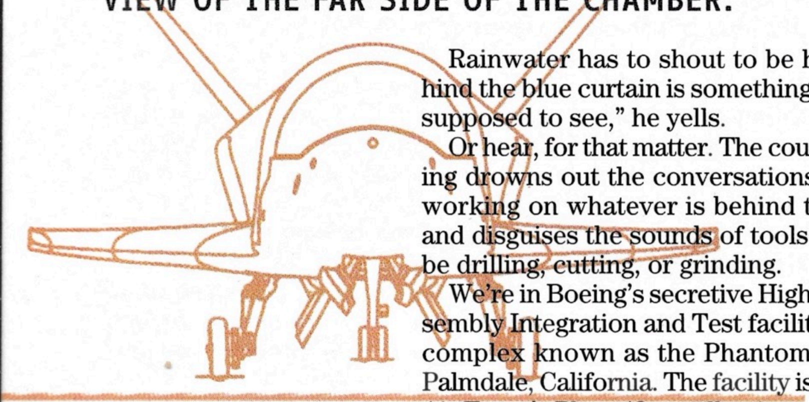
COUNTRY MUSIC SUDDENLY BLARES FROM UNSEEN LOUDSPEAKERS AS VETERAN BOEING MANAGER DENNIS RAINWATER OPENS THE DOOR TO A LARGE, GYMNASIUM-LIKE ROOM. INSIDE, A BLUE CURTAIN BLOCKS THE VIEW OF THE FAR SIDE OF THE CHAMBER.



Rainwater has to shout to be heard. "Behind the blue curtain is something you're not supposed to see," he yells.

Or hear, for that matter. The country crooning drowns out the conversations of people working on whatever is behind the curtain and disguises the sounds of tools that might be drilling, cutting, or grinding.

We're in Boeing's secretive High Desert Assembly Integration and Test facility, part of a complex known as the Phantom Works, in Palmdale, California. The facility is part of the Air Force's Plant 42, a collection of buildings where, historically, aerospace companies have worked on the projects that have made the United States the world leader in military and space technology. F-117 stealth fighters, B-2 stealth bombers, and space shuttle orbiters all sprang from Plant 42. Today, another technological push is taking place here. Lying on the unclassified side of this particular high bay is the partially assembled lower fuselage of a 28-foot-long experimental craft called the X-37. It is a technology demonstrator for a spacecraft that, launched on an expendable rocket, could eventually fly almost any of the missions of the bombers and orbiters that preceded it. At long last the Air Force would have the spaceplane it has pursued since the late 1950s.

Origin of the Species

It was named the Aerospaceplane when the 1950s designs first appeared. In the '60s, it became the X-20 Dyna-Soar. Secretary of Defense Robert McNamara canceled Dyna-Soar in 1963, before it ever flew, but the dream of a spaceplane survived through the next three decades in a series of studies and programs. The most ambitious was the National Aerospace Plane, a 1980s effort nicknamed the Orient Express (for its farfetched goal of carrying passengers from New York to Tokyo in two hours), but the technological leap it required overwhelmed the Air Force-NASA partnership formed to build it. The program dissipated into small technology development projects before being canceled altogether in 1992.

The direct antecedent of the Reusable Spaceplane was born in the early 1990s at the Air Force Research Laboratory at Kirtland Air Force Base in New Mexico. The program was called the Military Space Plane. Its advocates envisioned a craft that could do in space what an unmanned Predator reconnaissance aircraft and an E-3 Sentry Airborne Warning and Control System do in the air. In a crisis, the Pentagon would launch spacecraft called Space Maneuver Vehicles to return images of enemy positions, eavesdrop, coordinate air forces, and jam satellites. To accomplish such missions, the Space Maneuver Vehicles would do what previous spacecraft have not been able to: change orbital planes and altitudes.

After a mission, each SMV would blaze back into the atmosphere toward a runway, where Air Force ground crews would scramble to refurbish it in hours or days in what Air Force planners call "aircraft-like operations." Space Maneuver Vehicles would be unpiloted, and, best of all, they would operate safely above surface-to-air missiles.

The Air Force Research Laboratory took an important step toward developing its spaceplane in 1996, when it hired Boeing to build the X-40, a 22-foot-long flight test vehicle. Made of a graphite/epoxy shell with an internal aluminum frame, the X-40 was to test the aerodynamic handling characteristics of a returning spacecraft and to prove that a small vehicle designed for reuse could land autonomously on a 10,000-foot runway. In 1998, Boeing dropped the unpiloted vehicle from a Black Hawk helicopter; it dove toward Holloman Air Force Base in New Mexico from an altitude of 9,000 feet and used its autonomous guidance, navigation, and control system to land successfully. Later, the Army Aviation Technical Test Center supplied Boeing with a CH-47 Chinook helicopter and pilots to conduct a series of seven test flights for NASA. The X-40, dropped from 15,000 feet, landed on Runway 22 at Edwards Air Force Base in California.

"We were not off on the lakebed; we were coming in with all the other airplanes," says Randy Hein, Boeing's X-40 program manager. "They cleared the airspace, but we were coming in on an operational runway, which was a neat thing to be able to do." As Hein

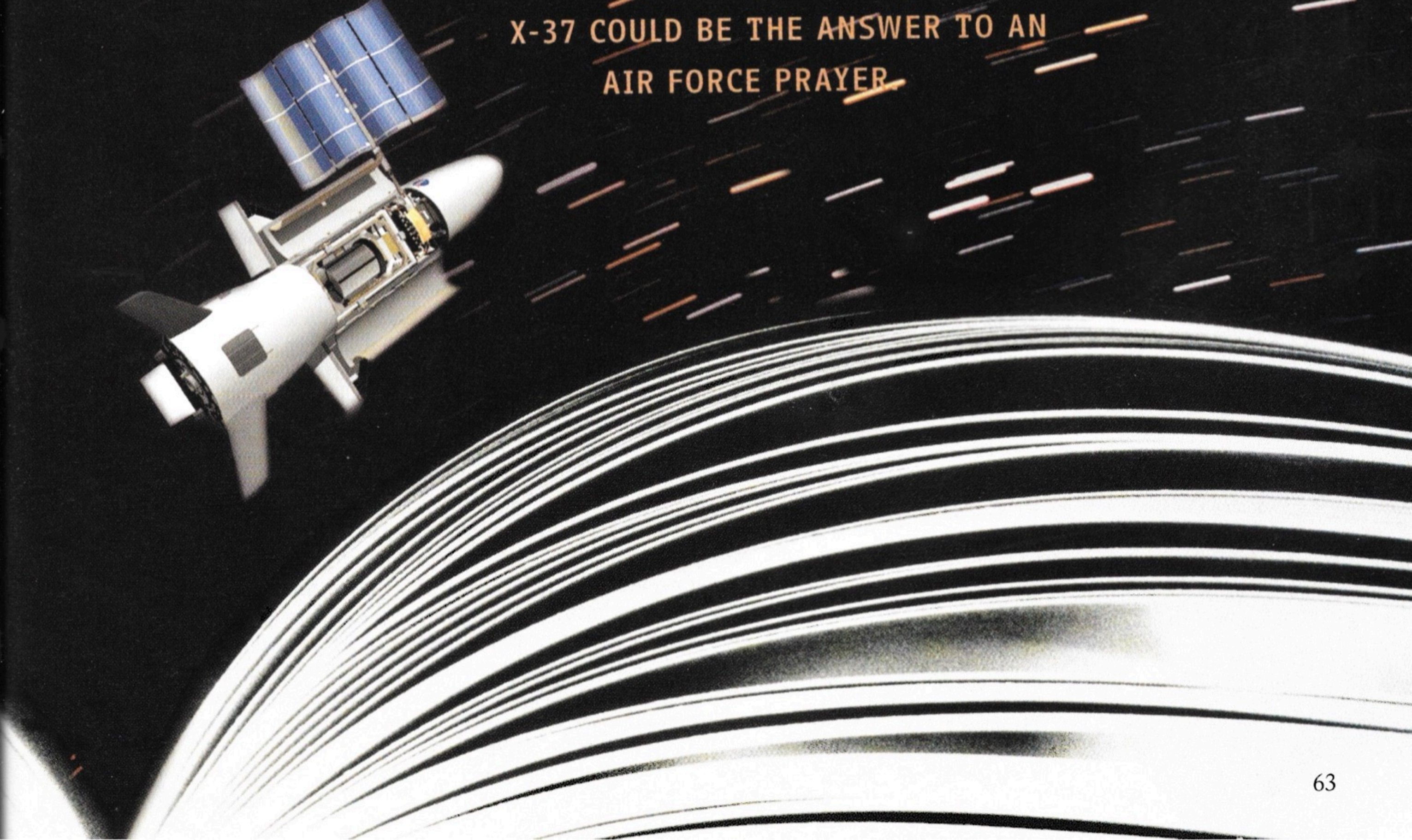
BY BEN IANNOTTA

Though the X-37 orbits only in artist renderings, it tests 40 technologies that any orbiting, reusable spacecraft will need.

X-37 ART: BOEING; PHOTO COLLAGES: TED LOPEZ

WILL THE AIR FORCE FINALLY GET A SPACEPLANE?

IF IT CAN RISE ABOVE COMMITTEE REPORTS AND BUDGET BATTLES, BOEING'S X-37 COULD BE THE ANSWER TO AN AIR FORCE PRAYER.



The daunting problem facing designers of reusable spacecraft is inventing a configuration that can achieve control through a full range of flight regimes.

speaks, the gleaming X-40 waits inside a storage facility at Boeing, like a Ferrari ready to be taken for another spin.

Hein and his team sweated out one moment during the first flight test at Holloman that captures the challenge of designing an aircraft to land without a pilot. "We had one touchdown where we lifted up and came back down—bounced, if you will," Hein says. The vehicle was undamaged, and the team's analysis quickly pinpointed the problem. When the X-40's tires touch down on the runway, the main gear tires spin up from zero to about 195 mph, creating a force that pushes the nose down. Piloted aircraft show the same nose-down tendency, and in training pilots learn how to compensate to keep the nose up on landing. In the X-40, flight software must compensate, and on the first landing, the X-40's automated control surfaces overcompensated (as more than one pilot has done), and the vehicle briefly lifted off. Boeing's engineers revised their computer model of the forces created by the tires' spin up and reprogrammed the flight software to increase the reaction rate of the control surfaces.

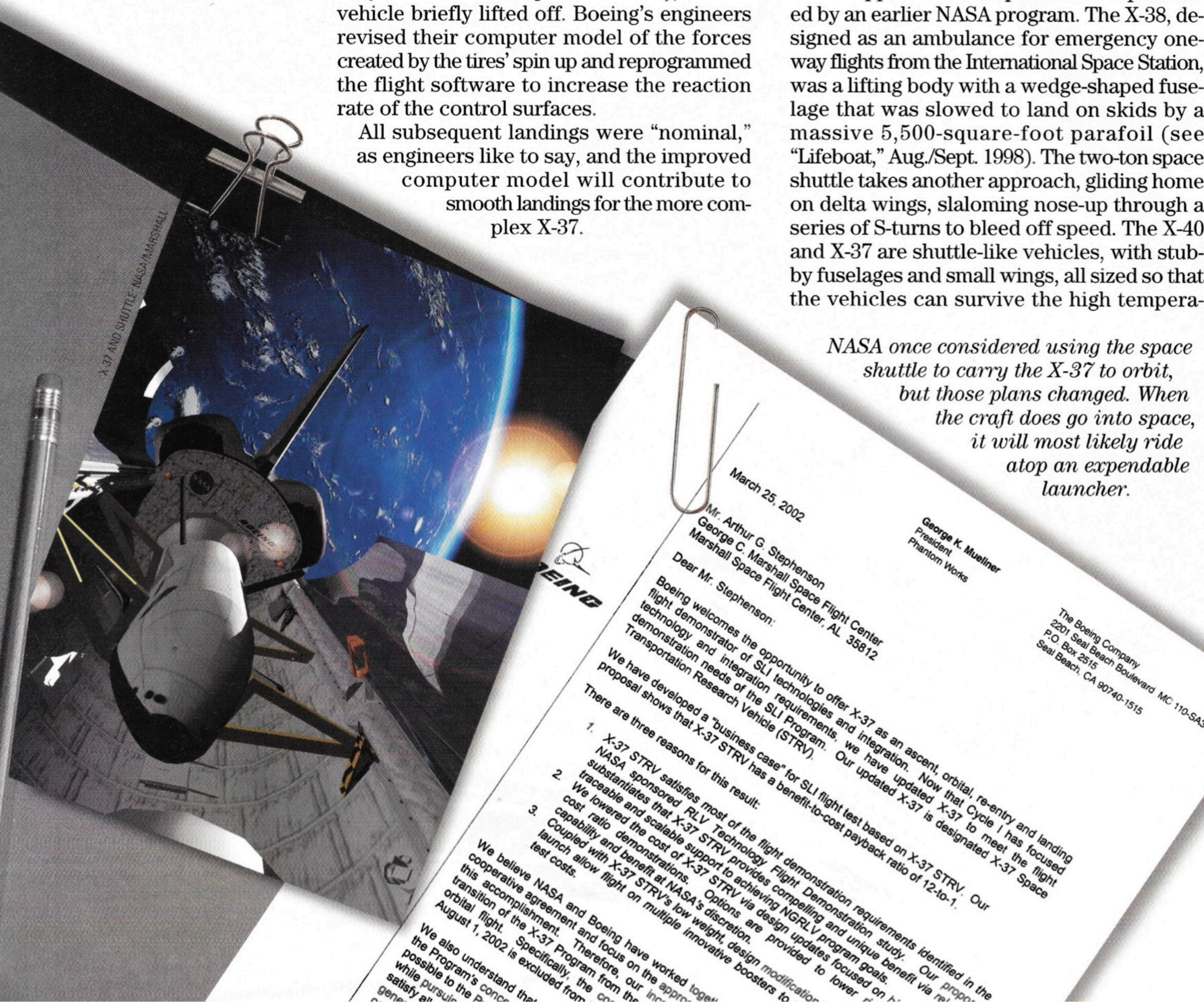
All subsequent landings were "nominal," as engineers like to say, and the improved computer model will contribute to smooth landings for the more complex X-37.

The X-37 is managed through a NASA program to test technologies in the propulsion, avionics, structures, and thermal protection systems of reusable launch vehicles. It is 25 percent larger than the X-40 and made of graphite/bismaleimide, a composite that can withstand higher temperatures than graphite/epoxy.

Like a Rock

The most daunting technological problem facing Boeing engineers in designing the X-40 and X-37—the problem facing any team designing a reusable spacecraft—is inventing a configuration that can achieve control through a range of flight regimes: reentry, hypersonic flight through the atmosphere, and subsonic approach and landing. "There are great debates" about the best way to land a returning spacecraft, concedes Randy Hein.

One approach to the problem is represented by an earlier NASA program. The X-38, designed as an ambulance for emergency one-way flights from the International Space Station, was a lifting body with a wedge-shaped fuselage that was slowed to land on skids by a massive 5,500-square-foot parafoil (see "Lifeboat," Aug./Sept. 1998). The two-ton space shuttle takes another approach, gliding home on delta wings, slaloming nose-up through a series of S-turns to bleed off speed. The X-40 and X-37 are shuttle-like vehicles, with stubby fuselages and small wings, all sized so that the vehicles can survive the high tempera-



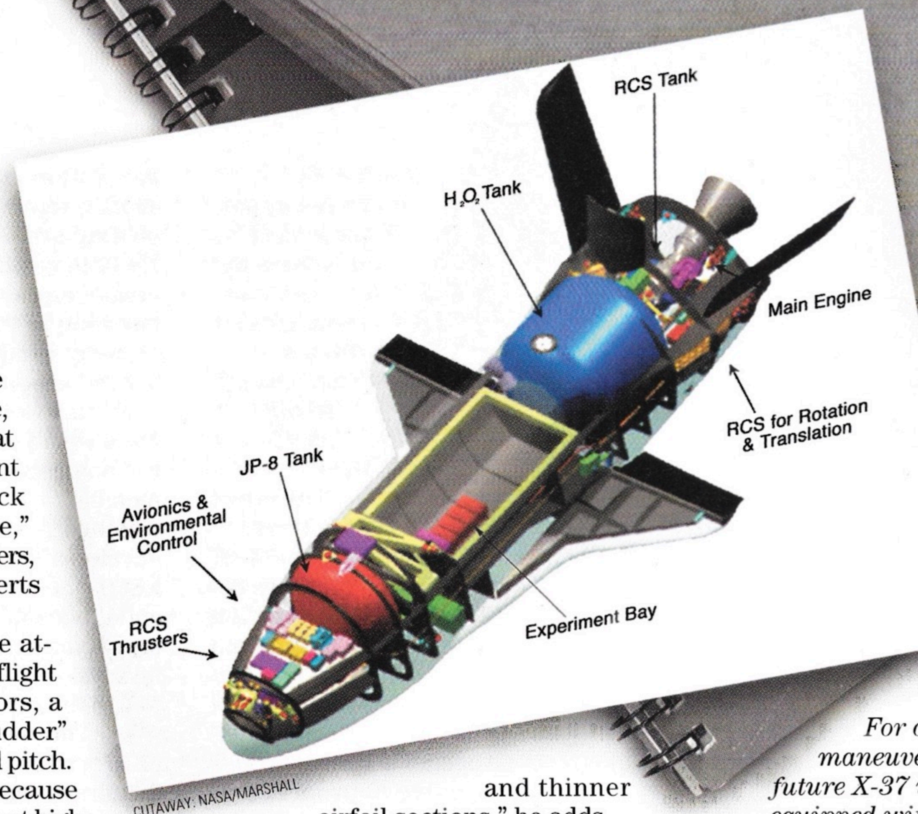
NASA once considered using the space shuttle to carry the X-37 to orbit, but those plans changed. When the craft does go into space, it will most likely ride atop an expendable launcher.

tures of hypersonic speeds and produce the lift needed at landing.

"We kind of refer to it as a 'lifting wing-body,'" says Arthur Grantz, Boeing's chief engineer for the X-37. While the fuselage produces more lift during the high- angle-of-attack entry phase, the wings are more important at landing and generate 60 percent of the lift. "We're more like a rock coming down than an airplane," says Boeing engineer Dave Childers, who is one of the team's experts for navigation.

For its descent through the atmosphere, the X-37 uses four flight control surfaces. Ruddervators, a combination of the words "rudder" and "elevator," control yaw and pitch. "The functions are combined because a centerline rudder is ineffective at high angles of attack [the X-37's attitude during most of its descent], and a horizontal tail and elevator would experience very high temperatures," says Grantz. The vehicle is also equipped with a body flap, a surface beneath the main engine that supplements pitch control at very high speeds.

On the wings' trailing edges, flaperons provide roll control and supplementary lift at landing. Finally, a speed brake is extended from the top of the fuselage to help control speed during the X-37's approach to the runway.



CUTAWAY: NASA/MARSHALL

For orbital maneuvering, a future X-37 is to be equipped with reaction control thrusters and a Rocketdyne engine, which has been used in high-altitude tests but has never flown in space.

Son of Shuttle

When Boeing absorbed space shuttle builder Rockwell in 1986, it inherited Rockwell's years of experience in studying the space shuttle's landing profile. "We know the shuttle's characteristics," says X-37 program manager Al Santana, "and that helps us correlate our data and devise flight control algorithms." Santana worked on the shuttle's guidance, navigation, and control systems when the vehicle was being designed by Rockwell.

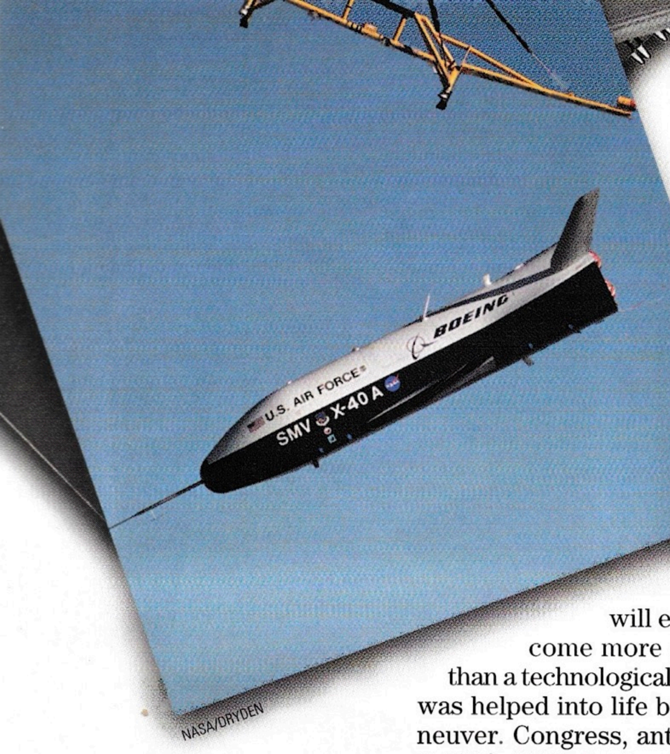
In the 21 years since the shuttle's first flight, according to Santana, the important advances for reusable spaceplanes have taken place in composite structures, thermal protection systems, and avionics. Boeing engineers are experimenting, for example, with a new heat-resistant composite material: carbon/silica carbide. Carbon/SiC, or C/SiC, can be used to form lightweight, thin control surfaces, Grantz says, that don't require the additional external insulation of ceramic tiles. "You can get aerodynamic surfaces with smaller radiuses and thinner airfoil sections," he adds.

Grantz expects the X-37 to withstand reentry temperatures even higher than those that the shuttle's ceramic-tiled skin protects it against. The surface of the X-37 will heat to 2,700 to 2,800 degrees Fahrenheit, compared with shuttle temperatures of 2,400 to 2,600 degrees, he says.

The trailing edges of the X-40's wings are an awkward-looking two inches thick because engineers assumed the X-37's trailing edges would require ceramic tiles. Now that engineers plan to use C/SiC for the flaperons and control surfaces on the ruddervators, the wing and ruddervator trailing edges will be only one inch thick.

The slenderizing of the trailing edges is a rare instance in which the X-37 has slimmed down. Program managers decided to control costs by using more off-the-shelf hardware than originally planned, and as a result, the vehicle grew heavier. Then in the early spring of 2001, the management team determined that the goals of atmospheric and orbital testing weren't as compatible as the team had first believed. The managers redefined the program's goals, confining the X-37, like the X-40, to atmospheric tests.

In 2004, the X-37 will be dropped from a B-52 at 50,000 feet to demonstrate landing and descent. Boeing is still hoping to interest NASA in a second X-37 for orbital tests as part of the agency's Space Launch Initiative, a program whose goal is to pave the way for new reusable launchers that would carry hardware and astronauts into orbit. SLI is being restructured, however, and NASA is studying a



NASA/DRYDEN

The X-37's predecessor, the X-40, landed autonomously on a runway seven times from an altitude of 15,000 feet.

number of options.

Whether the X-37 will ever reach orbit has become more of a political question than a technological one. The X-37 program was helped into life by a Congressional maneuver. Congress, anticipating trouble with NASA's X-33 single-stage-to-orbit program, added funding to the agency's 1998 appropriations to study alternative approaches to reusable launchers. The following year, the House of Representatives earmarked $20 million for NASA's participation in the Military Space Plane, reinvigorating a program that President Bill Clinton had killed with a line-item veto. The X-37 was the result of a Congressional effort to keep the Military Space Plane alive and its directive to explore alternatives to the troubled X-33. (NASA later canceled the X-33 program.)

The Rumsfeld report seemed to endorse Air Force spending for a Space Maneuver Vehicle and a larger Space Operations Vehicle, which would fly to a location in orbit and dispense conventionally armed bombs.

Can This Marriage Be Saved?

The contract to develop the X-37 included Boeing's agreement to pay approximately 50 percent of the cost. The government's share included $16 million from the Air Force and the rest from NASA. The estimated cost of building and testing the vehicle ballooned from $173 million, which was to have paid for two orbital flights, to $234 million, which covers no orbital flights. But in August 2001, Air Force Secretary James Roche decided to hold the Air Force contribution at $16 million. "If it has no maneuverability because of weight growth, then you can't demonstrate the concept of maneuverability," says Colonel Mike Wolfert, a strategist in the programs and plans office at the Air Force Space Command in Colorado Springs.

Wolfert is the team leader of a joint NASA-Department of Defense panel convened to determine how the two agencies could cooperate in the future on spaceplane research. "In the past we've [demanded] too integrated a vehicle, and all we've done is set ourselves up for failure," says Wolfert.

Kevin Neifert, Boeing's director for next-generation launch systems at the Phantom Works, represented industry's point of view on the panel, which conducted a 120-day study. He believes the Air Force and NASA could collaborate on spaceplane research. "Everybody needs thermal protection systems; everybody needs autonomous control and advanced propulsion," he says.

Former Congressional staff member James Muncy isn't so sure. As a legislative assistant to Congressman Dana Rohrabacher and a staff member on the House Science Committee, he watched in frustration as the Air Force's X-40 developed into NASA's X-37. "The Air Force lost the operational concept from the program and it became a pure technology demonstrator because that's what NASA likes to build," he says.

Will the Air Force get its spaceplane?

The current administration is much friendlier to the idea of a military spaceplane than the former was. Secretary of Defense Donald Rumsfeld is presiding over what he calls a "transformation" in the armed services, a modernization process that includes developing weapons for space. Rumsfeld, while still in the private sector, led the Commission to Assess United States National Security Space Management and Organization, which, in its January 2001 report, warned of a "Space Pearl Harbor" and called for "power projection in, from and through space" and greater funding for these new capabilities. The report seemed to endorse Air Force spending for a Space Maneuver Vehicle as well as a follow-on Space Operations Vehicle, a larger spacecraft that would fly to a location in orbit and dispense a new breed of yet-to-be-developed, conventionally armed bombs.

The Final Battlefield

The concept of space warfare, however, still has opponents both inside and outside the Department of Defense. The NASA-Air Force 120-day-study team has not released its findings because spaceplane proponents fear the multi-billion-dollar estimates alone could sink a proposal for a Space Maneuver Vehicle, according to one Air Force official. Boosting spaceplanes into orbit would be a costly way to wage war. The Space Maneuver Vehicles would lack the powerful engines required to reach orbit, so at least initially they would have to be launched atop expendable rockets, which can cost more than $100 million each. That is more than twice as much as the cost of building a single next-generation Joint Strike Fighter, which would fly hundreds of sorties. The Air Force is an enormous organization with many factions, not all of them marching in lockstep behind Rumsfeld's flag of transformation, and many leaders believe the risk inherent in spaceflight is still too great.

Outside the Pentagon, space warfare proposals are sure to spark international debate over the 1967 "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies." Better known as the Outer Space Treaty, it bars countries from using the moon or other celestial bodies as military bases. It also bars countries from launching "weapons of mass destruction" from space, though it omits mention of conventional weapons. "There are no treaty limitations here," Wolfert says.

Joanne Gabrynowicz, a space law scholar at the University of Mississippi, disagrees. The intent of the space treaty was "to ensure space [remains] a stable environment used for peaceful purposes," she says. "The goal was to not introduce the cold war to space, the horror of weapons floating around in orbit. That's just as true today."

To Wolfert and other strategists, the distinction between air-based assets and space-based assets is an arbitrary one. "I guarantee you that if people start seeing American forces dying on CNN, that policy concern will evaporate in about 10 seconds," Wolfert says.

Surface-to-air missiles "are very lethal systems," he continues. "If you wish to stay ahead, you need to be able to counter them. It's a chess game. He moves a piece. You move a piece. If you wait till that threat environment exists, it's too late."

A panel that sets Air Force missions recently urged the Pentagon's multi-service Joint Requirements Oversight Council to approve two mission-needs statements that could justify space weapons. Mission-needs statements typically precede formal White House budget requests for development of new weapons.

Meanwhile last fall, in response to Air Force interest, the Phantom Works began designing a refined spaceplane, the X-40C. It's a step back from the original, aggressive approach on the X-37. Air Force officials would be content to release a payload in orbit and safely return the vehicle to the runway in the service's first test of a reusable spaceplane. The X-40C would be launched on an expendable rocket, Wolfert says, but the timing is dependent, of course, on funding.

Boeing's Grantz is confident that the X-37 will be important in the development of any reusable vehicle that will maneuver in space. "We're thinking [the Space Maneuver Vehicle] will look very much like an X-37," he says. And although the Air Force didn't get the payload or maneuverability it wanted, if NASA and Boeing manage to finish a second X-37 and boost it toward orbit, it's hard to imagine that Air Force officials won't be watching. Unless of course they have something better hiding behind a blue curtain somewhere.

The X-37 can withstand the enormous heat of reentry—and could blaze a trail for missions described in the Rumsfeld report.

NASA/MARSHALL