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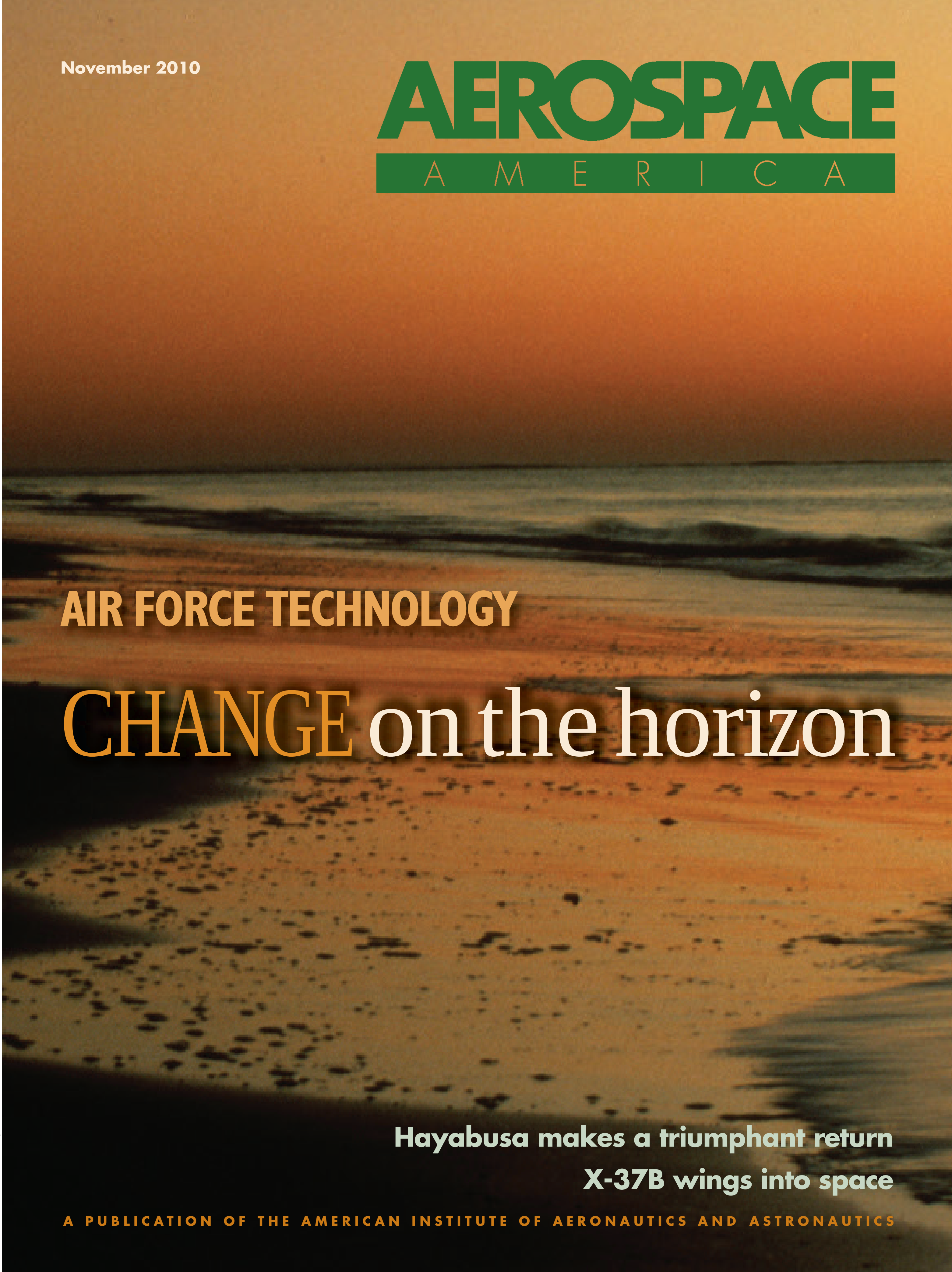

AIR FORCE TECHNOLOGY

CHANGE on the horizon

Hayabusa makes a triumphant return

X-37B wings into space

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Air Force X-37B wings into

After 50 years of study, the Air Force finally has its own military spaceplane, the X-37B. Built by Boeing's Phantom Works and launched in April, the reusable craft has gone through many iterations under three different agencies. On this first orbital flight it is seeking to demonstrate several new technologies and systems—the most important of which, managers say, is the spaceplane itself.

In a historic milestone, the Air Force finally has a winged space vehicle—the X-37B—to demonstrate the diverse missions that can be carried out by a robotic reusable military spaceplane.

The first flight of the 5.5-ton Boeing Phantom Works X-37B, under way since April, is a major step forward as the Air Force begins building a new, more responsive space system infrastructure. An additional vehicle, now nearing completion, is to fly the second USAF spaceplane mission in 2011.

The challenge for the Air Force in exploiting the new fleet's capabilities will be to develop a new "concept of operations" for the military spaceplane, said Gary Payton, then-deputy undersecretary of the Air Force for space at a briefing. These new concepts must transcend the USAF's traditional "wild blue yonder" mindset and provide truly higher, faster operations where that blue sky turns to black in the vacuum of space.

Launched April 22 from Cape Canaveral, Fla., on board a United Launch Alliance Atlas V rocket, the X-37B carries enough hydrazine propellant to remain aloft for nine months, though it will likely return earlier.

As part of a move by NASA and the Air Force to take greater advantage of commercial facilities, the craft underwent final assembly and checkout several miles outside the launch site, at the Astrotech commercial spacecraft processing facility. "As a first-of-its-kind vehicle, it was remarkably easy to work with," says Lt. Col. Erik Bowman, commander of the Launch Support Squadron for the 45th Space Wing, which manages Cape Canaveral launch operations.

The vehicle is testing second-generation reusable spacecraft technologies, especially a greatly improved reentry thermal protection system, says Payton, who flew in 1985 as a military payload specialist astronaut on shuttle Mission 51C. His flight launched a top-secret eavesdropping satellite into geosynchronous orbit. Payton provided a detailed media briefing on the X-37B.

Tougher, lighter, smaller

The new spaceplane's most notable thermal

by Craig Covault
Contributing writer

space

protection advance is at the wing leading edge, which on the shuttle is covered with reinforced carbon carbon (RCC). The ceramic-type material is relatively fragile, as the loss of the orbiter Columbia and her crew tragically demonstrated in 2003, after a piece of external tank insulation pierced the leading edge of the left wing RCC.

The X-37B, however, is using a different material, called toughened unipiece fibrous reinforced oxidation-resistant composite, or TUFROC. Developed by NASA Ames, it is thicker than RCC and heats at a slower rate, which makes it stronger and less susceptible to degradation from oxidation. TUFROC is also lighter than RCC, which improves vehicle payload performance. Thermal engineers are eager to see how the new material holds up to quick-turnaround ground processing.

On its belly the X-37B is carrying tough-

The X-37B spaceplane sits on its Atlas V interface mount as a booster nose shroud is placed around it at Astrotech facilities near Cape Canaveral. USAF photos.

ened unipiece fibrous insulation, or TUFI, tiles similar to those flown on the space shuttle for 15 years. TUFI is more durable and provides a better barrier against water absorption when rained on.

Instead of a human crew, redundant autonomous flight control systems are being used to maneuver the vehicle in orbit. These feature computers that are much smaller but more powerful than those of the shuttle.

The spaceplane, which can carry 500 lb, is 29 ft 3 in. long with a wingspan of just under 15 ft and a tail height of 9 ft 6 in. Its payload bay measures 7 ft x 4 ft.

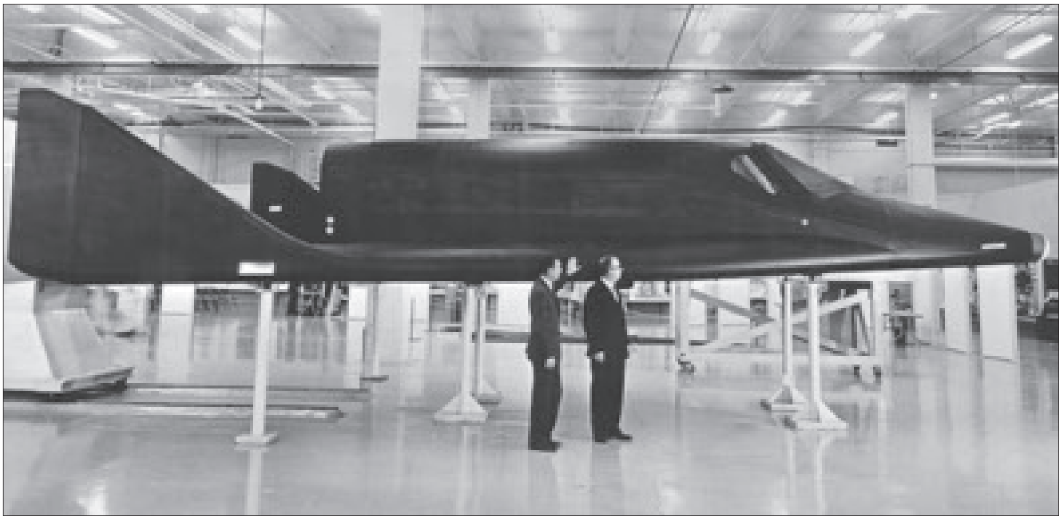
Like the shuttle, the X-37B has two clamshell doors that are kept closed during reentry and launch. At this size, the new vehicle can carry any two of several small satellites currently under development by the Air Force and the other military and intelligence services, says Payton.

spacecraft routinely fly unclassified missions with elements of their payloads kept secret.

In fact, the X-37B's current mission is like those of nonrecoverable Air Force Space Test Program satellites, which since 1965 have flown over 450 space sensor and other hardware tests on more than 175 space missions.

The Air Force kept the X-37B's orbit classified, but a skilled group of civilian space trackers based around the world eventually sighted the spacecraft in a 255-mi. circular orbit inclined 40 deg to the equator. The ground track of this orbit repeats every four days.

The NRO's imaging reconnaissance satellites often use the altitude and inclination of this orbit, says Canadian-based tracker Ted Molczan, who helps coordinate the observations. This makes it likely that the X-37B is testing reconnaissance sensors, perhaps related to advanced technologies such as hyperspectral imaging, he says.



The USAF/Boeing X-20 Dyna-Soar spaceplane was approved for development in 1957 but later canceled. USAF photo.

Element of secrecy

The X-37B and its technologies are not classified, but on this mission it carries a classified payload. The first flight, however, does not involve the deployment or retrieval of other spacecraft, nor will it entail any rendezvous or proximity operations with other satellites. The mission is demonstrating one of the primary uses planned for the X-37B: flying attached sensor payloads so that their performance can be assessed before they are integrated with much more costly free-flying systems.

The existence of a new winged military spaceplane carrying a secret payload has intrigued the media considerably. This interest is overblown and unwarranted, say military managers, who point out that U.S. military

With a double delta wing that duplicates space shuttle aerodynamics, the X-37B will perform a fully automatic reentry and steep 20-deg final approach to land on the 15,000-ft space shuttle runway at Vandenberg AFB. NASA and the Air Force adopted the shuttle design when they were developing the X-37B so the same complex reentry flight algorithms could be used to fly the spaceplane. Edwards AFB will be the backup landing site.

Origin and goals

The X-37B comes 50 years after cancellation of the X-20 Dyna-Soar program, the first Air Force initiative for a winged space vehicle. Test pilot Neil Armstrong, who nine years later would command Apollo 11 on the first manned lunar landing, was among several pilots secretly selected as X-20 military astronauts in 1960, before Armstrong transferred to NASA.

The Air Force proposed other winged space vehicles but, in decisions made 40 years ago by the Nixon administration, had to compromise with NASA for military use of the manned shuttle. That proved to be a costly and unhappy marriage for both parties.

The X-37B itself grew out of a NASA program, but as a dedicated robotic military spaceplane it will benefit from lessons learned on the manned shuttle.

Instead of serving only as a launch vehicle, however, the X-37B will be more responsive to rapidly changing mission needs that place greater emphasis on small spacecraft well suited to launch and recovery by a spaceplane this size.

The primary goal of this first mission is to demonstrate the performance of specific X-37B technologies. Most, including thermal protection and electromechanical systems, represent second-generation reusable spacecraft hardware that was proven initially on the space shuttle.

"If the technologies on the vehicle prove to be as good as we currently estimate," notes Payton, "it will make our access to space more responsive, perhaps cheaper, and push us toward being able to react to warfighter needs more quickly."

Not your father's STS

The new spaceplane, which has redundant and fault-tolerant robotics, is just one-fourth the size of the space shuttle. The other major difference between the two vehicles is that the X-37B uses a several-foot-long gallium arsenide solar array panel that extends from its payload bay to feed power into lithium-ion batteries. The shuttle instead uses liquid oxygen and hydrogen fuel cells for electricity and auxiliary power units to generate hydraulic pressure and move its large control surfaces.

The X-37B is an all-electric vehicle that will use the battery power to move its control surfaces during reentry. It uses hydrazine propellant in its attitude control thrusters and in its single 6,000-lb-thrust maneuvering engine. It carries no manipulator arm.

Unlike the shuttle, whose large vertical tail/rudder splits open as a speed brake, the X-37B uses twin tails for better yaw control and an aft-fuselage top-mounted speed-brake panel somewhat like that of the F-15 fighter.

Smaller twin tails also keep the X-37B's height to under 10 ft so it can fit under a launch vehicle nose shroud. An initial plan calling for the spaceplane to be exposed to the airflow atop a Delta II during launch was dropped when analysis showed there would be excessive aerodynamic loads without a nose shroud to cover the vehicle.

In this NASA graphic, the X-37B flies in space with its payload bay open and solar array extended. NASA graphic.

New missions

The flight kicks off a twin vehicle effort to forge—at Mach 25 and 250-mi. altitude—the same multirole space capability inherent in many military aircraft operations.

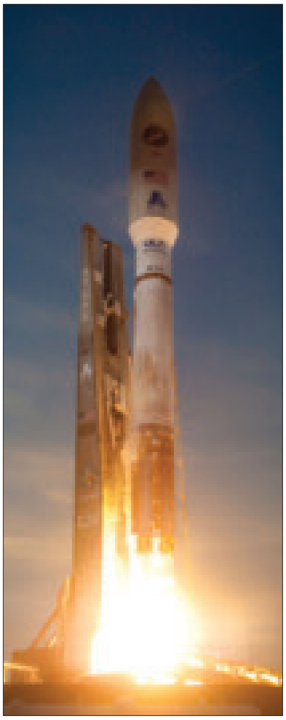
While proving new technologies such as advanced thermal protection materials, the two X-37s will also demonstrate entirely new missions, including the emergency surge-launch of small critical satellites. The spaceplane's payload bay provides a standard interface for user satellites, and the X-37B itself has a standard user interface with the Atlas V, Delta IV, and possibly other launchers such as the SpaceX Falcon 9.

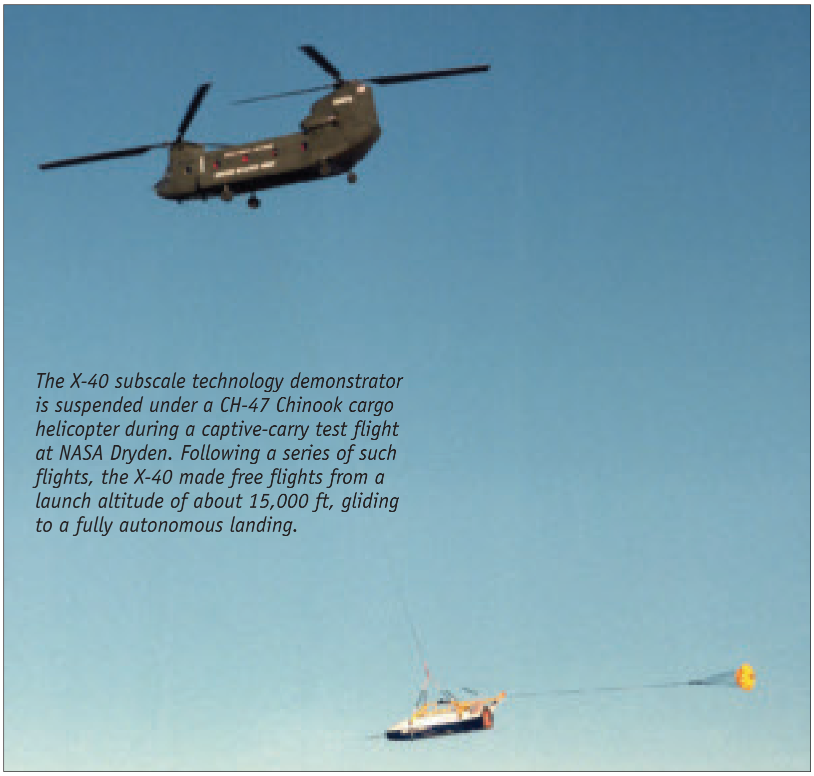
Payton points out that, in an emergency, launchers already in their processing flows at the Cape or Vandenberg would be used for quick-reaction spaceplane flights. A decision would be made on which payloads are more important; if those capable of X-37B launch are needed, the previously planned payload for the Atlas or Delta would be bumped to open a slot for the X-37B mission.

Unlike the shuttle orbiter, however, the unmanned X-37B carries a destruct system that allows safety officers to destroy the vehicle over the Pacific should it stray from its reentry corridor enroute to Vandenberg.

Landing at Vandenberg will position the spacecraft at the Air Force's west coast launch site—only a few thousand feet from processing facilities and launch pads for any of four different rockets that could be used to launch it into polar orbit, in contrast to its current equatorial mission.

On April 22 an Atlas V lifted off from Space Launch Complex 41 carrying the X-37B on its first spaceflight.





The X-40 subscale technology demonstrator is suspended under a CH-47 Chinook cargo helicopter during a captive-carry test flight at NASA Dryden. Following a series of such flights, the X-40 made free flights from a launch altitude of about 15,000 ft, gliding to a fully autonomous landing.

Research conducted at the Air Force Institute of Technology at Wright-Patterson AFB, Ohio, shows that an operational X-37B-type spaceplane will support the Air Force Space Command Strategic Master Plan. The research found that it would have a "direct and substantial" effect on several goals. Key among them are:

•Intelligence, surveillance, and reconnaissance of ground targets with either integrated sensors or deployed surveillance satellites.

•Deployment of space control micro satellites for key surveillance and intelligence missions in a crisis.

•Rapid replenishment of constellations by the small satellites that can be carried in the X-37B payload bay.

The X-37B test vehicle is readied for ground testing. USAF photo.

Top priority

Payton stresses that obtaining cost and workflow data once the vehicle is back on the ground will be especially important.

"The top-priority technology demonstration is, on this first flight, the vehicle itself. Getting it into orbit, getting the payload bay doors open, solar array deployed, learning about on-orbit attitude control, and then bringing it all back.

"But probably the most important demonstration will be on the ground, once we get the bird back: to see what it really takes…how much it really costs to do this turnaround on the ground with these new technologies," he says. "So it's as much a ground experiment in low-cost operations and maintenance as it is an on-orbit experiment with the vehicle itself."

Managers hope that processing of the spaceplane will be more like that of the SR-71, with perhaps one or two weeks between flights instead of the months it takes to process existing spacecraft, says David Hamilton of the Air Force Rapid Capabilities Office, which is overseeing X-37B operations. Managing the actual flight operations will be the Air Force Space Command's 3rd Space Experimental Squadron and Space Command at Colorado Springs, Colo.

X-37B development has gone through so many iterations at NASA, DARPA, and now the Air Force that Payton says he has no idea what the program's total costs have been since its inception in 1996.

That fits well with the Rapid Capabilities Office that handles the X-37B. The motto on the organization's insignia reads, "Opus Dei cum pecunia alienum efficemus," which is Latin for "Doing God's work with other people's money."

Evolutionary steps

The vehicle that became the X-37B is derived from the Air Force X-40 Space Maneuver Vehicle project and NASA's Future-X reusable launch vehicle concept. Key steps in the evolution of the vehicle were:

•1996: The Air Force awards a contract to Boeing for a Space Maneuver Vehicle demonstrator that could be launched by the shuttle or atop an expendable booster. A year later it is designated the X-40. At the same time NASA is evolving concepts for its Future-X program, aimed at developing future reusable launch vehicles. NASA reserves the X-37 designation for use later as it does conceptual work on its X-34, which will later be turned over to industry for possible commercial development.

•1998: Initial X-40 auto-land drop tests from a UH-60 helicopter at 9,000 ft take place at Holloman AFB, N.M.

•1999: NASA selects a Boeing proposal to use the X-40 as the basis for its Future-X pathfinder program, with the vehicle redesignated the X-37A. Built by Boeing, the X-37A is a 20% larger version of the X-40 design begun with the Air Force.

•2000: The Air Force agrees to participate in the X-37A program and gives NASA the X-40 for ambitious drop tests from 15,000 ft. The tests, which employ air data and software developed by Boeing and

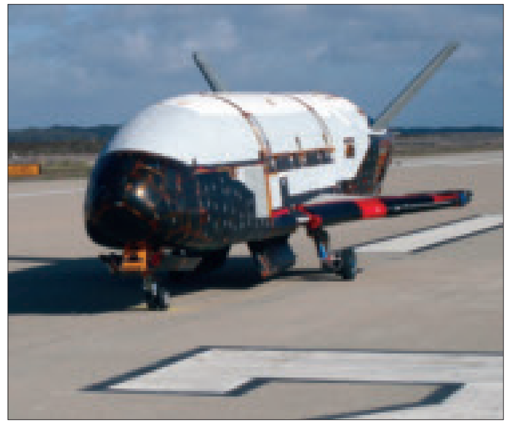
NASA, use a CH-47D helicopter to drop the X-40 seven times.

•2001: More drop tests are completed, but cost factors compel the Air Force to pull out of the program. NASA continues to plan for an X-37A orbital test mission that could be deployed from the space shuttle as early as 2002. A plan is also drawn up to launch the vehicle in 2006 atop a Delta II booster, then later on an Atlas V with a nose shroud covering the spaceplane.

•2003-2004: NASA, facing cost issues, is reevaluating the need for any space test of the X-37A. But in late 2004, DARPA agrees to take the craft.

•2006: After adding more avionics to the X-37A, DARPA begins its own series of tests on the Scaled Composites White Knight carrier aircraft that has dropped the SpaceShipOne commercial manned suborbital vehicle. In April 2006 it makes its first drop test from the White Knight.

•2007: By early 2007 the Air Force is moving ahead with a new plan to develop a variant of the drop test vehicle, to be flown in space and designated the X-37B orbital test vehicle. A USAF statement says the OTV's objectives will be "risk reduction, experimentation, and operational concept development for reusable space vehicle technologies, in support of long-term developmental space objectives." Aspects of the project are also classified. The vehicle then enters preparation for launch into space, and a second vehicle is also procured to give the USAF an initial robotic spaceplane fleet.



The X-37B completes its rollout on the runway after a drop test. USAF photo.