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High and Mighty

The next killer app for DuPont's super-strong Kevlar polymer may be in outer space, as a nano- fiber for next-generation rockets and space shuttles.

By Peter Galuszka

In March 2003, a month after the space shuttle Columbia disintegrated over Texas, killing seven astronauts aboard, a NASA official made a telephone call to Arnie Frances, a senior research associate at DuPont's sprawling Spruance production facility in Richmond.

The Columbia had exploded on re-entry because a piece of insulating foam had broken away during launch and damaged the Shuttle. Did chemical giant DuPont have anything new in its fibers research pipeline that could help prevent future disasters?

"It turned out we did have something very new on the drawing board," says Frances. DuPont's Spruance works have turned out steadily improved versions of Kevlar, a bullet-stopping fiber that is five times stronger than steel, for four decades. The latest developments involve using nanotechnology to make very tiny slivers of Kevlar. In this new form, Kevlar could be inserted into cell walls of foam insulation in ways that would make it stronger and hopefully more damage resistant.

A few months after the initial phone call, DuPont and officials at NASA's Marshall Space Flight Center in Huntsville, Ala., signed an agreement to explore using Kevlar "micro pulp" or "nano pulp" in what would be a dynamic new application. It might be used as insulation in the next generation of launch vehicles – the Ares I and V – that will take the replacement for the space shuttle into orbit, to the moon and Mars, and perhaps beyond.

Although it won't be known for a year if Kevlar will be used commercially in this form, early tests are promising, says Edmund Semmes, a NASA aerospace technologies specialist at the Marshall Space Flight Center in Huntsville. The 2003 agreement calls for DuPont and NASA to bear their own costs of research until a final decision is made to proceed. "DuPont has been very good to us over the years and we have especially close ties with Richmond," Semmes says.

Such ties are long-standing. NASA has used many DuPont products since it started its space program in the 1950s. Space suits worn by astronauts use Nomex, a fire retardant made at DuPont's sprawling Spruance plant. And Kevlar, discovered in 1965 and made mostly at Spruance, has been used in various space applications over the years, such as shielding against meteorites. The fiber's contribution to body armor and shields for vehicles in war zones is so critical that in September the firm announced a $500 million global expansion of Kevlar production, including a $50 million addition in Richmond.

As years have passed, DuPont has constantly refined Kevlar and introduced new applications. One of the latest involves nanotechnology that uses Kevlar fibers in an ultra light form, says Kathy Kowalski, director of global new business at DuPont's Advanced Fiber Systems in Richmond.

The focus of current research is to see if Kevlar can help strengthen foam insulation, shielding the second stage of the two-stage Ares I rocket. Atop the rocket will be a six-person capsule called the "Orion" that will be the space vehicle that will serve as the new space shuttle. Like the existing shuttle, it will orbit the earth, perform missions and dock with the International Space Station. Unlike the current space shuttles, it won't fly back to earth like an airplane but, like older capsules, will

parachute to Earth after re-entry in the atmosphere. The first flight of Ares I is expected in 2009 and trips to the space station are expected by 2014.

Breaking free of Earth's gravity is, of course, a major factor in putting the 25-ton Orion payload into orbit. In the first stage of Ares I, solid-fuel propellants will burn for two and a half minutes after blast-off until the vehicle reaches a height of 38 miles and a speed nearly six times the speed of sound.

After the first stage burns its fuel and falls away, the second stage takes over. Its J2X engine, which evolved from Apollo-era programs of the early 1970s, will be fueled by liquid hydrogen and oxygen. They will burn until the vehicle is 83 miles above Earth's surface, enough to throw Orion into orbit. Liquid hydrogen and oxygen must be kept at extremely low temperatures -- at this critical phase of the launch. Liquid hydrogen, for example, must be stored at less than minus 423 degrees Fahrenheit or it starts to boil and evaporate. Liquid oxygen starts to do the same at minus 238 degrees, Semmes says. If the fuel evaporates, then the Orion capsule won't be able to reach the desired orbit, with potentially disastrous results.

That's where Kevlar might play a role. NASA and DuPont are experimenting with inserting Kevlar into the foam on the cladding around the rocket's second stage. The substance's strength and light weight in the new, micro form could serve two important functions. It could ensure that the fuel stays cold enough. And it could protect the cladding from falling away the way it did in the Columbia disaster and shield against outside objects that might puncture the fuel cells.

NASA and DuPont officials are careful not to draw too much of a comparison with the Columbia situation. In that case, during the launch, a piece of foam insulation about the size of a small briefcase broke from the main propellant tank. Parts of it damaged shuttle's left wing and thermal protection system. When the Columbia was returning to Cape Kennedy and was penetrating the atmosphere over Texas on its landing approach, there wasn't enough protection against the intense heat. The shuttle broke apart in a spectacular explosion that killed the crew.

"The best way to say it," notes Semmes, "is that if there was foam that had a higher strength, it possibly could have prevented the Columbia accident."

One safeguard being built into the Orion capsule is a better way of letting the module containing the astronauts break away in an emergency. Upgrading foam to higher strength levels is another, although Semmes notes that foam itself "would not be capable of protecting the shuttle in re-entry."

DuPont's Kowalski says that, at least initially, only small portions of the new Kevlar material would be used if the Ares I cooperation proceeds. It will not involve any major new production increases of Kevlar at the 3,000-worker Spruance plant. However, the program announced Sept. 19 to increase Kevlar production worldwide by 25 percent should bring some new jobs in the Richmond area. Spruance will get a $50 million expansion to increase production of polymers used in Kevlar.

If Kevlar is used in Ares I, it has a good chance of being deployed in the much-bigger Ares V rockets, Semmes notes. Those larger launch vehicles will be used to take new capsules to the moon, perhaps by 2020. There are also plans to use Ares V for Martian missions. Since they are bigger, they could involve greater use of Kevlar.

Adapting to outer space applications is only one way in which the high-performance fiber has evolved at Spruance. Kevlar is also used to create "storm rooms" in homes in tornado- and hurricane-prone areas. In a weather emergency, families can retreat to the rooms and be safe from projectiles hurled about by extremely strong winds.

Kowalski says that the Spruance expansion is part of a corporate-wide "megatrends" study that examined potential new markets and products. Regarding Kevlar, "certainly the war is critical," she notes. "But we're finding that we're growing in all categories." Using it to get astronauts to Mars might be just one of them.

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