Making satellites safer: the search for new propellants

March 30 2020, by Kelly Oakes

The current standard propellant for satellites based on hydrazine, which is highly toxic, so researchers are developing safer alternatives. Credit: NASA-JPL/Caltech

Developing new propellants for satellites to replace toxic hydrazine would make launching and handling satellites safer but it also requires disrupting current systems, according to researchers.

As the number of satellites soars, so will the amount of fuel we use to launch them. And getting into orbit is only half of the equation. Once a satellite is in position above Earth it needs a method of propulsion to make sure it can move if needed, avoiding space debris, compensating for drag over time, and even de-orbiting itself at the end of its mission.

The current standard propellant for satellites is hydrazine-based fuel, which is highly toxic. Exposure to high levels of hydrazine can cause a host of health problems, including damage to the liver, kidneys and central nervous system. If hydrazine spills while a satellite is still on the ground, its violent and explosive nature can become a public safety problem.

Preparing a hydrazine-fuelled satellite for space is a hazardous task requiring special precautions for anyone involved, including space suit-like clothing that makes sure, if something were to go wrong, the people handling the fuel wouldn't breathe in the gas itself. "They look a bit like a Michelin Man," said Dr. Norbert Frischauf, a partner at space consultancy SpaceTec Partners in Belgium.

So it's no surprise that engineers are looking for new, cleaner ways to launch and propel satellites that use non-toxic fuels instead. "Hydrazine is pretty nasty to work with from a health and safety perspective, so we're seeing a lot more interest in these sorts of propellants," said Erikas Kneižys, Chief Design Officer at NanoAvionics, a spacecraft equipment manufacturer based in Europe and the US.

In 2011, the European Chemicals Agency added hydrazine to its list of 'substances of very high concern', meaning its usage could soon be restricted.

CubeSats

NanoAvionics specialises in technology for nanosatellites, including CubeSats, which are miniature satellites made of 10cm cube-shaped units, typically built using off-the-shelf components and weighing around 1kg each. As smaller satellites like these become more commonplace—NanoAvionics say there has been a 300% increase in small satellite launches between 2016 and 2020—demand for clean propellants suited to them is likely to rise.

"There were basically no products when looking at the CubeSat market and when looking especially at (chemical) propulsion using (clean fuel)," said Kneižys. "So we've seen this niche and started working on it."

Through a project titled EPSS, NanoAvionics has developed a less harmful propellant based on ammonium dinitramide, or ADN, a compound made up of nitrogen, oxygen, and hydrogen, especially for small satellites. The system has been integrated into a pilot satellite and has undergone a demonstration in orbit.

The new system is what's known as a monopropellant, which works by passing the fuel over a catalyst that causes it to decompose, producing heat and gases that propel the spacecraft. Other systems use a bipropellant, in which two liquids are kept separate and typically ignite on mixing.

Using a bipropellant ups the risk during manufacturing, says Kneižys, as the two substances could accidentally come into contact and ignite before they are supposed to. "In our monopropellant you have to go miles to make sure it burns, so it's relatively benign and stable compared to (most) bipropellant systems," said Kneižys.

But it's not just smaller satellites that could benefit from non-toxic propellant.

HyproGEO, a project coordinated by aerospace company Airbus, has also developed a non-toxic propulsion system, this time focussing on satellites in geostationary orbit around Earth. Orbiting at 36,000 km, these satellites appear to stay at a fixed point above Earth's surface and are typically used for things like communications and broadcasting.

"To get up there, it takes quite a lot of energy," says Dr. Frischauf of SpaceTec Partners, a member of the HyproGEO consortium.

Right now, that energy is provided mostly by hydrazine-based propellants. But HyproGEO has developed a hybrid propulsion system that uses hydrogen peroxide instead. The fuel, which is 98% hydrogen peroxide—compared to the 6% or so solution you'd use for bleaching your hair—is highly acidic, but still less risky to work with than hydrazine. It also breaks down to oxygen and water, avoiding the release of fumes that are harmful to humans.

Geostationary satellites are designed to last a decade or longer, so the propellant, which is also used to manoeuvre them once they're in orbit, must be similarly robust. "You have to make sure that it will still be running after 15 years, so it should be a simple system, because if it's complicated there's always a risk that something breaks," said Dr. Frischauf.

Hybrid

The solution HyproGEO came up with was to use hybrid propulsion, which involves passing the hydrogen peroxide over a catalyser to produce very hot oxygen as well as water vapour. That oxygen can provide the propulsion by itself, or it can be used to ignite another substance for an extra boost. "When you control the flow of the oxygen, you can control the thrust of the engine," said Dr. Frischauf.

The team successfully developed a test engine to store the new propellant , showed that it decomposed as expected, and then designed a rocket engine using the fuel. Since that work was completed in 2018, Norwegian defence company Nammo have used the HyproGEO hybrid engine to launch a rocket 107km from Earth's surface in just three minutes, a timescale typical of suborbital rockets using traditional propulsion systems.

Using these new propellants doesn't just benefit the people working with the current toxic fuels, it makes the whole infrastructure more efficient and cheaper too. Kneižys says the EPSS system designed by NanoAvionics costs roughly a third of similar products that use traditional propellants.

With all those benefits, what's holding these new propellants back? For one, hybrid propulsion systems traditionally haven't been capable of the long-duration firing needed to put satellites into geostationary orbit, a problem that HyproGEO managed to overcome.

And the industry already has procedures set up to deal with traditional fuels like hydrazine—transitioning to something new requires disrupting those systems, said Dr. Frischauf. "It always takes a bit of an impetus, a bit of a push to make sure the new technology can prevail."

Provided by Horizon: The EU Research & Innovation Magazine