Union of Concerned Scientists

The X-37B "Space Plane": Still No Clear Mission, at a High Price

Summary

The X-37B is a reusable unmanned spacecraft that is carried into orbit on a large launch vehicle, and is designed to return from space and land like an airplane. While this "space plane" could perform a range of missions, in each case we can identify a better, more efficient, and/or cheaper way of doing each of those tasks.

Because it is an Air Force project and details about it are classified, and because it does not have a clear mission compared to simpler systems, this project has generated confusion, speculation, and in some cases concern about its purpose.

The distinctive capability of the X-37B space plane is its ability to return from orbit and land on a runway. Other systems can carry payloads into orbit, maneuver in space, rendezvous with satellites, release multiple payloads, and/or return to Earth, and can do these things at much lower cost than a space plane.

For objects being launched into orbit and maneuvering in space, it is important to keep the mass as low as possible. Designing a spacecraft to reenter the atmosphere and land like a plane adds several tons of extra mass since it requires wings and landing gear as well as more robust construction and heat-shielding to withstand the rigors of atmospheric reentry. That large additional mass makes it much more difficult and expensive to get a space plane and its payload into orbit, since it requires a much larger booster rocket. It also reduces the amount of maneuvering it can do with a given amount of fuel once it is in orbit.

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Thus, the ability to return to Earth carries a high cost. Many missions in space do not require bringing a spacecraft back to Earth, and the space plane makes no sense for those. And even in cases when return does make sense, a spacecraft can land using a parachute rather than wings and landing gear.

The fact that the Orion space capsule that will replace the Space Shuttle is designed to return the crew to Earth in a reusable capsule using parachutes indicates the advantage of landing with parachutes rather than with wings. Orion is designed to land on the ground, as Russian and Chinese space capsules do.

Requiring the space plane to return to Earth and land like an airplane is a design constraint that reduces maneuverability and launch responsiveness, and increases cost compared to alternative systems for achieving orbital missions. With the Pentagon spending money on space-plane development, it is less likely to develop alternative systems optimized to do a given job better and cheaper. That inertia may help keep the space-plane concept alive, even as a poor fit for the missions it is expected to carry out.

The administration and Congress should re-examine the program and be clear about its goal and why they are spending money on the X-37B.

Technicians inspect an X-37B in June 2012 after it completed the program's second mission. Photo: USAF/Boeing

In More Detail: What Can the X-37B Do, and What Are Its Limitations?

None of the rationales given for the X-37B justify its design to land like an airplane on a runway. And many of the rationales do not justify developing a system that returns to Earth.

The Air Force says that the primary objectives of the X-37B are to develop reusable spacecraft technologies and to carry experiments into space and return them to Earth.

These do not require the craft to land on a runway. Payloads have returned safely to Earth using a capsule with parachutes or small retrorockets for decades. The spacecraft that will replace the Space Shuttle—called Orion—is being designed to be reusable and to return the crew to Earth in a capsule that lands on the ground using a parachute.

Other possible missions discussed for a space plane include deploying and recovering microsatellites, deploying multiple satellites on different orbits, and carrying sensors that can move around in orbit to observe areas on the ground or objects in space. These rely on the ability of the space plane to maneuver in space. Indeed, the term "space plane" suggests the ability to zoom about on orbit. Yet building in the capability to return to Earth and land on a runway adds significant mass, which works against maneuverability. This drawback very likely outweighs the advantage of reusing the spacecraft.

In particular, the equipment that permits the X-37B to re-enter and land like an airplane (heat shielding, wings, landing gear) makes it several tons heavier than a spacecraft optimized for maneuvering that does not return to Earth. Maneuvering in space can require very large amounts of fuel, and the mass of required maneuvering fuel grows with the mass of the spacecraft. The mass of fuel also increases exponentially with the desired amount of maneuvering.

As a result, a lightweight spacecraft can offer the same amount of maneuverability as a space plane with a much lower launch mass. Alternately, such a craft could give much greater maneuverability than the space plane for the same launch mass.

This additional mass also requires the space plane to be launched on a much larger launch vehicle and at significantly higher cost. With a weight of five tons even without a payload, the X-37B must be launched on a very large booster—the Atlas V launcher—which is twice as massive as the Delta II that is routinely used to launch multiple satellites. For example, the Delta II has been used to lift into orbit a maneuvering deployment stage carrying four half-ton Globalstar satellites. The X-37B could not even carry one of these satellites into orbit.

Requiring such a large launcher, which also requires a large launch facility, works against the goal of "launch responsiveness," which foresees using small launchers to carry lightweight payloads into orbit quickly. In addition, a typical rule of thumb for launch costs into low Earth orbit is that each additional ton of mass costs an additional $20 million to launch.

These considerations provide a tremendous incentive to keep the mass of the spacecraft as low as possible. The requirement of the X-37B to return to Earth and land like an airplane is a design constraint that reduces maneuverability for a given about of fuel, increases cost, and limits launch responsiveness.

X-37B: Poor Platform for Potential Missions

Orbital inspection

While a system like X-37B could carry sensors and rendezvous with and inspect an orbiting satellite, it is not optimized for this task. Inspection satellites designed without the ability to return to Earth can be smaller, intrinsically stealthier, and more maneuverable. The 225 kg U.S. MiTEx satellites in geo-synchronous orbits that were used to inspect the failed U.S. DSP-23 satellite are examples of lightweight inspection satellites. Using the X-37B to launch a satellite like MiTex would increase the launch mass by 5,000 kg—a factor of 20.

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Spy platform

For similar reasons, the X-37B is not well-suited to quick-response, unpredictable reconnaissance. A spacecraft carrying Earth-observing sensors and optimized for this task would be smaller and more maneuverable and be able to make much larger orbital changes. A lightweight spacecraft would also be easier to launch promptly on demand using a small launch vehicle.

Testing sensors and equipment in space

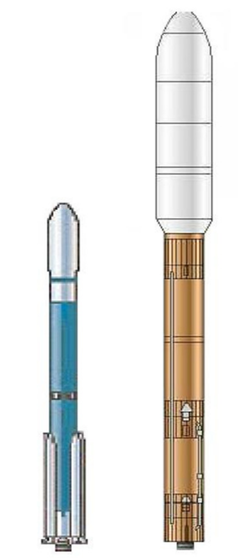
A common suggestion is that the X-37B could be used to test the space-worthiness of sensors or other equipment in space and bring them back down to be examined. However, for decades technology developers have carried out this work simply by sending this type of data back via radio signals or by returning test equipment to Earth using a capsule with a parachute. The convenience of landing on a runway comes at great expense.

Replenishing a satellite constellation
The X-37B could in theory be provided the equipment to dispense a number of satellites in different orbits to rapidly replenish a satellite constellation. However, the X-37B has very little room for cargo. While future versions of the space plane could be bigger, this mission still would be vastly more efficiently done by a lightweight, disposable satellite "bus." As noted above, four half-ton satellites on a maneuvering deployment bus can be launched on a much smaller launcher than is required for the X-37B; the bay on X-37B is too small to hold even one of these satellites. The costs associated with returning the bus to Earth are likely to outweigh the value of reusing it, and there is no reason to land on a runway in any event.

Refueling or repairing a satellite on orbit
The critical technology for refueling or repairing an orbiting satellite is the ability to rendezvous and dock with a target satellite. The X-37B does not have this technology. Even if it did in the future, this mission does not require the ability to return to Earth and land on a runway, and the associated additional mass would likely reduce its maneuverability and the amount of fuel it could carry.

Capturing satellites
The X-37B's return capability could theoretically also allow it to capture a satellite and bring it back from orbit to U.S. territory either to see what went wrong with it or to investigate an adversary's space capabilities. Even if the X-37B was given the ability to approach and grab satellites, its cargo space can only accommodate the smallest satellites, and it is unlikely to make economic sense to recover small satellites. For example, even a Globalstar satellite (which is too large to fit in the X-37B cargo bay even without its solar panels) costs less than $20 million—much less than even the $100 million launch cost for sending the X-37B on a rescue mission. A larger version of a space plane that might accommodate larger satellites would also have correspondingly larger launch costs. And as discussed above, even if there were a case in which it made sense to return a satellite to Earth, it could be done more economically without using a space plane.

While visually the X-37B may resemble the Space Shuttle, the craft are very different.



The Delta II rocket (left) launches sets of four Globalstar satellites. The X-37B needs the much larger Atlas V (right) to launch but could not carry a single Globalstar into orbit.

X-37B Does Not Make Sense as a Space Weapon

The secrecy surrounding the X-37B and its development by the military has raised speculation about it having a specialized military role, such as attacking satellites or dispensing Earth-targeting weapons. However, neither the prototypes themselves nor the concept of a reusable, autonomously landing spacecraft is especially suited to space-based weapons missions.

Anti-satellite weapon
An anti-satellite weapon designed to maneuver close to a satellite and interfere with it would benefit from being much smaller than the X-37B. A smaller craft could be stealthier, have greater maneuverability, and have a much lower mass so that it could be launched promptly on a small, responsive launcher. It is also important to remember that the X-37B has not been designed with the capability to interfere with satellites, and that capability would have to be added.

Ground-targeting weapon: A "Space Bomber"
Space-based weapons intended to leave orbit and attack targets on the Earth are much more costly (and less secure and reliable) than ground-based options, because they require getting the weapons up into orbit and then back down. This means that the launch mass includes not just the weapon, but also all the fuel needed to accelerate the weapon out of orbit and back down to the ground. Launching ground-targeting weapons on a space plane merely increases the launch mass and makes them even less efficient.

What Can't the X-37B Do?

Rapid, On-demand Launch
The X-37B does not advance the cause of quick, on-demand launch. The X-37B must be carried into space on a launch vehicle, and its mass is large enough to require a large launcher. In contrast, the current approach to on-demand "responsive" launch is to develop small space launchers that can be quickly readied and do not require scheduling a date in a large launch facility. A 500 kg satellite could be put into orbit using a small launcher, but including the weight of the X-37B in the launch would raise the mass to 5500 kg, requiring a heavy-lift launcher.

Troop Transport
The X-37B could not provide a better or faster way to ferry troops to a distant military hotspot, as it cannot carry people. Some concepts of larger space planes in the future include a pressurized capsule inside the cargo bay to carry people, but recall that even a vehicle the size of the Space Shuttle could only carry a few people. It would require launch equipment on the scale of that used for the Shuttle and it is unlikely that it could be launched promptly on demand.

A space plane would have a somewhat shorter transit time than an airplane—two hours, compared to 12 hours on an airplane to get a quarter of the way around the world. But in order to keep the total delivery time short, the preparation time for the launch of the space plane would also need to be short. It would also require at its destination a secure runway designed for such a vehicle. For all these reasons, a space plane is unlikely to be a useful way of moving troops around.

Background

The X-37B began as a NASA program in the late 1990s, was transferred to DARPA in 2004, and then finally found its home at the Air Force in 2006. Currently, the effort is led by the Air Force Rapid Capabilities Office with the Boeing Company as prime contractor. Two prototypes of the X-37B have been built, OTV-1 and OTV-2. The OTV-1 was launched in April 2010 and stayed on orbit for seven-months (225 days). The second prototype, launched in March 2011, stayed on orbit for 469 days, longer than the designed orbital lifetime of 270 days. Another launch of OTV-1 is planned for November 2012.

The five-ton X-37 B is launched on a heavy-lift Atlas V 501 rocket from Cape Canaveral, Florida. It is 29 feet in length, with a 15 foot wingspan, and stands 9.5 feet tall. It lands at Vandenberg Air Force Base, with Edwards Air Force Base as a backup.

The X-37B is an experimental vehicle and technology demonstrator. The Air Force's fact sheet on the X-37B describes its objectives as "space experimentation, risk reduction and concept of operations development for reusable space vehicle technologies."

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Despite concerns about what the OTV-1 and 2 might have been doing on orbit, these flights were probably primarily developing technology, rather than accomplishing goals with a specific payload.

While visually the X-37B may resemble the Space Shuttle, the craft are very different. Besides being about a quarter of the size of the Shuttle, the X-37B cannot carry people. While it can carry cargo, its capacity is limited, with a cargo bay about the size of a pickup truck bed; two X-37Bs could fit into the Shuttle's cargo bay. The Shuttle launches using its own engine and reusable boosters, but the X-37B is launched as a payload on an expendable rocket.

One area the X-37B exceeds the shuttle is on-orbit lifetime. The Shuttle generated power using fuel cells, and its longest mission was 17 days. The X-37B draws power from solar panels and batteries, which provide a longer designed lifetime on-orbit of 270 days.

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