A Safer Liftoff

An innovative rocket-fuel system taps a novel source of power and breakthrough engineering to deliver high-energy thrust with improved safety.

On a broad mesquite plain in central New Mexico, a small crew fits a metal cylinder into a rocket the size of a baseball bat, then slips the rocket onto guide rods on a platform. A "Los Alamos" logo on the fuselage certifies this launch as official science by the world-famous national laboratory, not a weekend outing with the kids.

Bryce Tappan and a handful of scientists, engineers, and students from Los Alamos National Laboratory and New Mexico Tech stand back as another crew member handles a control box set on a folding table. He counts down, "Three, two, one, zero!" The rocket issues a loud *pssshhhhhewwwweeee!* and whisks into the cobalt sky, the cylinder trailing a stream of gases and tilting toward horizontal as it soars to its apogee.

The small group cheers, perhaps a little more vigorously than one might expect, but that's because this 41-inch rocket just proved that a novel fuel invented by Tappan and others at the Lab actually works.

Powerful, safe, and potentially powerful enough to launch a full-sized spacecraft, the breakthrough segregated-fuel-oxidizer system, called IsoFOX, enables a new era in propellants. For rockets, missiles, and satellites the fuel is a "humongous safety improvement," according to Dan Hooks, director of the Los Alamos Explosives Center. Hooks explains that missiles carry "a huge tonnage of propellant," which multiplies the risk of their detonable fuels exploding accidentally, "so any safety improvement is tremendous."

From Failure to Breakthrough

Ironically, Tappan, who came to the Lab first as an undergraduate in 1996, then returned as a postdoctoral researcher in 2003, stumbled onto this propellant in the wake of a disappointment. He was studying an energetic material called TAGzT (triaminoguanidinium azotetrazolate) and related compounds. (Energetic materials store chemical energy, which is a useful characteristic for making explosives, propellants, or fuels.) It had failed miserably as an explosive.

"For more than 20 years, Los Alamos had been experimenting with synthesizing high-nitrogen materials for use in energetic materials," Tappan explains. "High nitrogen content is interesting in explosives because it can reduce the amount of oxygen needed to burn the fuel atoms in the molecule, making an oxygen balance easier to achieve." Managing the amount of oxygen in a fuel helps tune its safety characteristics. The nitrogen makes for a higher-energy-density system that works much like an automobile efficiently burning gasoline. Tappan was experimenting with these high-nitrogen/high-hydrogen materials, which contain little or no oxygen, for their applications to explosives.

In his first large-scale test with TAGzT, the material didn't detonate.

"I thought, this sucks," Tappan recalls with a laugh. "Then I thought, wow, this could be an important discovery as a propellant ingredient. Non-detonable materials that combust well are good for propellants and bad for explosives." TAGzT—and the novel fuel that Tappan would later develop from it—"doesn't detonate at all. It just burns." That property opened up the potential for a new kind of rocket fuel several years later, when a collaborator from Penn State University came to Tappan for oxidizer pellets to use with a liquid fuel. Tappan had a better idea, based on his research: use a high-nitrogen/high-hydrogen energetic material.

"There was nothing else out there like it in the research literature," he says.

Actually, It Is Rocket Science

In a slow-motion video of the test showing the simultaneous launch of Tappan's rocket beside a conventionally fueled twin, Tappan's rocket ignites and vanishes from the frame as the other lumbers up. It's a jackrabbit leaving a tortoise in the dust.

The next-generation rocket? Los Alamos scientists recently tested a powerful new rocket fuel and motor that are safer because the fuel is kept separate from its oxidizer. The new rocket motor and fuel outperformed commercial rockets in thrust with at least twice the velocity. (Photo: Los Alamos)

"The actual rocket launch was definitely tense," Tappan says. "If you go to YouTube and search 'rocket motor failure,' you'll get thousands of videos, and these are rockets that had who-knows-how-many millions of dollars poured into them. It's never a given the rocket is going to work because the tests in a laboratory don't necessarily translate to an actual successful launch. So it was a very exciting moment to demonstrate something we had been working on for a couple years." The flight data showed the Los Alamos rocket motors outperformed the commercial rocket motors in thrust with at least twice the velocity.

"The main goal of this project is to get something that offers very high safety in a completely non-detonable system without an energy penalty," Tappan explains, meaning the material would still provide plenty of propulsion. "Typically, when you look at something that's high performance, it's not a safe a material. We're trying to break that performance versus sensitivity curve and make a rocket propellant that's high-energy and high-performance as well as very safe."

Tappan explains that the "enabling technology" involves "physically separating the energetic fuel material and a solid oxidizer." A typical solid rocket propellant keeps the fuel and oxidizer together, with potentially dangerous and explosive results. The Lab's segregated-fuel-oxidizer system, IsoFOX, keeps the fuel and oxidizer apart because the initial stage of ignition does not require oxygen. The high-nitrogen/high-hydrogen energetic material decomposes when ignited, creating a fuel that flows into the separate secondary section of the rocket containing the solid oxidizer. There the fuel combusts with oxygen released from a reaction with the oxidizer, and full propulsion is achieved—fast! This design dramatically reduces the chance of accidental detonation. It's also completely insensitive to shock, meaning a sharp impact won't blow up the rocket.

What's Next

Becky Olinger, associate director of the Los Alamos Explosives Center, sums up Tappan's breakthrough: "Tappan's rocket technology provides a safer alternative to propellants without compromising performance." The project began under Laboratory Directed Research and Development funding, which supports high-risk, potentially high-payoff research in promising directions. The next steps are refining the fuel system and exploring industrial partnerships to commercialize it.

Tappan intends to follow two tracks: scaling up the system to larger motors and miniaturizing it for use on satellites. As an on-board satellite fuel system, IsoFOX addresses concerns about the risk of an explosion destroying the craft in space. Such a system could shift a satellite between orbital planes or bring it back into Earth's atmosphere when its mission is complete.

One day, Tappan suggests, IsoFOX might even power a small satellite to the moon. That's a lofty target for a material that once fizzled in a lab test.

~Charles C. Poling

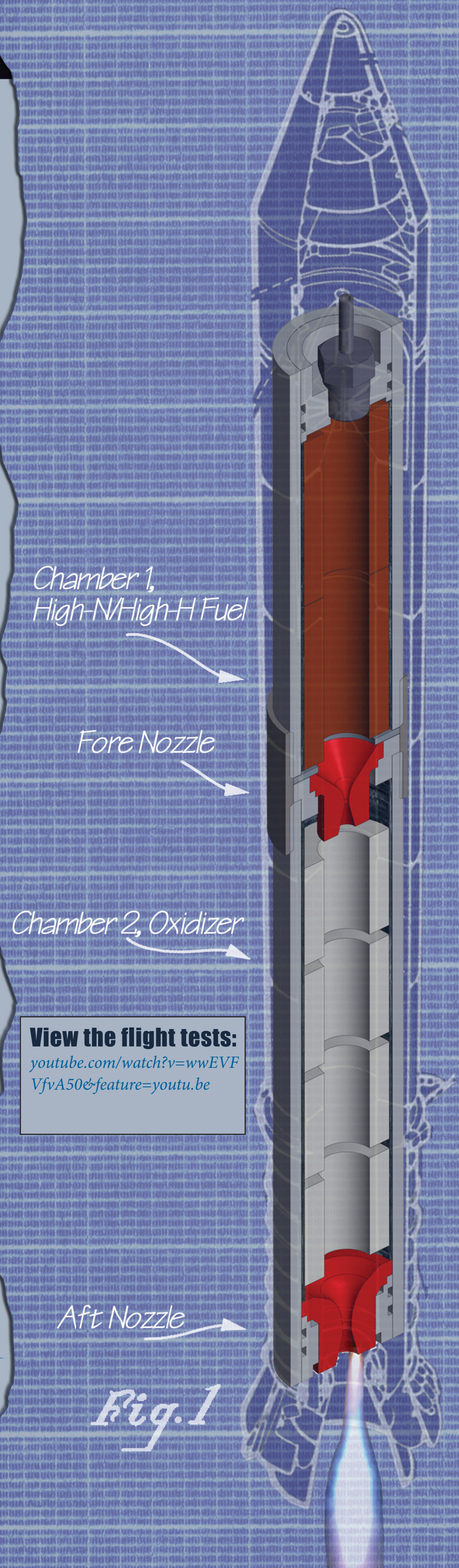

Fig.1

View the flight tests:
youtube.com/watch?v=wwEVFVfvA50&feature=youtu.be