stable liquid that can provide precision thrusts for small orbital adjustments.

But hydrazine also causes a host of health problems if breathed in or touched. The US National Toxicology Program classifies it as a probable human carcinogen. When the space shuttle *Columbia* disintegrated on re-entry in 2003, showering debris across Texas, Louisiana and other southern states, NASA warned people not to approach or touch the wreckage in part because of the risk of hydrazine exposure.

In 1995, Sweden's national space board funded work to explore alternatives that ▶

would perform at least as well as hydrazine but that would be easier to handle. A less unwieldy propellant would help to save time and money at launch pads, says Mathias Persson, president of ECAPS, the company near Stockholm that developed the green propellant.

Called LMP-103S, the Swedish fuel is based on ammonium dinitramide, a high-energy salt. It made its debut in 2010 aboard PRISMA, a Swedish satellite meant to demonstrate the fuel in precision flying with small thrusters. For comparison, the mission also carried hydrazine. It took 3 people 7 days to load the green propellant on the launch pad, and 5 people and 14 days to load the hydrazine.

ECAPS is now seeking general approval from the European Space Agency for the propellant. France's space agency, CNES, is considering it for a new line of small satellites, and the company Skybox Imaging of Mountain View, California, will begin using the fuel when it launches the third of its 24-craft Earth-imaging constellation in 2015. "We really believe this is going to be the future, especially for small spacecraft," says Jonny Dyer, Skybox's chief engineer.

Green fuels aren't just easier to handle; they can also provide better performance per kilogram of propellant than hydrazine (see 'Designer fuels'). That means more manoeuvres can be done on a single tank of fuel. In fact, the US green propellant came about when two Air Force research programmes collided: one looking at next-generation propulsion technologies, the other studying extremely energy-dense materials.

DESIGNER FUELS
Hydrazine could be unseated as the go-to fuel for satellite orbital manoeuvres by two propellants with lower toxicity and more punch.

	Hydrazine	LMP-103S	AF-M315E
Developed by	Multiple	ECAPS, Sweden	US Air Force Research Laboratory
Contains	Hydrogen and nitrogen	Ammonium dinitramide	Hydroxyl ammonium nitrate
Specific impulse	2,373 $N s kg^{-1}$	2,477 $N s kg^{-1}$	2,609 $N s kg^{-1}$
Density	1.01 $g cm^{-3}$	1.24 $g cm^{-3}$	1.465 $g cm^{-3}$
Toxicity (lethal dose in 50% of rats, LD_{50})	60 $mg kg^{-1}$	1,300 $mg kg^{-1}$	550 $mg kg^{-1}$

Source: AFRL; ECAPS

The result was AF-M315E, a salmon-coloured liquid created by Tom Hawkins, a chemist at the Air Force Research Laboratory at Edwards Air Force Base in California. The fuel is based on hydroxyl ammonium nitrate, which is slightly more efficient than the Swedish propellant. "What I get excited about is the performance part of it," says Christopher McLean, the programme manager at Ball Aerospace & Technologies in Boulder, Colorado.

Ball is building NASA's Green Propellant Infusion Mission, a US$45-million spacecraft expected to launch in 2015, carrying 14.2 kilograms of the Air Force fuel. Its five engines will burn in different operations for months, testing how reliably the engines thrust.

If it works, the new propellant could enable future missions that are expensive to do at the moment, says McLean. AF-M315E undergoes a glass transition at −80 °C, from which it can be heated back up with no change in its properties. That could make it more attractive than hydrazine for missions to ultra-cold locations, like a comet's surface or the Martian polar cap, as hydrazine has to be kept above its freezing point at all times, which wastes energy.

Hydrazine won't be displaced overnight. There is a long heritage of tanks and thrusters based around the chemical, and spacecraft engineers are accustomed to using those parts. The new propellants, says Hawkins, will have to demonstrate reliability and performance over time.

But change is coming, says Kjell Anflo, chief engineer for ECAPS. "We are just at the beginning." ■

PUBLISHING

Brazilian citation scheme outed

Thomson Reuters suspends journals from its rankings for 'citation stacking'.

BY RICHARD VAN NOORDEN

Mauricio Rocha-e-Silva thought that he had spotted an easy way to raise the profiles of Brazilian journals. From 2009, he and several other editors published articles containing hundreds of references to papers in each others' journals — in order, he says, to elevate the journals' impact factors.

Because each article avoided citing papers published by its own journal, the agreement flew under the radar of analyses that spot extremes in self-citation — until 19 June, when the pattern was discovered. Thomson Reuters, the firm that calculates and publishes the impact factor, revealed that it had designed a program to spot concentrated bursts of citations from one journal to another, a practice that it has dubbed 'citation stacking'. Four Brazilian journals were among 14 to have their impact factors suspended for a year for such stacking. And in July, Rocha-e-Silva was fired from his position as editor of one of them, the journal *Clinics*, based in São Paulo.

"We've been caught wrong-footed," says Rocha-e-Silva, a retired physiologist. The editors of the other three Brazilian journals collared by Thomson Reuters remain in place. In addition to these four journals, "there are a few others which played a part in this game, and they escaped", he says.

Editors have tried before to artificially boost impact factors, usually by encouraging the citation of a journal's own papers. Each year, Thomson Reuters detects and cracks down on excessive self-citation. This year alone, it red-flagged 23 more journals for the wearily familiar practice. But the revelation that journals have gained excessively from citations elsewhere suggests that some editors may be searching for less detectable ways to boost their journals' profiles. In some cases, authors may be responsible for stacking, perhaps trying to boost citations of their own papers.

The journals flagged by the new algorithm extend beyond Brazil — but only in that case has an explanation for the results emerged. Rocha-e-Silva says the agreement grew out of frustration with his country's fixation on impact factor. In Brazil, an agency in the education ministry, called CAPES, evaluates graduate programmes in part by the impact factors of the journals in which students publish research. As emerging Brazilian journals are in the lowest ranks, few graduates want to publish in them. This vicious cycle, in his view, prevents local journals improving.

Abel Packer, who coordinates Brazil's system of free government-sponsored journals, known as SciELO, says that the citation-stacking venture was "unfortunate and unacceptable". But he adds that many editors have long been similarly critical of the CAPES policy