Shooting the Moon

Internet multimillionaire Elon Musk bets his entire fortune developing a subcompact rocket that could make outer space as accessible as cyberspace.

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Photography by Misha Gravenor
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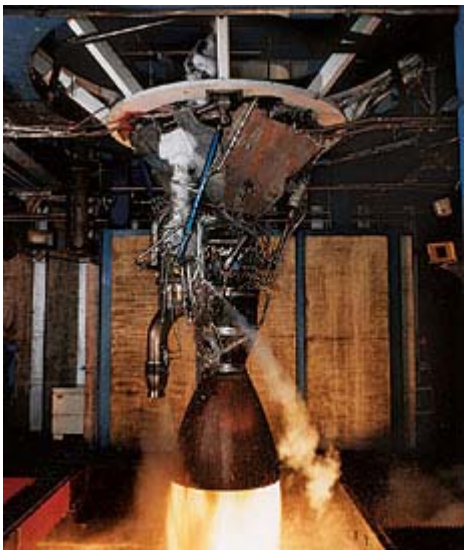
On a sparkling morning at Vandenberg Air Force Base on the California coast, the answer is clearly yes. All around are towering launch-pad gantries that have sent dozens of big, expensive, aggressively not-cute rockets skyward since 1958. But rising out of the base's lupines and sage is a plain, white "event tent"—one that would look more natural at a bar mitzvah than here at big-league rocketry's West Coast headquarters. And inside, lying on a semitrailer, is Falcon I.

At 70 feet, it is barely one-fifth the length of a Saturn V, the rocket that propelled Apollo astronauts to the moon. Technicians could straddle the hull, which is five and a half feet in diameter, like Slim Pickens riding the nuke in *Dr. Strangelove or: How I Learned to Stop Worrying and Love the Bomb*. While most rockets have three or four stages, this one has just two, and it runs on refined kerosene that costs less per gallon than regular unleaded at a California gas station. At the moment, 10 engineers are running it through a pre–test-fire check, a job that for most rockets requires a cast of hundreds. Watching them swarm over the little craft, one can't help but reflect that the name Falcon seems a stretch: Were Sparrow and Titmouse taken?



READY TO ROCK

Bolted down and roaring away at a test facility in McGregor, Texas, the Merlin engine that will power the new Falcon I rocket at liftoff mixes kerosene and liquid oxygen at 785 pounds per square inch, then blasts out 75,000 pounds of thrust. "We have run 17 tests in one day," says Dean Ono, a senior propulsion engineer for the upstart rocket manufacturer Space Exploration Technologies, or SpaceX. "That's a month's worth of testing at a big company."

But this unassuming subcompact promises to dramatically slash the cost of putting satellites into orbit and maybe even resurrect America's moribund space effort. Falcon I is the first rocket produced by Space Exploration Technologies, SpaceX for short. The three-year-old El Segundo, California, firm aims to loft 1,400-pound payloads into orbit for a dirt-cheap $6.5 million a pop, as opposed to the roughly $30 million charged by the next-cheapest aerospace company, and that's just for starters. The company has already begun prototyping and selling payload space for a larger rocket and hopes eventually to offer both manned and unmanned vehicles for one-tenth the current standard price. "Getting to the moon in 10 years is definitely doable," says SpaceX vice president Chris Thompson.

Indeed, for a small company, the SpaceX principals tend to think very big. Chairman and CEO Elon Musk, an Internet multimillionaire who is personally bankrolling the

whole effort, says his ultimate motivation for starting the company is no less than saving humanity from suicide. “Sixty years ago, we didn’t have atomic weapons. What might we have 60 years from now?” he muses. “Establishing a self-sustaining second human civilization on Mars” is, in his view, “the most important goal. If you need to back up your data, then backing up the biosphere is important too.”

Musk’s boldness runs throughout the 130-person enterprise, which fills four industrial buildings just south of Los Angeles International Airport. On the surface, SpaceX could be mistaken for a California-casual, surfer-dude outfit: T-shirts and jeans are de rigueur, the company sponsors staff outings to *Star Wars: Episode III–Revenge of the Sith* and other geeky flicks, and one of the chief testing engineers is a tattooed 23-year-old. But the managerial staff, mostly recruited from big aerospace’s upper echelons, is deadly serious and plans to show Boeing and Lockheed Martin no more mercy than Wal-Mart does old-line department stores. “What those companies are charging to put something into space is nothing less than highway robbery,” declares Thompson, who should know; he managed production and testing at McDonnell Douglas, now part of Boeing, for 15 years. “They say they are commercial, but the truth is they are overregulated, overstaffed government programs. We definitely want to take all of their business.”

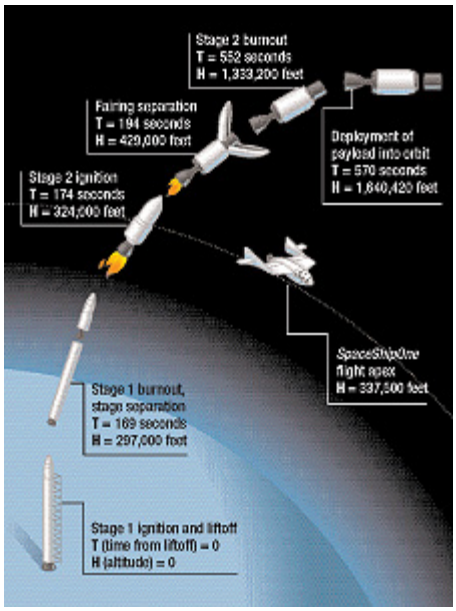
“We are going to start a revolution,” agrees Tom Mueller, vice president of propulsion, who formerly ran rocket-engine development for TRW, now part of Northrop Grumman.

Outside observers aren’t quite so sure, but they grant the effort respect. “They are young and inexperienced, but they are doing the right things, and I think they will make it,” says Robert Sackheim, chief propulsion engineer at NASA’s Marshall Space Flight Center. He adds that it’s about time. Thirty years ago, he says, U.S. aerospace firms handled about 80 percent of the world’s launches; now, it is closer to 20 percent. “Today there are at least 30 spacefaring countries. We’re slipping behind. We’re on the verge of going out of business in space.”

Still, this is rocket science. Gravity is heavy, atmosphere is thick, rockets—even simple ones—tend to explode, and the corporate testing ground is strewn with private orbital-services start-ups that have crashed and burned. Maverick aircraft designer Burt Rutan captured the Ansari X Prize in 2004 by lofting his manned, reusable rocket plane *SpaceShipOne* into space, but that was a suborbital flight requiring about 2 percent of the energy needed to reach and maintain orbit. Whether SpaceX sends just one payload whirling around Earth—much less a colony to Mars—depends on many slippery variables, not least of which is the mettle of its main man.

REACHING NEW HEIGHTS

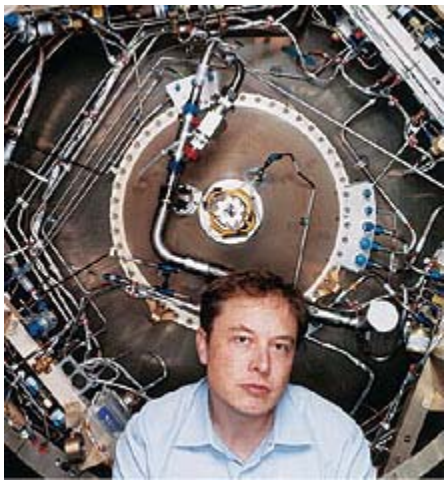
SpaceX’s Falcon I is an unmanned two-stage rocket with a reusable first stage that will parachute to a water landing soon after liftoff. The upper stage is designed to boost a satellite into orbit 317 miles above Earth’s surface. If successful, Falcon I will reach much greater heights than *SpaceShipOne*, which was developed by Burt Rutan and his aviation company, Scaled Composites, and garnered the $10 million Ansari X Prize in October 2004 as the first privately financed craft to carry three people to a suborbital altitude of 100 kilometers, or 62.5 miles. For his part, SpaceX CEO Elon Musk hopes that Rutan and other private rocketeers will stay in



Graphic by Christoph Niemann

the game. “This supersedes competition,” he says. “Frankly, I think it would be a good thing if there were other companies besides SpaceX pursuing low-cost access to space orbit and beyond.”

Elon Musk is 34 years old, worth hundreds of millions, owns two jets, and even has straight teeth, so it’s quite natural to hate him. Unfortunately, in person he turns out to be a chatty, self-deprecating fellow who’s virtually impossible to dislike. Born in South Africa, he has a not-quite-British accent and an arid wit: “When people ask me why I started a rocket company, I say, ‘I was trying to learn how to turn a large fortune into a small one.’ ”



RESTLESS ROCKETEER

“I could be sitting on a beach in front of the world’s finest hotel drinking mai tais. In fact, I could buy the hotel, I suppose,” muses SpaceX CEO Elon Musk. “But I could only take it for a few days.” Instead Musk (seated here in front of the second-stage engine, dubbed Kestrel) has invested his dot-com millions in Falcon I. “Somebody who is wired to do high-intensity things can’t switch to low intensity without getting a lobotomy,” he says.

If he succeeds, poverty won’t be a new experience. At age 17, he left home to enroll at Queen’s University in Kingston, Ontario, subsisting on less than $1 a day—he calls it a forced experiment in avoiding scurvy—before landing a scholarship and earning an undergraduate physics degree at the University of Pennsylvania. Enrolled in a doctorate program at Stanford University, he dropped out after just two days to start a media-services software company called Zip2 in 1995, which he sold in 1999. He then cofounded PayPal, the world’s leading electronic payment system, and sold it to online auctioneer eBay in 2002. As a major shareholder in both ventures, his resulting net worth has been estimated at $324 million. Asked if the figure is correct, he shrugs: “That depends on how you value SpaceX.”

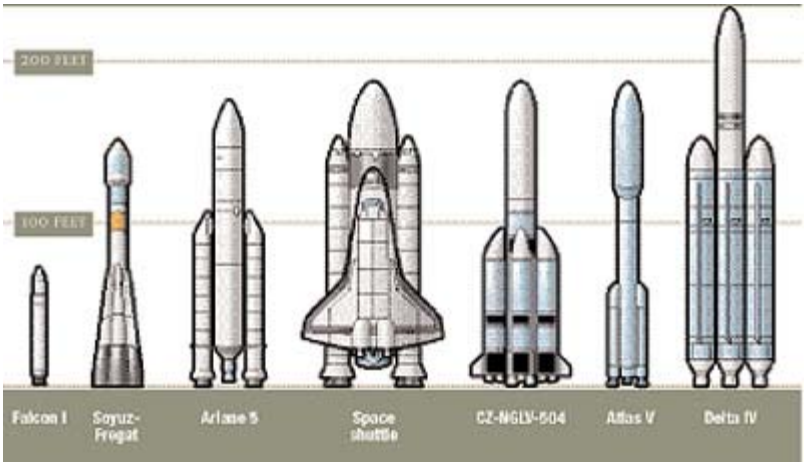
Musk decided to found the company after a 2002 feasibility study convinced him that "there is nothing inherently expensive about rockets. It's just that those who have built and operated them in the past have done so with horrendously poor efficiency." A major problem, he found, has been the bureaucratic tendency to cling to obsolete hardware. "The space shuttle still uses reel-to-reel tape recorders with less data capacity than a ThumbDrive," he says, shaking his head. "They have to search for replacement parts on eBay." He also found that the staffs behind rockets such as Boeing's Delta IV tended to number in the thousands, but he knew from his Internet days that smaller working groups could execute projects far more quickly.

Sackheim, who consulted with Musk in the early days of SpaceX, concurred that big aerospace could learn a thing or two from leaner, more nimble Silicon Valley organizational structures. "While Moore's law has been making chips so much better, at the same time we have been going backward in rockets," he says. "What we have now is no better than the V-2."

Confident of an opportunity, Musk immediately began plucking top young talent from leading aerospace firms. "It was very scary, but it was also a dream come true," recalls Mueller of the early days. "I can't tell you how many times people said it can't be done."

SMALL WONDER

Knee-high to typical American, European, and Russian rockets, the Falcon I aims to do to spacecraft what the 1960s Volkswagen Beetle did to oversize, overpriced cars. Musk's goal is to shake up and revitalize the rocket industry in America. "There has not been a forcing function to make the big aerospace companies lower costs," he says. "In any industry, things improve when new entrants come in."



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From the start, SpaceX has hewed to one sacred principle: simplicity. "It's our mantra because it gets you both reliability and low cost," says Musk. Falcon I's engineers began by focusing on an efficient engine. In the last 30 years, only two new American rocket engines have been developed. SpaceX designers "literally began with a clean sheet of paper," says Mueller, grinning at the memory. "We said, 'What thrust do we need, what payload do we want,' and we went from there."

Chewing on a bran muffin (there are full kitchens and abundant munchies in all four of the El Segundo buildings), Musk waves a hand at the production floor, where technicians built the Falcon I's space-grade 2219 aluminum alloy fuel tank, its first-stage engine, dubbed Merlin, and the upper-stage engine, called Kestrel. Both engines

were birthed via the mantra of simplicity. “Just one engine per stage and just two stages,” says Musk. “We think it’s the simplest configuration you can have and still get something useful into orbit.”

A freshly built Merlin gleams in a corner of the clean room. An example of what rocketeers call a pintle engine, even to a lay observer it is brilliantly straightforward, with one high-pressure coaxial fuel injector to mix rocket-grade kerosene and liquid oxygen instead of the hundreds of smaller injector holes used in other rocket engines. “Getting the Merlin right was the hardest single thing,” says Musk, who says that during testing, the engine had its share of RUD events (short for rapid unscheduled disassembly—who says rocket scientists aren’t funny?). But rigorous runs at the company’s 300-acre test site in McGregor, Texas, have persuaded him that Merlin is a trouper, reliably cranking out 75,000 pounds of thrust. It also has the marvelous capability to be shut down whenever engineers want. That will allow the launch crew to hold Falcon I on the launchpad, firing away, until they are convinced all systems are go, or if not, to stop the engine. Solid-rocket boosters such as those on the space shuttle can’t shut down once they are lit.

Merlin is the key to SpaceX’s long-term success. Once Falcon I establishes a track record, SpaceX plans to cluster five Merlins to propel the first stage of Falcon V, the next launch vehicle, which will be capable of lofting 10,000-pound payloads into orbit for about $15.8 million a shot. That compares remarkably well with the $60 million per flight Boeing charges for its Delta IV. Having just one kind of first-stage engine in all of its rockets “is like Southwest Airlines deciding to use only 737s,” says Musk. “It simplifies everything.”

But that’s hardly all there is to Falcon’s efficiencies over present-day spacecraft. For example, 80 percent of Falcon I’s components are designed to be parachuted back earthward, fished out of the ocean, refurbished, and used again. Flotation won’t be a problem. “With the fuel tank empty, it will be like an empty beer can,” says Musk. Falcon V is configured to be completely reusable—the first fully reusable orbital vehicle. Musk hopes to get at least 100 flights out of the components.

For the rocket as a whole, Mueller, Thompson, and their fellow designers exploited bleeding-edge technologies such as computer-controlled parts machining, lightweight carbon-fiber materials, and GPS-aided guidance systems. Falcon V’s avionics components will chat with each other via Ethernet, the same technology that connects devices in home and small-office networks. And the booster tank’s seams are friction stir welded, an exotic technology that knits materials with high pressure and friction rather than globs of weak, imprecisely added metal.

One of the most revolutionary changes is that all of SpaceX’s rockets will be constructed in the El Segundo machine shop, then trucked to launchpads, ready to go. Other rockets are often slowly and painstakingly built on the pad. “We’re treating these like airplanes—that’s our model,” says Thompson.

Falcons I and V also promise to be versatile. SpaceX has hammered out deals allowing launches from Vandenberg, Kodiak Island, Cape Canaveral, Wallops Island, and the Marshall Islands, and that means satellite payloads can be put into virtually any orbit.

On paper, of course, lots of grand

EASY ASSEMBLY

Falcon I rises modestly out of Vandenberg Air Force Base's scrubby brown hills. "It takes some rockets two or three months to get stacked, assembled, and checked out on the pad," says Tim Buzza, who runs SpaceX's test and launch operations. "But when we stand our rocket up, it is essentially ready to fly." SpaceX's second flight will depart from Vandenberg, possibly in December. The first will launch from the Marshall Islands in October.

adventures make sense. But third-party studies back up Musk's confident predictions. A design-reliability analysis by the Futron Corporation placed Falcon I's expected failure rate at a mere 2.8 percent. That's lower than the predicted rate for any other contemporary American launch vehicle, including the Pegasus XL made by Orbital Sciences, Falcon I's direct competitor in the small-payload market. Orbital charges roughly $30 million per flight.

The ultimate success in rocketry is doing it. But when Tim Buzza, SpaceX's vice president for test-launch operations, gazes fondly at the little rocket resting in its truck-bed rack at Vandenberg, he's quite certain that if there are any surprises, they will indeed be surprises. "We have looked at every single failure in every rocket out there and analyzed how that applies to our vehicle," he says. "If we fail, we will at least fail in a new way."

The pleasant twisting drive up California Highway 101 from the El Segundo factory floor to Vandenberg takes three hours. The 155-square-mile tract hardly seems like a place to launch rockets, with its breathtaking oceanfront cliffs and rolling hills for which developers would gladly fork over a few billion dollars. The Air Force gave SpaceX a license to use Space Launch Command Three West, a rundown Atlas launchpad on the base's west side. It has not been used for about a decade. Essentially a concrete pillbox with a launchpad on its roof, Three West was plucked clean by Air Force–sanctioned salvagers right down to the plumbing; a portable latrine services the SpaceX launch crew. "The guys working up there can get a little scruffy," says Dianne Molina, SpaceX's marketing manager.

Falcon I arrived here by truck on April 24, cloaked by a tarp. "We really have to cover it in transit," says Anne Chinnery of the launch operations team. "If people see a big missile being hauled on the public roadways, they can get a little overexcited." At the launchpad, she and the crew monitor the rocket's systems out of another SpaceX innovation—a sleek mobile launch-command trailer tricked out with laptops and plasma screens that makes Houston's Mission Control Center look like a cold-war relic.

The maiden flight of Falcon I was originally scheduled for this August, and the first payload was supposed to be a 250-pound Department of Defense–Naval Research Laboratory experimental communications satellite called TacSat-1.

But as launch day approached, SpaceX hit a snag. Air Force rules require that the Titan 4 rocket on a nearby pad launch first, on the off chance that the Falcon I's flight, which would pass nearly overhead, might fail and rain damaging debris. And the Titan flight was unexpectedly pushed back indefinitely.

PRECIOUS PAYLOAD

Roughly 12 feet tall and made of aluminum alloy, Falcon I's nosecone fairing will protect a satellite during liftoff, then open like a clamshell to release it once orbit is achieved. Will human beings ever ride in SpaceX rockets? "We are not quite ready to talk about our plans for human flight, except to say we are definitely headed that way long term," says Musk.

Instead of waiting out the Titan flight, the SpaceX team decided to pack up the rocket and move it to another launch site. "Our first launch will now be from our island launch complex in the Kwajalein Atoll" in the Marshall Islands, says Molina. The payload: FalconSat-2, a 43-pound space-plasma monitor built by Air Force Academy cadets.

While the launch location has changed, the imperative remains the same. A great deal is riding on the first attempt, which is scheduled for October. "Right now, we are simply alleging we can get into space," says Musk. But, citing the Futron study, he says, "The odds look good, touch wood." With that he taps his forehead.

Even if Falcon I fails, Musk's pockets won't be empty. By launch day, he estimates, he will have spent about $100 million, but he is willing to dig deeper if necessary. "I will give it everything I've got," he says. "I will keep funding this until there is really not much left. My wife will be upset with me if I sell the house, but aside from that . . ."

How many failures could he finance?

"Three."

Back in El Segundo, as Musk and I chat, my gaze drifts to the only decoration in his spartan cubicle (typical of an egalitarian dot-com manager, his office is as accessible—and not much larger—than anyone else's). It is a blowup of the famous first-round photo of the 1965 Muhammad Ali–Sonny Liston heavyweight-title fight. A defiant, glowering Ali cocks his right arm over the knocked-out Liston, as if daring the older fighter to struggle to his feet and suffer another punch. Musk smiles. "That's our competition," he says, jerking a thumb at Liston's supine form. "Although it's not really about beating up Boeing and Lockheed."

No, it clearly is not. Musk was obviously sincere when he spoke of wanting to back up the biosphere and save humanity, and I doubt that this genial South African whiz kid derives much motivation from a hatred of big American aerospace. On the other hand, it seems extraordinarily unlikely that Musk's rocket will suffer three failures in a row, which means the company is likely to survive, which means that those old-line companies would do well to keep their guard up. As Liston discovered, an aging champion who dismisses a young, cocky—and, perhaps, cute—adversary can easily wind up on the mat, wondering what the hell hit him.