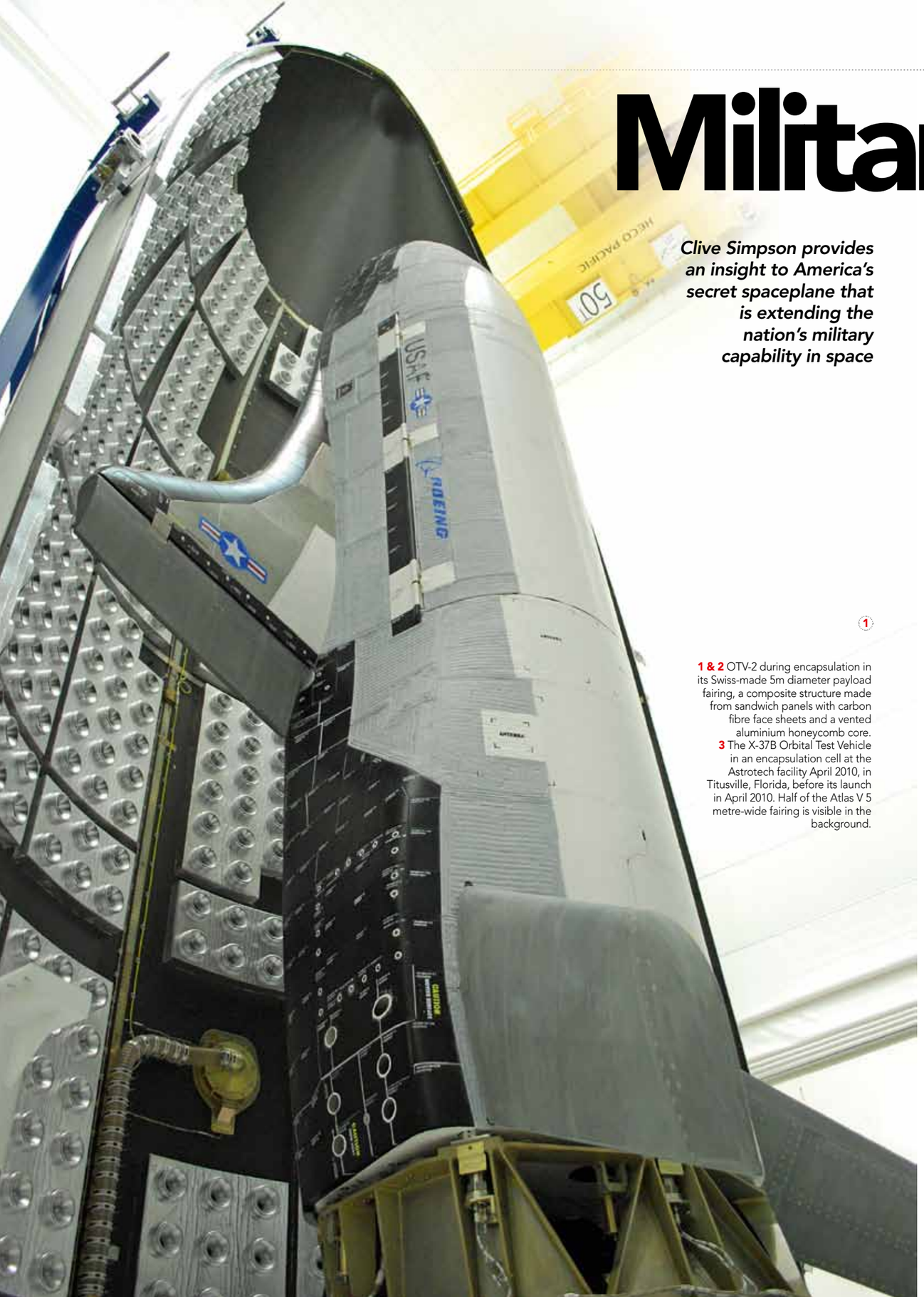
Military Spaceplanes

Clive Simpson provides an insight to America's secret spaceplane that is extending the nation's military capability in space



1 & 2 OTV-2 during encapsulation in its Swiss-made 5m diameter payload fairing, a composite structure made from sandwich panels with carbon fibre face sheets and a vented aluminium honeycomb core.
3 The X-37B Orbital Test Vehicle in an encapsulation cell at the Astrotech facility April 2010, in Titusville, Florida, before its launch in April 2010. Half of the Atlas V 5 metre-wide fairing is visible in the background.

For decades in the US both NASA and the Air Force have been working on projects to carry people and cargo into space. The most striking example is, of course, the recently retired Space Shuttle. But with the exception of a few, such as the X-37, projects of varying configurations have come and gone.

On March 5, the US Air Force's latest X-37 robotic spaceplane surpassed an entire year in Earth orbit. A significant milestone in its secret mission. The spacecraft continues to chalk up mileage and operational experience on its military mission, which was originally due to end in December 2011.

US Air Force officials initially planned a 270-day test flight but mission controllers announced in November they would try to extend it as circumstances allow. Doing so has provided programme officials with additional experimentation opportunities and enabled them to get maximum value out of the mission.

The reusable spacecraft, which looks like a miniature space shuttle, launched on its clandestine mission on March 5, 2011 from Cape Canaveral Air Force Station, Florida The spaceplane is the second X-37B spacecraft built for the Air Force by Boeing's Phantom Works and carries the name Orbital Test Vehicle 2 (OTV-2).

X-37B

The US Air Force's second X-37B spaceplane was launched in a lower orbit than its predecessor — 315 x 340km (195 x 211 miles) compared to OTV-1, which flew at 400km (250 miles) — and with a slightly higher inclination of 43 degrees, meaning the second craft has been regularly flying low over a large part of Asia including Turkey, Iran, Pakistan, (south) Uzbekistan, China and North Korea.

Reports that the orbit was not significantly changed in the first five months (by early August the orbit was some 320 x 330km/200 x 205 miles) fuelled speculation that surveillance may be its main goal.

The Air Force has been typically reluctant to talk about its second such spaceplane flight and also about any differences with the first craft. Officials only mentioned that OTV-2 tests a new solar panel design, though photos of both craft seem to show a colour difference in some places. Growing confidence in the programme was seemed to be reflected in the fact that for the second launch live footage of the OTV-2 clearly showed fairing separation, while an animation was shown during OTV-1's launch from this point on.

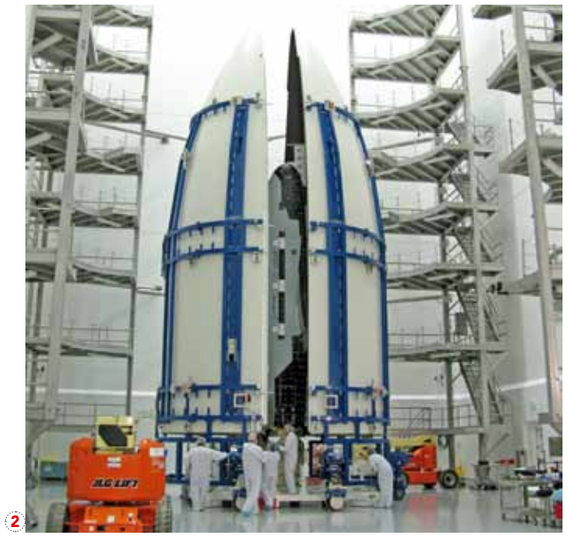
The US Air Force and Boeing anticipate more missions for the X-37B spaceplane to finish testing the craft's flight characteristics and carry 'top secret' experiments into orbit, but they say no firm timetable for additional launches is set.

Boeing's Phantom Works division built two X-37 vehicles for the Air Force and the second of these blasted off from Cape Canaveral Air Force Station, Florida last March.

The reusable spaceplane thundered off the launch pad atop a mighty Atlas V rocket powered by a Russian-built RD-180 first-stage engine. Around 18 minutes after launch the Air Force imposed a news blackout on the classified mission. Details about the cargo and experiments loaded aboard the Air Force spaceplane are shrouded behind a veil of military security.

OTV-1 blasted off from Cape Canaveral on April 22, 2010 and after spending 224 'blacked-out' days in orbit it touched down safely at Vandenberg Air Force Base, California, on December 3, 2010.

The OTV is the United States



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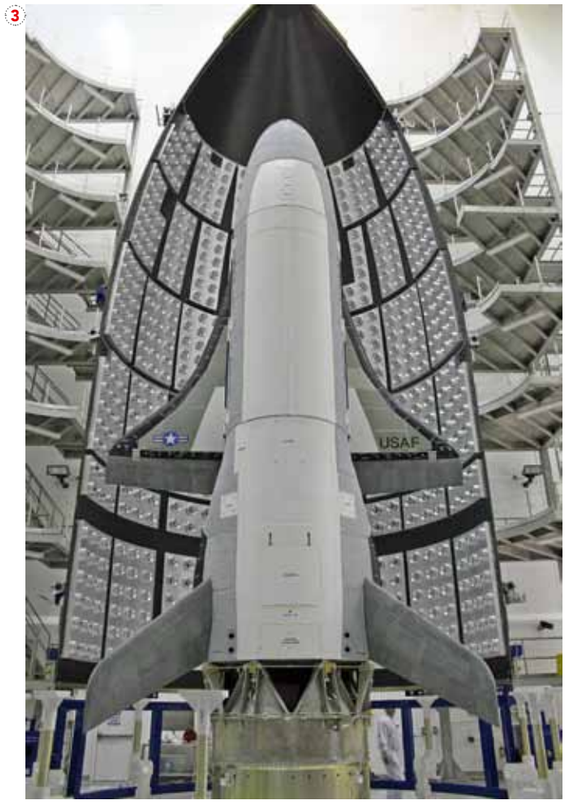

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US X-PLANES INTENDED FOR USE IN SPACE

Designation	*Name*	*Goal*	*No. of flights*	*Remarks*
X-15		Manned hypersonic research aircraft	199 in 1959-1968	Launched from a B-52, reached max. height of 108 km (67 miles)
X-20	Dyna Soar	Manned reusable military spaceplace	First flight planned for 1966	Cancelled when construction had just begun
X-23	PRIME	Unmanned lifting body re-entry test vehicle	Three in 1966-1967	Launched on Atlas rocket, reached max.height of 30 km (18 miles)
X-24		Manned lifting body for landing tests (design was based on X-23)	X-24A: 28 in 1969-1971, X-24B: 36 in 1973-1975	Dropped from a B-52 at max. height of 22 km (13.6 miles)
X-30	NASP	Manned single-stage-to-orbit spacecraft.		Was never built
X-33	VentureStar	Unmanned sub-scale technology test model	First flight planned for 2002	Prototype (+Aerospike engine) nearly ready when cancelled
X-34		Unmanned testbed for reusable spaceplane	Captive flight tests in 1999-2001	Prototypes (+Fastrac engine) ready when programme stopped
X-37B	Pathfinder/ ALTV	Unmanned NASA (later USAF) test spaceplane	Six in 2006, X-37B in orbit April 2010 and March 2011	X-37A dropped from White Knight at height of 11 km (6.8 miles)
X-38	CRV	Manned ISS rescue vehicle based on X-24, first spaceflight planned in 2002-3 (STS-116)	Eight drop tests in 1998-2001	Prototype dropped from a B-52 at height of 14 km (8.7 miles), project cancelled after demonstrator flight model was nearly ready
X-40A		Scale model of X-37, used for landing tests	Four in 1998-1999, seven in 2001	Dropped from UH-60 or CH-47 helicopter at height of 5 km (3.1 miles)
X-41	Falcon: CAV/ HTV-2	Re-entry test vehicle for military spaceplane	First test flight on 22 April 2010; second test flight in August 2011	Both launched on Minotaur rockets, first reached max. height of 80 km (49.7 miles), second contact lost after 10 mins

newest and most advanced re-entry spacecraft. The X-37 was developed as part of a NASA programme, which was taken over by the Defense Advanced Research Projects Agency (DARPA). Built by Boeing, the 11,000lb (4,989kg) X-37B spacecraft is 29ft 2in (8.9m) long, and has a wing span of 14ft 9in (4.5m) and is 9ft 6in (2.9m) high. Once in orbit the spacecraft opens a small payload bay and deploys a gallium arsenide solar array to power its flight.

Closer Look

At first, analysts thought the tail section, with its rudders, was for reboost or atmospheric manoeuvring during re-entry, but as project leader and former Shuttle astronaut Gary Payton explained, the vehicle's shape has a bad hypersonic lift-drag factor so the vehicle has limited orbital manoeuvring capabilities; the aft section contains propellant and engines.

For manoeuvring in space the X-37 uses two shuttle-derived RCS thrusters at the back, supported by smaller vernier thrusters, all using hydrazine as propellant of which approximately 2,645lb (1,200kg) is onboard. It turns out that the small, dark grey shuttle is hard to see from Earth, even with powerful telescopes, so it appears to be made of refractive and light-absorbing materials.

"No major changes were required from the OTV-1 flight based on post-flight assessments but we did make a few minor modifications based on lessons learned from the first flight," Tracy Bunko, an Air Force spokesperson said.

"OTV-1 had a tyre blow out on landing at Vandenberg. It was found to be caused by a very small runway imperfection so we decreased the tyre pressure in the main landing gear by 15% to compensate," she explained.

Bunko confirmed that OTV-1 and OTV-2 were built exactly the same. "Since it is a test programme, a second vehicle allows us to validate the tests we performed with OTV-1 – and a second flight allows us to expand and fine-tune our test parameters," she said.

"We're pleased with what we've seen so far. Technology assessments are ongoing in areas including re-entry guidance, navigation and control, thermal protection systems, and flight actuation systems. Assessments will continue during the refurbishment of OTV-1, which will demonstrate the reusability of the X-37B."

Bunko added that post-flight assessment showed potential for greater flexibility in the craft's landing profile. "Based on the demonstrated ability of the electromechanical flight control and autonomous algorithms in OTV-1, the OTV-2 landing placards will be opened up to allow for greater landing opportunities during high winds or orbital cross range – essentially we want to test the landing capabilities in stronger wind conditions," she said.

The X-37B Orbital Test Vehicle (OTV) is the newest and most advanced re-entry spacecraft. Based on NASA's X-37 design, the unmanned OTV is designed for vertical launch to low Earth orbit where it can perform long-duration space technology experimentation and testing. The X-37B was originally designed to fit inside the Space Shuttle's payload bay for launch to orbit. Following the Columbia accident the X-37B was initially transferred to a Delta II before being switched to the Atlas V in light of concerns over the spacecraft's aerodynamic properties during launch.

The OTV can deploy satellites in orbit. But since the purpose of the first two flights remains classified, the exact mission is a mystery, and it is not known if that capability was used or will be left to future flights.

Future Flight

Asked about plans for further flights, Bunko said: "We anticipate additional flights in order to meet all of the test objectives, but OTV-1 has not been scheduled for another launch.

"Data from OTV-1's performance continues to be reviewed by the Air Force Rapid Capabilities Office and our prime contractor, Boeing. We have also brought in experts from both NASA and the Air Force Research Lab to help," Bunko explained.

The X-37B is the first vehicle since NASA's Shuttle orbiter with the ability to return experiments to Earth. It can stay on orbit for at least 270 days, far longer than the Space Shuttle.

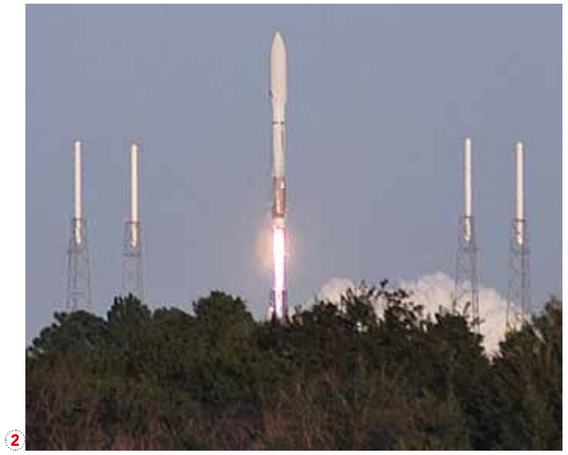
The spacecraft completed a series of captive carry and free-flight tests in 2006 underneath the privately-owned *WhiteKnight* aircraft from Scaled Composites. Taxi tests were conducted at Vandenberg in 2007.

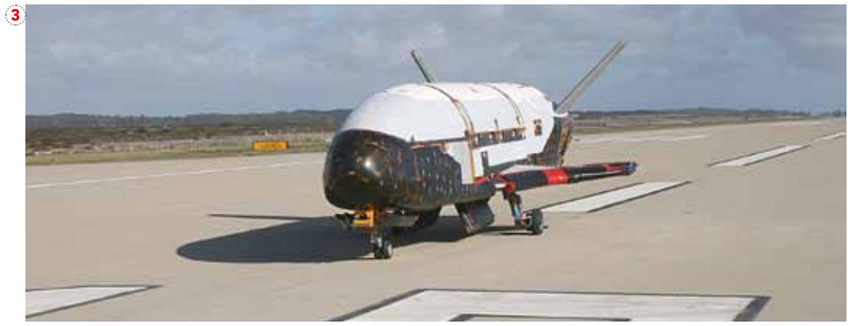
The X-37 was transferred from NASA to the Defense Advanced Research Projects Agency (DARPA) in September 2004 and became a classified project, though it is not known whether DARPA will maintain this status indefinitely. Ultimately, the vehicle has the potential to become the United States' first operational military spaceplane. It is expected to operate in a velocity range of up to Mach 25.

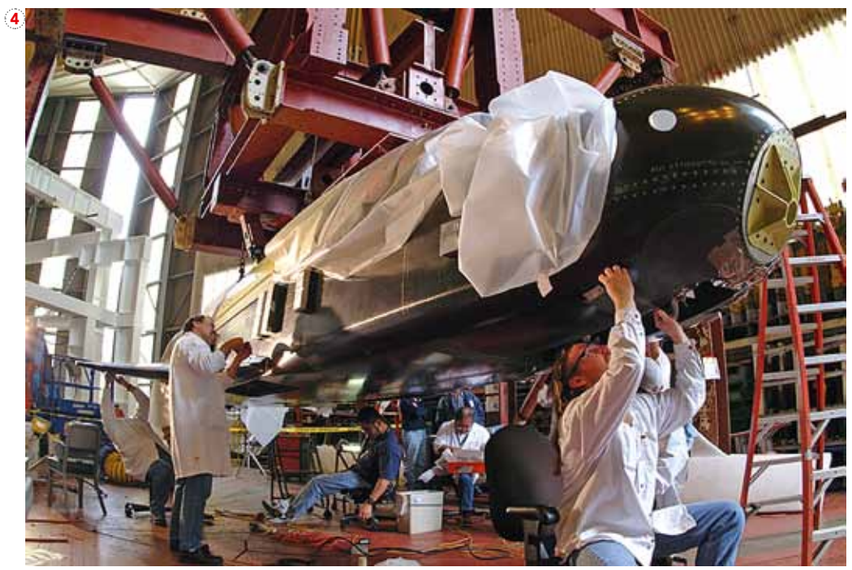
Among the technologies being demonstrated with the X-37 are improved thermal protection systems, avionics, an autonomous guidance system, and an advanced airframe. The onboard engine is the Rocketdyne AR-2/3, which is fuelled by hydrogen peroxide and JP-8.

"Fundamentally, this is an updated version of the Space Shuttle," said Gary Payton. "The Air Force has a suite of military missions in space and this new vehicle could potentially help us do those missions better."

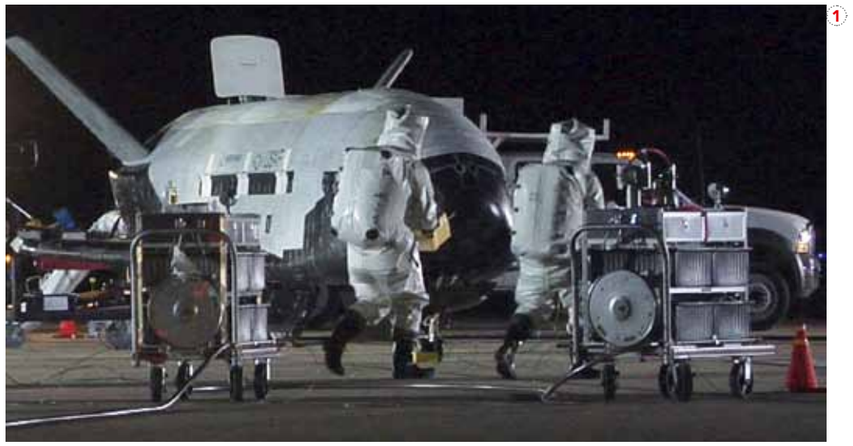
According to Paul Rusnock, Boeing Vice-President of Experimental Systems and Programme Director for the X-37B, the OTV combines "the best of aircraft and spacecraft to







1 Artist's impression of the X-37B in orbit. 2 X-37B blasts off from Cape Canaveral Air Force Station in Florida on March 5, 2011. 3 X-37B vehicle taxi tests on a runway in California after a drop test in 2006. 4 The X-37B Orbital Test Vehicle undergoing tests at Astrotech.



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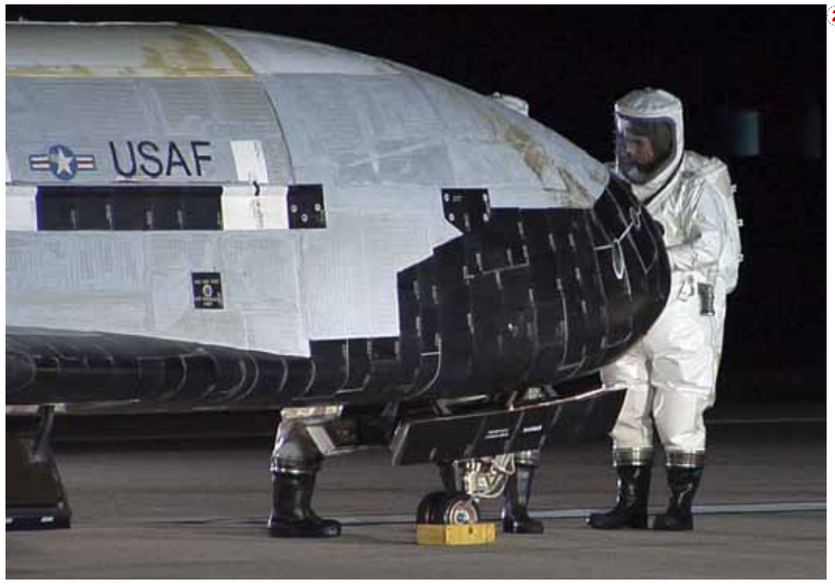

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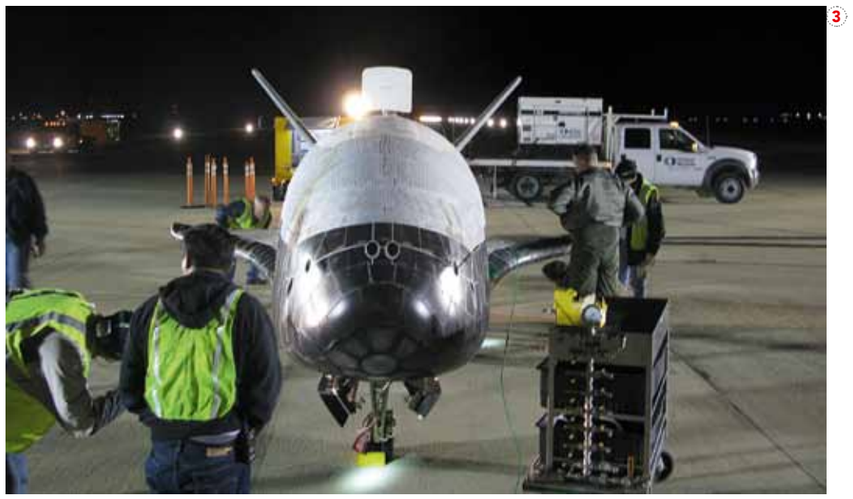

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enable flexible and responsive missions."

The spaceplane's tiles are tougher than the Shuttle's, its electromechanical flight control system replaces the orbiter's hydraulic actuators, and the X-37B is powered by a deployable solar panel instead of cryogenic fuel cells. These upgrades enable the X-37B to stay in orbit months longer than the Space Shuttle, which was limited to missions lasting about two and a half weeks.

The X-37 was originally designed for autonomous flight to demonstrate a future manned space transportation system called Orbital Space Plane (OSP) to be launched operationally on a Delta 4 Heavy rocket.

The first X-37 was to be used for drop tests and was called Approach and Landing Test Vehicle (ALTV). In late 2002 Boeing was also awarded the contract for development of an orbital X-37 vehicle, named Pathfinder (a generic name for the whole X-37 programme at the time).

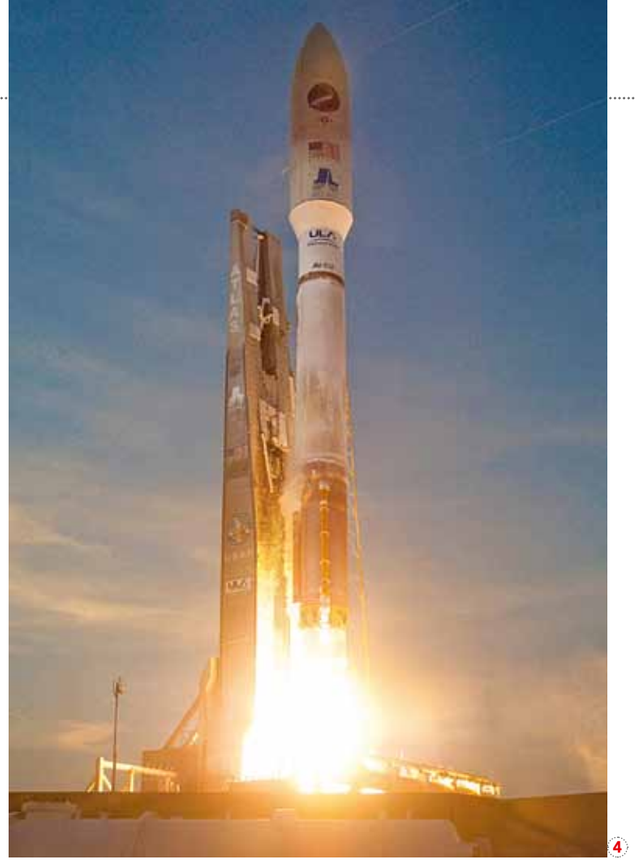
Launch would be in mid-2006 from the Space Shuttle's cargo bay. The STS-136 flight was originally manifested for this and the ALTV was planned to be drop-tested five times in 2004 from a B-52 at a height of 13km (8 miles), but this was delayed to 2005.

In late 2004 NASA decided the X-37 did not fit its 'new exploration agenda' and the spaceplane programme was transferred to the Pentagon's DARPA, which moved the launch to a Delta 2 Heavy following the Columbia Space Shuttle accident. After another year-long delay, drop tests from the new *WhiteKnight* carrier plane took place between April and September 2006; the ALTV flew for about three minutes before landing at Edwards AFB in California.

Two months later, on November 17, 2006, the Air Force announced it would develop the X-37B from NASA's X-37A (ALTV). The Air Force version was designated X-37B OTV.

Air Force Control

With the Air Force now in control, launch of the orbital vehicle was transferred from Delta 2 Heavy to Atlas V once it had been established that no available Delta 2 shroud could cover the vehicle (needed for aerodynamic reasons or because the Air Force did not want a visible OTV on top of the rocket).



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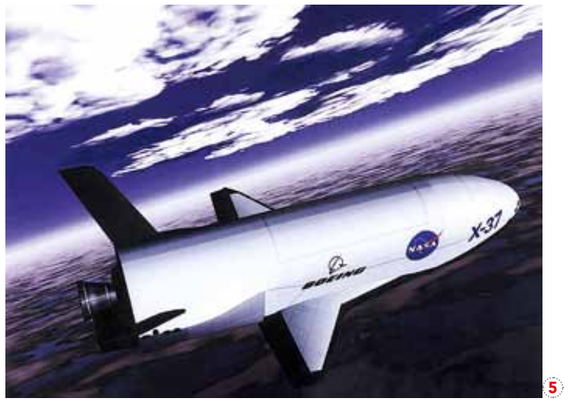

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1,2 &3 US Air Force photos of the space flown X-37B on the runway at Vandenberg after its successful landing in December 2010. **4** A United Launch Alliance Atlas V rocket with the X-37B Orbital Test Vehicle launches April 22 2010, from Cape Canaveral, Florida. **5** An artist's impression of the X-37 in orbit. **6** The X-37B Orbital Test Vehicle in an encapsulation cell at the Astrotech facility April 2010, in Titusville, Florida, before its launch in April 2010. Half of the Atlas V 5 metre-wide fairing is visible in the background.

Launch was initially planned for 2008 but as Boeing only delivered the vehicle early in 2010 the launch was delayed by two years.

On February 22, 2010, the first OTV arrived in Florida by cargo plane and was transported to Astrotech, Titusville, for final servicing. Launch was first set for April 19 but because of changing landing dates of the then orbiting Space Shuttle *Discovery,* the date moved to April 20, then the 21st and finally the 22nd. On the morning of April 21 the rocket and its payload rolled to the launch pad. Some 3.5 minutes into the launch the shroud was jettisoned, revealing the X-37B in flight — though this was not broadcast.

Initial orbital elements were 407km x 425km (253 x 264 miles), achieved with the aid of the Centaur upper stage booster, which burned for 12.5 minutes; later the Centaur propelled itself into orbit around the Sun.

The second X-37B continues to circle Earth 210 miles (338km) overhead moving at more than 17,000mph (27,353km/h). The stubby-winged spaceship is designed to glide back to Earth guided by GPS navigation signals and touch down precisely on a runway in California.

"We initially planned for a nine-month mission but will continue to extend it as circumstances allow," explained Bunko. "This will provide us with additional experimentation opportunities and allow us to extract the maximum value out of the mission."

The Air Force says it will not announce a return date until landing nears — the first X-37 mission's homecoming day was only revealed 24 hours before it flew to a successful landing at Vandenberg AFB, California.

When engineers decide to end the mission, the X-37 will fire a thruster to drop from orbit and plunge back into the atmosphere. As it soars over the Pacific Ocean, the spaceplane will be shielded from scorching temperatures by ceramic tiles, and its guidance computer will autonomously hone in on the 15,000ft (4,572m) runway at Vandenberg.

There are many potential applications and developments for such a vehicle, some more secret than others. Among them might be the ability to approach US or foreign satellites, recover old spacecraft, or test out surveillance and repair techniques. Studies are also under way into a version capable of carrying people. Whatever its final form, a shuttle-like X-37B will certainly expand US military capabilities in space and could also usher in a new age for civilian orbital operations.

X-41/HTV-2 HYPERSONIC TECHNOLOGY VEHICLE

The US Air Force has also been testing another top secret X-vehicle. The first X-41/HTV-2 (Hypersonic Technology Vehicle) was put on a ballistic trajectory on April 22, 2010 by a Minotaur-IV rocket from Vandenberg AFB, travelling 6,500km (4,039 miles) west and ditching into the Pacific north of Kwajalein after a 30-minute glide following communication loss nine minutes after launch.

A second test flight (HTV-2b) on August 11, 2011 also ended in failure after the launch on a Minotaur rocket from Vandenberg AFB. Lift-off and spacecraft separation occurred as scheduled but about 10 minutes into the solo glide flight, while flying at Mach 20, contact was lost and the vehicle crashed in the Pacific.

It seems the second flight had the same orientation control problems as the first vehicle in 2010, and at about the same moment (not even halfway into the scheduled half hour parabolic mission). Officials only commented they had learned more and are confident to find a solution to the control problem.