

The Lite Stuff: Brian Stofiel Stumbled Onto the Right Stuff For Orbit: a Plastic Rocket

By Danny Wicentowski

March 7, 2019

In theory, getting to space is simple — just go up, then keep going.

In reality, there are some additional steps: Collect a few billion dollars, build a rocket taller than a ten-story building, gain access to vast quantities of fuel and, preferably, buy a deserted plot of land that you wouldn't mind obliterating on launch day.

Or, you could do it like Brian Stofiel — just print a rocket in your basement and drag it to the edge of space on a weather balloon. Then, and only then, would you fire the rocket, which would have to be light enough to lift with a bit of helium but also sturdy enough to survive a prolonged burn through the upper atmosphere.

You probably wouldn't build that rocket out of plastic.

But Stofiel, a St. Louis-based Air Force veteran without a bachelor's degree, is doing just that, utilizing a heat-resistant, chemically treated plastic that he himself invented. Stofiel's breakthrough has caught the attention of rocket scientists who know intimately what it takes to engineer an escape from Earth.

His creation, extruded inch by inch by an overworked 3D printer nicknamed "the Beast," is at the heart of what he calls the "Boreas" launch system.

Without burning a drop of fuel, Boreas' launch would send an unguided balloon/rocket hybrid — a "rockoon" — bobbing and twisting into the sky. In Stofiel's plan, the balloon's single passenger would be a rocket named Hermes. Aside from its payload and fuel (and a bit of carbon fiber tube), Hermes would be made entirely of plastic.

Within an hour, Stofiel says, the balloon could rise to 90,000 feet, far above the domain of commercial aircraft.

Some 70 years ago, early rockets broke into orbit by using the technology behind ballistic missiles, their massive engines burning liquid oxygen and producing enough thrust to hit 17,000 miles per hour. But to a balloon, the sky simply opens its arms.

Beneath the rocket, tethered by yet another umbilical rope, would be a space plane with folded, swept-back wings. The size of a Mini Cooper, it looks like the fusion of a fighter jet and an origami crane. Called Artemis, it will hold Boreas' brain.

At nineteen miles up, the guidance computer would snap to work, writing a firing solution and sending the cue to Hermes to punch its ticket to space. When Hermes' engine ignites, its plastic motor would eject a pillar of flames at nearly 4,000 degrees Fahrenheit. With so little atmosphere remaining, Hermes would need only around two minutes of burn before it enters low-earth orbit, where it could then disgorge an army of imaging satellites.

Currently, Boreas is science fiction, a reflection of the still-unrealized ambitions of its creator and his company, Stofiel Aerospace. But the

technology underpinning it is very real. Stofiel printed and fired dozens of small-scale Hermes prototypes from the backyard of his home in Boulevard Heights, and he's twice tested the rockoon design that would allow the rocket to bypass the thickest parts of the atmosphere.

He's still waiting to prove his central thesis: that in under a week, Stofiel Aerospace can custom-print a rocket, blast it into space and deliver an orbiting payload at an industry-low \$20,000 per kilogram. That payload could be imaging satellites or scientific experiments. Eventually, Stofiel envisions Boreas becoming the preferred delivery service of the orbital economy, dropping packages on the other side of the world using a variation of the Artemis as a reentry vehicle.

It's a long overdue service for the commercial space age, Stofiel says, making his pitch above the noisy conversation of a monthly networking event at Cortex.

"You really need to be able to have that on-demand access to low-earth orbit," he adds. "I don't want to wait two years, or six months, I want to go to space next week. I just got tired of waiting on everybody else to do this."

With his biker-guy long hair, messy basement laboratory and intense antipathy for NASA, Stofiel often seems like a mad rocket scientist, both figuratively and literally. Stofiel Aerospace is also a family business, and Stofiel credits his daughter for inspiring Boreas in 2012, when she was five. (Now twelve years old and a veteran of NASA space camp, Stofiel's daughter is an official member of his company's board of directors.)

By any stretch, Stofiel Aerospace doesn't yet pose a challenge to SpaceX, the company founded by Elon Musk that now services more than half of all American commercial orbital space launches with a fleet of rockets that fire at \$62 million a pop.

Rather, Stofiel has spent years taking the first small steps to turning his ideas into a viable space service. The modern space race remains dominated by governments, deep-pocketed entrepreneurs and massive aerospace corporations. But Stofiel's first steps have intrigued both rocket scientists and industry insiders.

Reaching into his briefcase, he produces a blackened rocket nozzle the diameter of a coffee mug. The surface is hard to the touch, the skin left bumpy and scarred by its encounter with rocket fuel.

"We call it positive structural molding," Stofiel says, describing the proprietary heat-shielded material in his hand. Turning the nozzle over, he points out the lack of structural distress, the strength of compartments designed to focus thousands of pounds of thrust.

It weighs almost nothing.

"And that's plastic from Microcenter at Brentwood," he adds, laughing. "That hit 2,000 degrees!"

From a St. Louis basement, Brian Stofiel's plastic rockets are printed in a matter of days.

In 1952, Earl Robb started his career designing airplanes at the McDonnell Aircraft Corporation, a St. Louis defense company

with a history of manufacturing military fighters and missiles. By 1955, Robb was working on the problem of spaceflight. His work helped put the first American astronauts into space in 1961.

More than six decades later, on a morning in March 2018, Robb and three other retired McDonnell engineers descended into Brian Stofiel's basement.

Combined, they possessed about 300 years of expertise in rocket design and space engineering. They'd come to see for themselves if this 40-year-old entrepreneur was just boasting or, perhaps, truly brilliant.

They arrived in a basement workspace cluttered with 3D printers and rocket parts in various stages of construction and chemical treatment. Robb, 88, was used to operating with specialized teams toiling in the best facilities money could buy, and yet the scene was still a familiar one.

On a table, Stofiel had arranged dozens of rocket nozzles and components for the engineers' inspection. He also dragged out the reams of data he'd collected in the past five years of launches and static fire tests.

It made a believer of Robb.

"All my life, I dealt with heavy-duty structural things," Robb says now, recalling what he observed that morning. "He had this very light rocket. That just impressed the heck out of me. It still does."

Robb and Stofiel first met through monthly luncheons arranged by members of "Mac's Old Team," the name adopted by the retired McDonnell engineers whose work set the stage for NASA's Apollo missions to the moon. By putting astronauts in space for both the Mercury and Gemini

projects, the McDonnell engineers left their mark on decades of space programs. Robb would later work on Skylab, the first manned U.S. space station, and his colleagues designed systems used in space-shuttle launches and the International Space Station.

Although NASA gets most of the credit for America's victories in the space race, early American programs were actually contracted to private industries, and McDonnell Aircraft was the major player of that era. The company's founder, James S. McDonnell Jr., would himself get on the intercom to make announcements to the Mercury and Gemini teams.

"This is Old Mac, Old Mac, calling all the team," Robb says, impersonating his old boss in a deadpan. The name stuck with the retirees, Robb explains, because it fits.

"We're all old now," he says, chuckling.

The group maintains a contact list with 200 or so names, and today's luncheon brings some twenty retirees to a private room in a Hibachi Grill in St. Charles. Stofiel, a regular attendee, is seated at a table against a wall, telling a former Gemini engineer about the impact of the government shutdown on planned rocket launches.

Robb steps into the middle of the room, welcomes the crowd and begins reading announcements. He informs the team of the passing one of its own, a former guidance and control-system designer for Mercury and Gemini spacecraft.

"Right now, it seems like we've got down to the point where there's not very many people passing away in our group," Robb remarks wryly. "The reason

for that is... most of them have already gone." The room replies with a knowing groan of laughter.

But Robb and the members of Mac's Old Team are doing more than just ticking down the names of their still-living colleagues. For the last several years, the retired engineers have made the drive south to Bonne Terre, the rural Missouri town where their legacy is being preserved in a space museum.

And Robb and others see a commonality in Stofiel, a self-taught rocket scientist. At the start of the space program, every engineer had to be self taught.

"Just think of all the rockets that blew up in the late '50s and '60s trying to develop reliable launch vehicles," says Ron Jones, a Boeing engineer whose aerospace career began in the early 1970s – more than a decade after McDonnell Aircraft launched the first Mercury flight that proved rockets could indeed take men to space without exploding.

"It's just darn tough to build a rocket; it's probably the most difficult thing we can do, period," Jones adds. "Brian is going through the same process right now, and he's using a radical, contemporary approach to achieve it."

Stofiel's approach impressed Jones just as it did Robb, whose work on the Mercury program involved endless, painstaking efforts to shave ounces of metal from the heavy capsule.

But instead of designing a metal rocket for peak efficiency and lowest weight, as early space engineers did, Stofiel went one step further.

He got rid of metal entirely.

On a recent Saturday morning, Stofiel leans back on his living-room couch. On the wall above him are two bronze-plated flintlock pistols and a framed photo of a southwestern desert scene. Stofiel is getting over a cold. He's wearing a worn company T-shirt and a pair of dusty jeans.

Stofiel, admittedly, would not fit into the clean-cut world of 1950s aerospace engineering. Shortly after his birth in Joliet, Illinois, his family moved to St. Louis, where his father and grandfather introduced him to the joys of model rocketry in Carondelet Park. As an adult, Stofiel returned to his hometown after multiple career changes, including a stint in an Air Force electronic-warfare unit and a job repairing medical equipment.

Like his father before him, he bonded with his daughter over launching things into the sky. Instead of hobby rockets, though, he set the five-year-old's sights on a 50-pound satellite.

"And then I ran into a problem," Stofiel continues. "It was going to cost us \$2 million to get that satellite into space, so I went to my daughter. She's like, 'I guess we gotta build a rocket.'"

It's a story that Stofiel has clearly practiced, an adorable (and true) anecdote honed over years pitching his company to investors and conference audiences. At times, Stofiel naturally lapses into the jargon of the startup world, enthusing about the potential for "disrupting" the space industry, or noting that he's "bootstrapping" the company — when what he simply means is that he's gotten other jobs while funneling every cent to the

startup. Between his own resources and his family's, he claims he's invested \$750,000 into putting the Boreas into space.

On March 27, 2015, he launched his first test rocket, Bella R1, named for his daughter.

"I started designing the rocket from everything I knew from the other industries I worked in," Stofiel says. The Boreas' design elements, for instance, were inspired by his work in medical imaging. He built the guidance computer with elements he'd learned in the Air Force.

But the heart of Stofiel's promised disruption is the process that turns a 3D printer's plastic into a hard, heat-absorbing ceramic — a transubstantiation that raises the material's melting point from 200 degrees to more than 2,000. Stofiel says the process — for which he has applied for a patent — was inspired by his observation of cooling systems in nuclear power plants.

"The heat gets retained," he explains of the chemically treated plastic in his rockets. "With my ceramic nozzle, you can walk up as it's firing and hold it in your hand if you really wanted to. The outside is 70 degrees."

For observers like Jones, of Boeing, Stofiel's invention seems nothing short of revolutionary. Initially, Jones says, "I thought he was a bit wacky." The idea of building a rocket out of plastic seemed "totally outlandish, ridiculous." But seeing the plastic Stofiel developed, along with the system that worked with it, changed his mind. "Brian's a visionary," he concludes.

Despite promising results, though, Stofiel has struggled to package his breakthrough in the data preferred by professionals. While he was living in Cleveland, Stofiel claims to have approached scientists at that city's NASA

Glenn Research Center. He was looking for a software simulation to describe the various forces inside his rocket. In response, Stofiel says the scientists told him to take a hike — no software, they said, could simulate what was happening inside a heretofore unknown rocket design in the moments after ignition.

"We didn't have a starting point; it was too complex," Stofiel says of his research. "Unlike what's been happening the last 20 or 30 years in aerospace, we couldn't simulate the problem in the computer."

The solution, says Stofiel, was "firing rockets as cheaply as possible to collect the data." There was so much basic information to ascertain: What was the rocket's thrust? How did the gas behave while moving through the nozzle? What was the pressure of the combustion chamber?

On that last point, says Stofiel, "It took us 37 test fires to finally figure out how to sensor that."

The test fires steadily filled in the data. In 2015, Stofiel launched two rockoons into the atmosphere, a risky venture that he carefully describes as "legal under the spirit of law." Although both the rockoons' rockets fired, neither was designed with sufficient power to break through the atmosphere. But to Stofiel, the results were still hopeful.

But by the time Stofiel moved back to St. Louis in 2016, his primary obstacles weren't technological. The next benchmark would require his company to launch rockets to 62 miles above sea level, the division between Earth and space known as the Karman Line.

Stofiel believes Boreas is ready. The only thing stopping the launch is money.

Before launching at the Karman Line, Hermes will need to be fitted with a specific transmitter that allows federal agencies to follow its flight — "The government wants to be able to track your rocket quickly," Stofiel notes — and it comes with a cost of some \$30,000. Each full-sized Hermes rocket adds another \$10,000 to the bill, and Stofiel wants to prove his doubters wrong with an ambitious demonstration: firing three rockets in three days.

He had hoped to arrange the shots at the Karman Line earlier this year, finally proving that his plastic rocket engine is more than a basement fantasy. But he has yet to do one. He says that the company is now aiming for a launch this summer.

"Most people think funding just occurs," Stofiel says, noting that around 100 other companies in the U.S. are developing rival technology to launch payloads cheaply into low-earth orbit. The competition forces companies to play the long game.

"It's common to not get investment for ten years in the space industry," Stofiel says. Even so, his impatience is audible. After all, he believes that he's already got a launch vehicle ready to go to space.

"I can build out a rocket in 83 hours," he adds. "You give me the money, and I'll build it."

Rising from the sofa, the CEO of Stofiel Aerospace pulls on a pair of boots and clomps down the stairs to his basement. To the right is the family room with a table and the sewing machine where he stitches his company's logos

on jacket patches. To the left lies the workshop, where a rocket-assembly line occupies two shelving units and three 3D printers.

Stofiel grabs two ends of a rocket, fitting the cylinders together to form a small-scale version of the Hermes. Its two meters of length barely clear the low basement ceiling.

With rocket-launch plans in stasis, Stofiel is turning to plan B — marketing and selling his heat-absorbing invention in the form of motorcycle exhaust systems. He's building a large kiln in his backyard to accommodate the new orders. He hopes the sales will supply funding for his space project.

Maybe it's not how SpaceX or Boeing would fund their research, but there is no guidebook to starting a space business, just as there was no guidebook for McDonnell Aircraft when it set to work building the Mercury. If Stofiel had that company's resources, he could throw a lab full of engineers at every question mark and buy rocket test after rocket test to document the wobble of every data point.

But it's been 58 years since Mercury's first mission, and Stofiel expects the space industry 2019 to be more open, a marketplace of possibility instead of a closed laboratory for the rich. He's got a rocket and a plan, and that's enough for him. It's also enough for some of his fans on Mac's Old Team.

"That's what the Mac guys really did tell me," Stofiel says. "They said, 'Stop trying to understand it. You've got something that works. Go use it.'"

At the entrance to the Grissom Center in Bonne Terre, visitors are greeted by a wall-sized quotation attributed to the engineers

of the McDonnell Aircraft Corporation: "We solved 100 unsolvable problems every day."

On a recent Saturday morning, three members of Mac's Old Team hold court around a circular table in the museum gift shop. They've already enjoyed a breakfast of cookies and coffee, and as a group of Girl Scouts noisily files into the museum, the three former engineers discuss Stofiel and his plastic rocket.

Earl Robb is just as enthusiastic as ever, but Dean Purdy, who worked as an electrical engineer on Mercury, had previously visited Stofiel's basement workshop and watched closely as Stofiel's plastic rockets caught light. He came away from the demonstration with interest, but also a familiar wariness.

"Compared to what we had, he's way ahead of the game," Purdy concedes. But he points out that some of the rocket tests in Stofiel's backyard had misfired, raising questions about what would happen to those same engines miles above the ground.

"It's the same thing we went through on Mercury," he says. "You go back to the drawing board, find out what happened, and do it over again."

Purdy is dressed in the museum's uniform, a blue polo shirt with his name stenciled on the left breast. The museum is a rather unusual one: Its home of Bonne Terre is a rural town of 6,000 known for its mining history and state prison. The town had no role in the twentieth century's race to space.

But the museum's founder, Earl Mullins, grew up in the 1960s. He'd watched the first Mercury launches on TV as a child. A lifetime later, in 2005, Mullins opened the museum as a passion project.

McDonnell Aircraft did no business in Bonne Terre. But four years ago, the company's former engineers began volunteering their presence, welcoming visitors and lending expertise to guided tours. When the museum expanded, Mac's Old Team assembled to assist with construction of the new exhibits.

Purdy ambles over to watch Mullins welcome the Girl Scouts to the museum. Mullins conducts the tour like a rural Bill Nye, and his voice booms unaided as he directs the group's attention to an original McDonnell drafting table, used by Purdy and other engineers tackling their daily allotment of unsolvable problems.

Though the quote is a fanciful piece of boasting, a photo on a nearby wall proves it wasn't entirely empty. The black-and-white image shows a group of 92 engineers clad in white lab coats and white caps. They're seated around the squat metal bullet of the 2,300-pound Freedom 7 capsule, a product of the Mercury program. After years of testing and failures, it became the first American craft to deliver a human to space.

Back at the gift shop, Purdy rejoins Robb and a third retired engineer, Lou Mavros.

Mavros' résumé could easily double as a comprehensive history of American space flight. If it had to do with space, Mavros probably worked on it, starting from the earliest rockets designed to lift Project Mercury to

the massive machinery required to transport, fire and fuel the fleet of shuttles.

The process wasn't always straightforward, and no system was foolproof. In the beginning of his career, Mavros notes, the biggest challenge was the Atlas booster rocket, whose design amounted to a bomb with skin as thin as a dime. It contained enough pressurized liquid oxygen to produce 300,000 pounds of thrust, or just enough to break into low-earth orbit.

"That early Atlas was nothing more than a stainless-steel balloon," Mavros says. "If the pressure got too high, the whole thing would explode."

And indeed, during Atlas' development, the rockets exploded with a distressing regularity, often within sight of the astronauts in training. Even the Atlas' critical safety devices were prone to exploding.

"I was testing a valve," Mavros recalls. "The first time, the thing blew. We blew all the air-conditioning ducts off the ceiling."

Those are the sorts of accidents that become disasters, and while the Mercury and Gemini programs concluded with no fatalities, it wasn't always so. In *The Right Stuff*, Tom Wolfe told the story of the fighter-jet pilots who preceded the first astronauts, racing past the speed of sound in rocket-powered aircraft. The peril they faced was real; an appalling number died in fiery accidents.

That danger persisted into the age of the space program. In 1966, two Project Gemini astronauts died in a catastrophic wreck when their training jet crashed at Lambert Field. A tragedy like the Challenger flight, in which the shuttle broke apart and killed seven people, may seem today like an

anomaly, but the space race was built on blood, and every success stood on the shoulders of past failure. The museum is a good reminder of that: Its namesake, Gus Grissom, died on the ground in a cabin fire on Apollo 1.

No lives are at stake in Stofiel's experiments. But the odds are against him. Despite its apparent simplicity, the odds rarely favor attempts to launch something more than 60 miles above sea level, past the Karman Line and into space. Stofiel's backers may burst with enthusiasm for a non-metal rocket, but Purdy has seen this road before.

He advises prudence.

"The process he's going through now is to prove his launch system can actually launch," he says. "And that has yet to be proven."

And the launch is just the beginning. Purdy runs through a rapid list of possible problems: The plastic nozzle is impressive on small rockets, but will the full-size version melt before it hits orbit? Can the rocket nozzle withstand more than a minute of rocket burn? How accurate is the guidance system? How many satellites can it successfully deploy? Can its reentry vehicle protect fragile cargo from the force of slamming back into the atmosphere?

Two weeks later, Stofiel is working in his backyard. He's lying on his stomach, his face inches from the rear of a test rocket engine wedged in a hole in the lawn that's been braced by a layer of bricks. The ground is wet from recent rain and snow storms, and the air somehow feels both humid and freezing. These conditions are poor for rocketry. Stofiel brushes hair out his eyes, straightens up and steps back, evaluating the launch site.

Stofiel signals to an intern — a local high school sophomore — that it's safe to hit the ignition switch.

There is no flame. Instead, there is a pop, and then nothing. Not even a whiff of smoke.

Stofiel sighs. "I think we burned all the fuses," he says, and he crouches down to pick through the wiring with a fingernail.

The entrepreneur starts walking back to the house. He has more fuses and rockets in the basement.

"It happens, man!" Stofiel shouts back to the intern. "This is all normal. This is just how it goes."