You're

You're the pilot

Flying *SpaceShipOne* with Mike Melvill and Pete Siebold

BY JASON PAUR

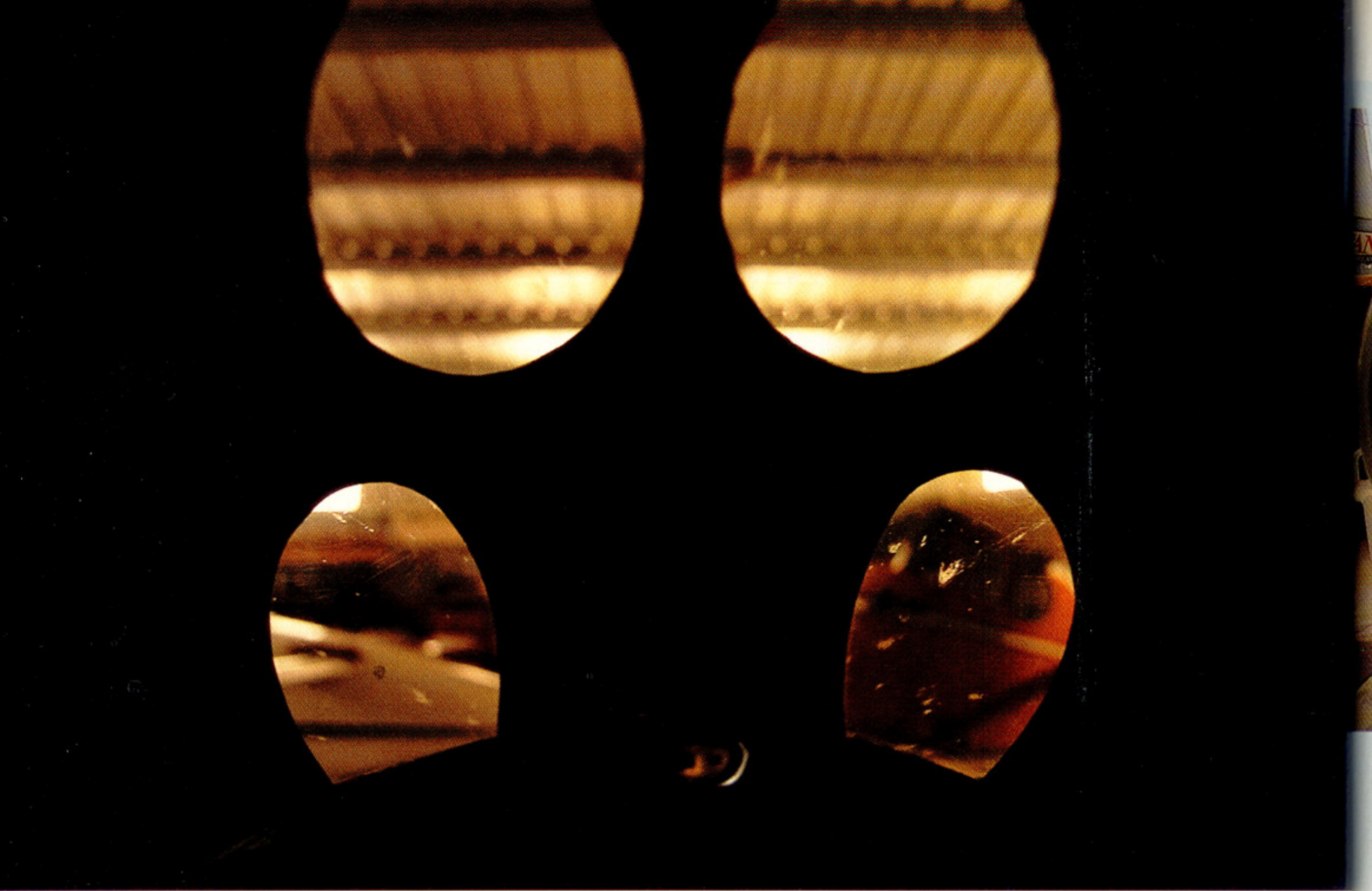
On a clear but breezy summer day, *SpaceShipOne* pilot Mike Melvill and I have just passed through "high key" above Mojave Airport in California. It's *SpaceShipOne's* entry point for a modified 360-degree approach pattern for Runway 30 (*high key* is how test pilots refer to an engine flameout pattern where the aircraft is positioned over the end of the runway at a high altitude). We're at 8,500 feet msl, Mojave is at 2,280 feet, and because of the limited forward visibility, I see the runway one-half mile off the right side of the aircraft through one of the porthole windows.

"One hundred thirty-five knots indicated, descending at 2,500 feet per minute," I hear through the headset. Moments later we start a right turn. "Passing through 7,200 over the runway, 135 knots, everything looks good." The rush of air outside the cockpit adds to the falling sensation from the steep approach. And despite the fact that the airport is still almost 5,000 feet below us, Melvill is careful not to let the winds blow us too far east. Because *SpaceShipOne* is a glider, he can't use power to get us closer to the runway if we wander from the planned teardrop approach.

On the downwind we're still dropping fast. "There's low key, 5,500 feet, 135 knots." We're now abeam the numbers and starting the 180-degree arcing turn to final. Despite still having more than 2,500 feet below us and the runway just off the right side, Melvill says making the runway in

***SpaceShipOne* (attached to *White Knight*) sits outside the Scaled Composites' hangar at the unveiling in June 2003, before thermal protection was added to leading-edge surfaces and the nose (far left). Turning on final more than 2,500 feet agl for Runway 30 at Mojave during a "*SpaceShipOne* approach" in a Long EZ (inset).**

PHOTOGRAPHY BY THE AUTHOR



SpaceShipOne can be difficult from this far out.

Turning to final we've managed to keep some altitude. "The runway is made, 130 knots; this is where the gear goes down." With the gear down, *SpaceShipOne's* glide ratio drops from roughly 7-to-1 to about 5-to-1 (if the gear were to inadvertently deploy before entering the pattern, high key would be raised to 13,200 feet).

The runway fills the view out front as our approach steepens.

On short final, the nose is still pointed down. This sight picture takes some getting used to, especially because we're still maintaining so much speed.

With our touchdown point at one-third the distance down Runway 30, we begin to flare at about 20 feet with the indicated airspeed dropping to 115 knots. This is where the lack of visibility is noticeable; in *SpaceShipOne*, you can't see the runway as you flare, so a chase pilot calls out the wheel height until contact is made.

We float a bit at first. There isn't the large sink rate you'd expect from such a stubby-winged glider. The wings on the aircraft we're flying—the Long EZ that Melvill and Brian Binnie used to become the first civilian astronauts in space—aren't that stubby, of course. Melvill says the float is the only part of our approach in the Long EZ that doesn't replicate the real thing in *SpaceShipOne*.

"In the spaceship we would have just settled right down on the runway," he explains. "With the Long EZ you'll just float all the way down the runway." Eventually the wheels do make contact, with some encouragement from the stick, and Melvill applies full power as we begin our climb for another "*SpaceShipOne* approach."

Simulator training

We're practicing approaches in one of several simulators—flying and ground-based—that the *SpaceShipOne* team used to hone their flying skills before the historic flight last June that put Melvill into space. The airplane we are flying approaches in is Melvill's own Long EZ, which he built more than 20 years ago and has flown around the world. He and Binnie used it numerous times to practice the base-tofinal part of the *SpaceShipOne* approach. Cardboard covered the inside of the cockpit window—minus four small holes cut into it—to replicate the limited visibility of *SpaceShipOne*.

"It's a damn good simulator," Melvill says of his Long EZ's ability to replicate the spacecraft on final. "With the gear and speed brake down and the power pulled, the approach speed and rate of descent are identical to the spaceship. Even the position of the main gear is pretty close," he adds.

Simulation was the secret for the *SpaceShipOne* team. No wind-tunnel testing was done, but hundreds of hours were flown in a ground-based computer simulator. Dozens of hours also were flown in *White Knight*, the aircraft that carried *SpaceShipOne* to altitude before dropping the spacecraft and which can be configured to fly like the spacecraft. And there were several hours spent lapping the Mojave pattern in Melvill's Long EZ. But the most valuable training and development tool was the ground-based simulator. "Pete just did an incredible job with that thing," says Melvill.

Pete is Peter Siebold, the 34-year-old test pilot, engineer, and software developer who designed, wrote, and tested all the software that ran the avionics for

***SpaceShipOne* pilot Mike Melvill (above) flew simulated flights in his Long EZ in preparation for the actual flight in *SpaceShipOne*. To replicate the limited forward visibility in *SpaceShipOne*, Melvill covered the inside of the Long EZ canopy with cardboard (above), which had four small holes cut into it, mimicking the spacecraft's cockpit.**

both *White Knight* and *SpaceShipOne* as well as the simulator. This work was in addition to flying both aircraft, including the first flight above 100,000 feet on only the second powered flight.

The ground-based simulator Siebold designed is a full-size mock-up of the *SpaceShipOne* cabin, right down to a paper cutout of the Garmin GPSMap 296 like the real thing found in the cabin. Much of the flying in both aircraft and the simulator is instrument based with a single-screen flight-director display linked to a GPS inertial navigation system. The package is called the TONU (pronounced *tuh-noo*, Tier One Navigational Unit). The simulator includes a view of the surroundings via 11 computers with monitors bolted to the outside of the side porthole windows and a rear projection screen placed in front of the four front windows.

With ground-based sim flights in the thousands, Siebold became very familiar with the return flight to Mojave. "So I flew it inverted several times just to mix things up. If I could do it inverted, I was really confident I could do it upright. I remember thinking after my first real flight that, wow, that was just like a simulator flight—it was that close to the real thing."

In the cockpit

All the practice in the ground-based simulator makes the cockpit of *SpaceShipOne* feel as familiar to the pilots as a Cessna 152 does to a flight instructor. The pilot sits in the center of the cockpit with two seats behind him. Directly in front of the carbon-fiber seat is the stick topped with a grip the team found advertised for crop dusters. Pitch trim is controlled by a switch on top of the grip. In the completely manual *SpaceShipOne*, the stick is attached to pushrods and cables to control the elevons; there are no hydraulic or fly-by-wire systems.

"The only stability this thing gets is mechanically from your hands and feet or electrically from the trim switches," Melvill says, admiring the true stick-and-rudder nature of the flight. "It's the pilot's brain that's keeping this thing on track. There's no autopilot or even augmented stability, not even a yaw damper." The trim control and stabilizer adjustment are operated by electric motors.

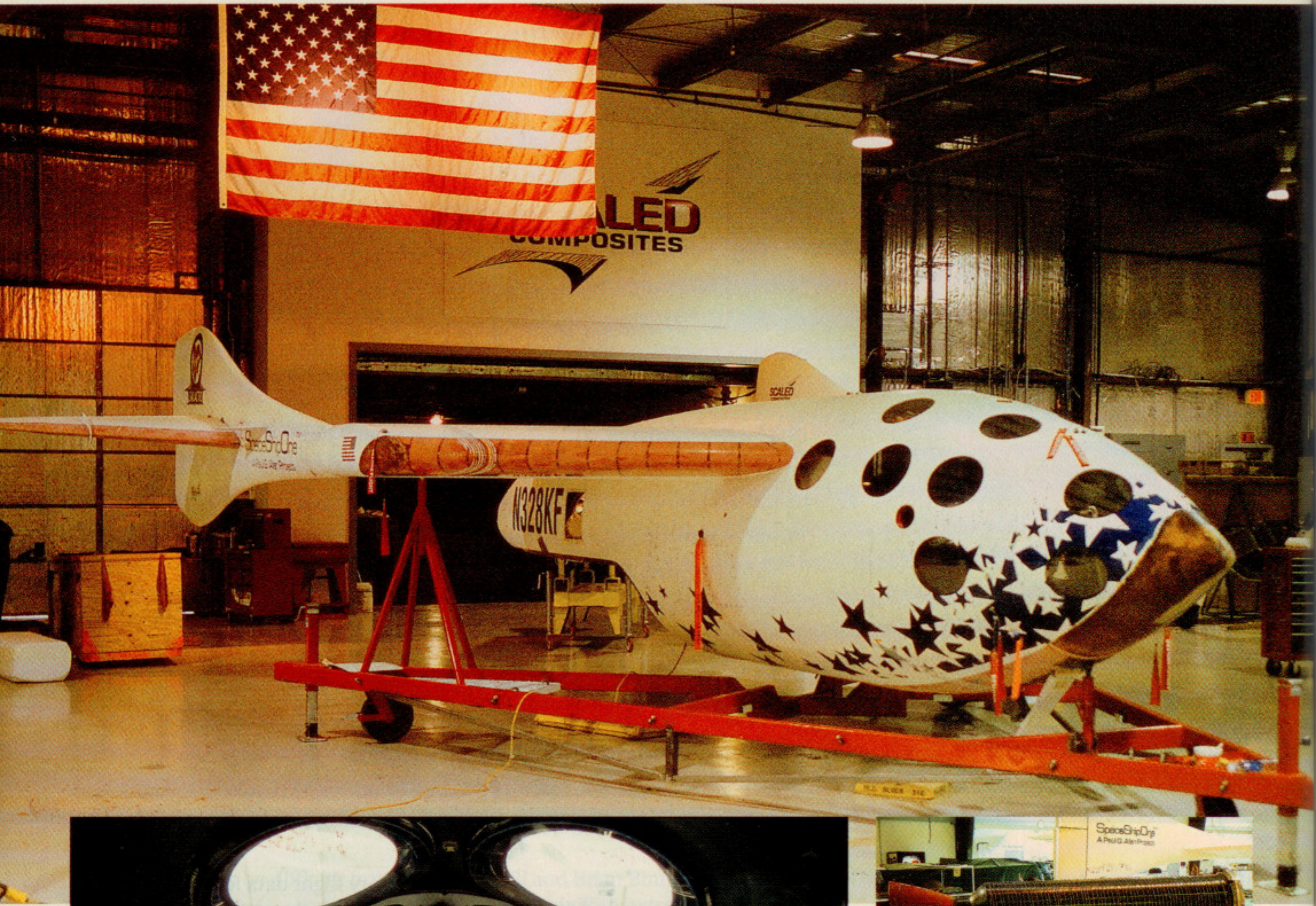
In front of the stick is the single-screen TONU, which at first glance looks like many of the new glass-cockpit displays found in general aviation aircraft. The TONU provides the pilot with all the necessary flight data for each stage of a flight on several screens that can be chosen by the pilot or set on automatic, in which case the computer automatically displays relevant information depending on where the airplane is on the flight (boost, space, re-entry, or glide).

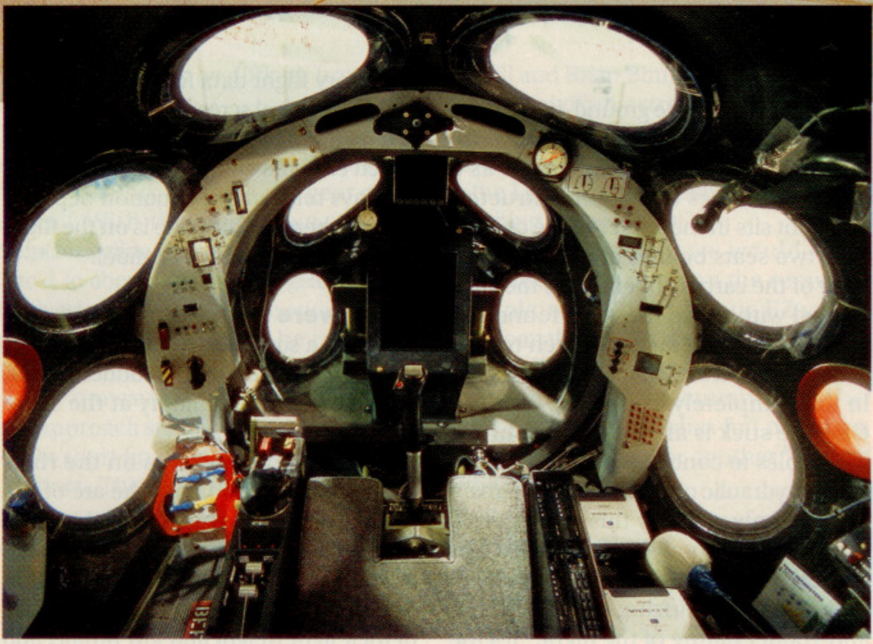
If you were the pilot

Sitting in a somewhat reclined position, the pilot's feet rest on the rudder pedals, which are approximately at the same height as the seat.

Lacking enough room on the ring-shape panel that follows the arc of the fuselage, the communication equipment is all located in the right armrest. Nothing too fancy here. A pair of Garmin Apollo SL40 nav/coms are used because of their light weight and low profile, and just aft of them are the transponder and a PS Engineering audio panel.

The left armrest is the site of much activity. Where a throttle lever might normally be located sits the *turtle*, a contoured knob that fits in the palm of the pilot's hand and is used for yaw trim by controlling the lower half of the split rudders on the tail (the pedals control the upper half). Just in front of the turtle is





With its engine and main landing gear removed, *SpaceShipOne* sits inside the Scaled Composites' hangar (above). The reddish color on the leading-edge surfaces and nose is a thermal protection system (TPS) to protect the aircraft from aerodynamic heating. Inside the cockpit, the turtle, along with the arm and fire switches for the rocket motor, sit on the left armrest. The solid-rubber rocket motor (above). If a leak allowed the fuel to burn through, it would sever the wire seen wrapped around the casing and turn off the supply of nitrous oxide, shutting down the engine.

a roll trim switch, and in front of that are two guarded switches—one to arm the rocket, the other to light it. Ahead of the rocket switches sits the lever to drop the landing gear.

Aft of the turtle are three buttons for controlling the information displayed on the TONU. And underneath the left forearm of the pilot sits a pair of nested levers; one unlocks or locks the feather system (Burt Rutan's breakthrough design that folds the tail section to near vertical, allowing for a safe and simple shuttlecocklike re-entry to the atmosphere), the other raises or lowers the feather. This also is the location of the two switches that activate the RCS (Reaction Control System), which uses small thrusters to maneuver the craft in space.

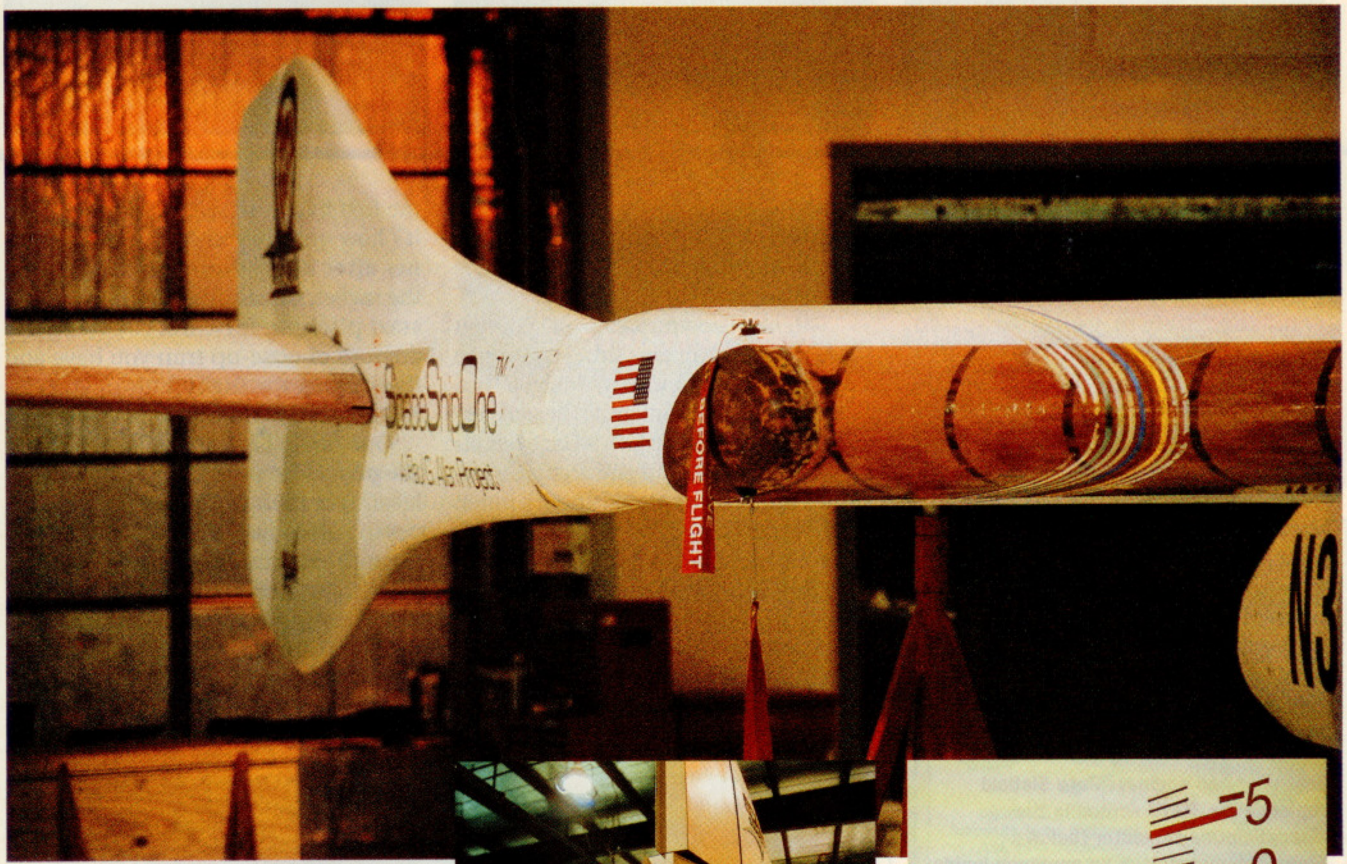
While the TONU dominates the cockpit and gives it a very modern feel, the rest of the view from the pilot seat is remarkably simple and low tech. There's even a ping-pong ball hanging from a

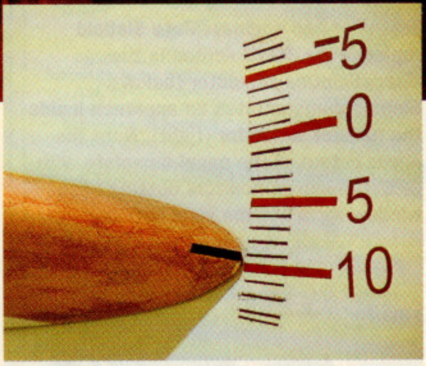
How would you do in *SpaceShipOne*?

When *SpaceShipOne* is gliding, Mike Melvill thinks, most pilots would not have too much trouble. Using the rudder pedals and trim to control roll takes some getting used to, but he believes that with some practice in the simulator to learn the approach—especially the technique of maintaining the high pattern speed (135 KIAS)—it would be possible for the average pilot to fly it to the runway.

Powered flight is a different story. Melvill says the chances of success here are much less for a pilot without experience. He says *SpaceShipOne* is a very difficult vehicle to fly under power. When the spaceship is pitched almost 90 degrees for about 80 seconds during the vertical climb, it's an unusual attitude for any pilot. Small changes in the rocket motor's thrust during burn, quickly changing winds aloft, and the sensitivity to roll inputs require extreme concentration. While Melvill managed to fly VFR during one of his powered rides, it's not a flight that you can do by looking out the window, he says. Because of the high volume of information coming from the TONU, he believes an instrument-rated pilot would stand a better chance. But Melvill adds that flying it isn't easy for anybody, including himself.

And few of the famous pilots who flew the sim were able to land on Runway 30 on their first try. *—JP*





The thermal protection system and heat-sensitive paint are along the leading edge of the wing (above). The pedals control the upper half of the rudder; trim controls the lower half. Blunt trailing edges are used because they are stiff and light, and give an acceptable trade-off for the drag (right). Stabilizer trim is set at 10 degrees nose up for its landing configuration (far right).

string as a G-force indicator—in case having your head slammed against the seat didn't tell you anything.

After preflight inspections are completed on the ground, with the aid of the crew chief who can confirm that flight surfaces are moving properly as the pilot exercises the stick and pedals, the last couple of pins are pulled from the gear and drop mechanism.

There are several checklists on the ride up. At 48,000 feet, the pilot checks the trim settings for launch. To make the climb to vertical after being dropped from *White Knight* ("turning the corner," as the pilots call it), a nearly full nose-up stabilizer trim setting is used for the release.

There's a twist to the normal flight-plan filing. The team received clearance to operate in the military operations area (MOA) on the ground where they also received separate transponder codes for *White Knight* and *Space-*

ally fast (peak climb rate is about 180,000 fpm), and below it is an apogee predictor that tells you how high you would go if you were to shut down at any particular moment.

Passing through 100,000 feet, the sky darkens and, if everything is going as planned, you're approaching Mach 2 as you continue to make adjustments to pitch and roll with the trim settings. Those are needed because of small thrust asymmetries that occur during the rocket burn. Just a handful of seconds later you're passing through 150,000 feet, indicated airspeed is dropping toward zero, but true airspeed is climbing to Mach 3.

When the motor shuts down (the burn varied from 76 to 83 seconds during the actual space flights) several things happen. The 3-G load ends immediately, and weightlessness begins. The TONU changes once again to RCS mode, showing tank pressures for the thrusters, rate indicators, and an indicator showing the angle of the tail section in feather. Now you're coasting, but coasting very fast, according to Siebold. "We're at 250,000 [feet] with the motor shut down, coasting up, going 1,500 KTAS, Mach 2.7, and my indicated airspeed is 3 knots, so we've effectively left the atmosphere." It's possible to be upside down, backwards, or even pointed in the right direction, but it won't affect your trajectory because there is very little aerodynamic load on *SpaceShipOne* at this point.

The RCS is activated with the stick and rudder pedals, which have switches at the extreme stops requiring full throws of the controls. Because there is no opposing force, every roll, yaw, or pitch input with the RCS must be stopped with an opposite input. The clicking of actuators in front of the seat and the sound of the thrusters just outside the cockpit give some tangible sense of flying in space. As apogee is approached (it was 328,491 feet, 337,500 feet, and 367,442 feet, respectively, on the three space flights) the feather unlock is pulled, followed by the feather activation lever, raising the tail.

This is where the pilots had a few moments to enjoy the view of the black sky, the sliver of blue atmosphere, and the expansive Earth below.

As *SpaceShipOne* begins to descend, the indicated airspeed slowly starts to build, which causes the feathered tail to orient the vehicle in the proper entry attitude. During re-entry, the pilot has the least control over the vehicle. There are oscillations in both roll and yaw, and the pilot is really just along for the ride. The TONU reads 30 KIAS, 2,000 KTAS straight down, as re-entry begins. "The goal is to slow down in the very thin parts of the atmosphere," Siebold says. The entire belly of the aircraft is now the leading edge and after re-entry will reach terminal velocity in feather at 85 KIAS. Peak-G forces occur as the atmosphere thickens during descent, hitting about 5.5 Gs (G forces last for about a minute; 10 seconds at 5.5). During the initial, supersonic part of the descent, the ride is fairly smooth. But once *SpaceShipOne* slows down, the ride gets bumpier. "Once you go subsonic, that's where the rumbling really starts. It's pretty significant, so right about 55,000 feet we take the feather out and fly it like a normal glider," says Siebold.

"Landing this thing is very similar to what you'd do in a Cessna or a Cherokee when you're doing an emergency landing when your engine fails," he adds. "You circle over your intended point of touchdown until you get to an altitude where you've got some knowns." In this case, the known is that

SPECSHEET

Scaled Composites *SpaceShipOne*

Base Price: Undisclosed (estimates put the entire cost of the program including all development, testing, and flying of *White Knight* and *SpaceShipOne* between $25 million to $30 million)

Specifications

Powerplant	SpaceDev solid rubber rocket fuel (hydroxy terminated polybutadiene) with oxidizer (N_2O)
TBO	approximately 80 seconds
Length	32 ft 10 in
Wingspan	16 ft 5 in
Wing area	160 sq ft
Empty weight	undisclosed
Max weight	undisclosed
Useful load	undisclosed
Payload w/full fuel	600 lb (X-Prize requirement for 3-person equivalent)
Crew	1
Seats	3
Cabin width	60 in tapering
Cabin height	60 in tapering

Performance (values approximated)

Takeoff distance	0 ft (dropped)
Landing distance	3,000 ft
Rate of climb	185,000+ fpm
Range	40 nm
Max operating altitude	367,000+ ft
Max crosswind component	15 kt
Lift/drag clean	7:1
Lift/drag gear down	5:1
Lift/drag feather	0.7:1
Max speed	2,000 kt/Mach 3+
Cabin altitude @ 367,000 ft	5,000 ft

Limiting and Recommended Airspeeds

V_{LD}	120 KIAS
V_{REF}	130 KIAS
V_{NE}	260 KIAS
V_{LE}	130 KIAS
V_{LO}	260 KIAS

More information on *SpaceShipOne* can be found online (www.scaled.com).

high-key mark at 8,500 feet just west of Runway 30 at Mojave.

Stick forces are light during glide with "nice harmony in the pitch and the roll and good rates," Siebold says demonstrating a "turbulence upset," the nose is lowered to gain a little speed, pull back on the stick, and once the nose comes up, put in some right stick and right rudder to help it come around. *SpaceShipOne* can do a nice roll, something Melvill knows firsthand. "On my last flight I did 29 on the way up [not on purpose], and one on the way down [on purpose]."

Maintaining 135 KIAS, Siebold aims for a point on the moving map indicating high key. Making a slow, easy, arcing right turn, he hits high key at 8,500 feet and uses the TONU to check altitudes at key points in the pattern. Cross the runway at 7,000 feet, downwind abeam the numbers at 5,500 (low key), turn base at 4,500, turn final at 3,500 (1,220 feet agl). Once the runway is made and the aircraft is below its 130 KIAS V_{LE}, the gear is lowered and immediately the nose is dropped to avoid a stall. At this point the pilots like to gain some energy for the flare by increasing the speed to 140 KIAS on short final. "It'll flare...once," says Melvill. "But there's no power, and there's no way to fix it if you over-flare; it's just going to hit really hard. But if you just fly it on at 110 knots, it's a piece of cake." With a chase pilot calling out wheel heights during the flare, the main gear is down; after a few seconds the nose skid makes contact, and *SpaceShipOne* comes to a stop on the runway. AOPA

Jason Paur is a pilot and journalist living in Seattle.