On wings and a prayer

In the wake of Columbia's loss, NASA's efforts to replace its ageing shuttle fleet are coming under fresh scrutiny. Geoff Brumfiel uncovers a tale of high hopes, false starts and immense technical hurdles.

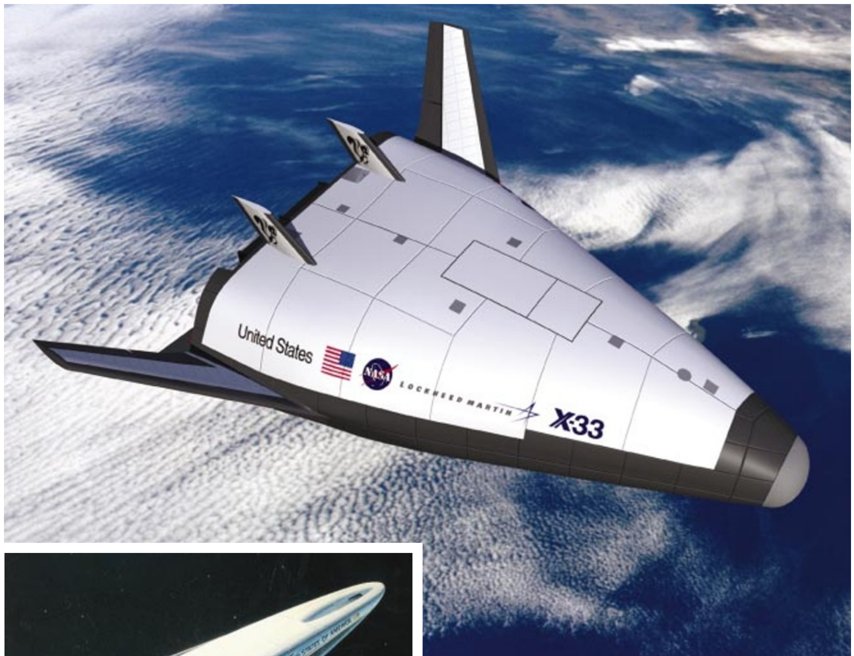
In 1986, just weeks after the space shuttle Challenger exploded, President Ronald Reagan announced plans to develop a successor to the craft. This "new Orient Express", as he called it, would speed from Washington to Tokyo in just two hours, flying at the edge of space.

Officially known as the National Aerospace Plane, the craft was to fly at 25 times the speed of sound, moving effortlessly in and out of orbit. It would be free of the bulky external fuel tanks and boosters of its shuttle predecessor. But, like so many concept vehicles advocated over the two decades since the shuttles began flying, it fell victim to formidable technical obstacles. In 1994, the project was cancelled, writing off some US$3 billion of research.

NASA's current plans, announced shortly before the Columbia disaster, are much less ambitious. Last November, after halving the agency's five-year, roughly $5-billion budget for new space-launch technologies, President George W. Bush's administration unveiled a two-pronged approach to replacing the shuttles. The first is to develop an Orbital Space Plane within a decade that, unlike Reagan's 'Orient Express', will be wedded to conventional launch technologies. The second is an open-ended study of advanced concepts which has no firm deadline for producing a new system.

Following Columbia's loss, those plans may shift once more. But it is clear that we're not going to see anything along the lines of the National Aerospace Plane in the foreseeable future. Ideally, spacecraft would be more like conventional aeroplanes. They would take off, fly to orbit and land in a single stage, needing only to be refuelled between flights. They would carry fuel in internal tanks, manoeuvre gracefully both in the atmosphere and in space, and be able to withstand the intense heat of re-entry. But meeting all of these requirements has so far proved beyond the capabilities of the world's leading aerospace engineers.

Given what happened to Columbia, manoeuvrability within the atmosphere and surviving re-entry are clearly key issues. The space shuttle looks rather like a brick with wings, and for a good reason. Its blunt shape creates a shock wave as it hurtles back into the atmosphere, which helps to protect the craft from the hot ionized gases that form around it. If it looked and could fly like a high-performance jet, the shuttle's leading edges would heat far beyond the roughly 1,600 °C they currently experience. Scientists at NASA's Ames Research Center in Moffett Field, California, are working on ceramic materials, based on composites of hafnium or zirconium diborides with silicon carbide, that might help a more manoeuvrable vehicle beat the heat of re-entry. These materials can survive temperatures of nearly 2,800 °C, but are currently brittle and bulky, and more research will be needed before they can be incorporated into designs for sleek spaceplanes.



LOCKHEED MARTIN

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It'll never fly: the ambitious National Aerospace Plane (inset) and the X-33 were each hailed as the future for space travel. But spiralling costs and insurmountable technical problems eventually scuppered both designs.

By far the biggest obstacle for any spacecraft, however, is getting into orbit in the first place. To escape the pull of Earth's gravity, a craft must accelerate to more than 40,000 kilometres per hour. Launching a 22-tonne payload to these speeds currently requires a rocket weighing nearly 1,000 tonnes, which consists mostly of liquid hydrogen and oxygen fuels and the tanks that hold them. Today's rockets shed their emptied tanks as they climb into space, but many aerospace engineers consider this 'stage' strategy a wasteful and inelegant solution to the launch problem.

Weighty issues

Over the decades, engineers have racked their brains to overcome the weight issue and move to a single-stage vehicle. As fuel makes up most of a rocket's weight, the simplest solution would be to find a lightweight, super-efficient propellant, but so far, none has emerged. "When Captain Kirk decides to send us some dilithium crystals, that will change," says T. K. Mattingly, a former Apollo and shuttle astronaut who has devoted the past 20 years to developing advanced launch-vehicle concepts. "But until then we have to live with chemistry."

The National Aerospace Plane would have used another trick to do away with much of its bulky fuel. Rather than carrying large amounts of liquid oxygen, the craft would have scooped it as a gas out of the atmosphere at hypersonic speeds, compressed it, and combusted it with on-board liquid hydrogen in a special chamber. After accelerating to many times the speed of sound, the plane would head upwards and zoom into orbit.

This novel engine design is known as a scramjet, and involves some major technical challenges. Because scramjets can only work in the thin atmosphere of very high altitudes, and at speeds greater than five times that of sound, such planes must incorporate more conventional engine technology for take-off and landing. And, as there is no oxygen in space, these planes would still need to carry some liquid oxygen on board to use once they are in orbit.

These complex technical needs proved to be too much for the National Aerospace Plane. "The programme lost political and financial backing because there wasn't enough confidence that you could make it work," says Vance Brand, who worked on the plane and is now acting director of aerospace projects at NASA's Dryden Flight Research Center in Edwards, California.

Lightening the load

Besides cutting the amount of fuel being carried, it may also be possible to reduce the weight of the spacecraft itself. This became NASA's leading strategy after the National Aerospace Plane's demise. In 1996, the agency selected contractor Lockheed Martin of Denver, Colorado, to help design a lightweight craft that could get into orbit in a single stage. The company turned the task over to its famous 'Skunk Works' design team in Palmdale, California. The result was the X-33, a wedge-shaped experimental aircraft that NASA hoped would prove the feasibility of a self-contained spaceship.

"Lockheed's approach was very bold," says Andrew Butrica, a former NASA historian who is now writing a book on the X-33 programme. The craft used graphite–epoxy composites that were a fraction of the weight of the aluminium conventionally used for spacecraft construction. But these high-tech materials were poorly understood and proved difficult to work with. "The thing that ultimately failed was the hydrogen tank," says John Paulson, who heads the Vehicle Analysis Branch at NASA's Langley Research Center in Hampton, Virginia. Among other problems, the craft's tanks had trouble dealing with the thermal stresses of holding fuels that were a few degrees above absolute zero. In a 1999 test filling, the walls of the hydrogen tank failed. After spending more than $1 billion on the project, NASA and Lockheed Martin bailed out in 2001.

Today, NASA's programme to replace the shuttle is much more conservative. Rather than betting heavily on advanced engines or lightweight composite materials, the agency plans to build a small craft called the Orbital Space Plane. The working designs are not revolutionary — in fact, one leading contender, put forward by Orbital Sciences of Dulles, Virginia, and Northrop Grumman of El Segundo, California, is based on a Soviet concept spacecraft called BOR-4, which was first spied by the West in the early 1980s. The Orbital Space Plane will be strapped to the top of a conventional, disposable rocket booster and shot into space. The plan is for it to be used initially as a 'lifeboat' for the International Space Station, and later as a taxi service for rotating the station's crews.

One small step

Paulson admits that the Orbital Space Plane is "not going to be a tremendous leap". But he stresses that practical considerations make it the next logical step. Mattingly concurs, noting that rocket pioneer Wernher von Braun was once asked what he thought was the best launch vehicle. "He answered: 'Whatever is affordable,'" says Mattingly.

Meanwhile, NASA and the Department of Defense continue to devote modest funding to concepts such as scramjets and advanced materials that might eventually lead to a single-stage reusable space vehicle. Many experts believe that this may come from an intermediate, two-stage system in which a scramjet-powered craft launches a rocket from the upper atmosphere.

The big question is whether the political will exists to bring these projects to fruition. The space shuttles were originally intended to launch scientific, military and commercial satellites — indeed, in the early days of the shuttle programme, US government satellites had to be launched on the craft by congressional order. But following the 1986 Challenger accident, those rules were abandoned. Today, satellite launches depend on expendable rockets. And in the light of the current slump in the airline industry, and the continuing risks of space travel, Reagan's vision of travellers zooming from Washington to Tokyo now looks more than a little starry-eyed. "I'm very pessimistic in the near term," says Butrica, "and I'm fearful that Columbia has dealt a near deathblow to the manned space programme."

Mattingly is certain that the technical obstacles to creating a fully reusable spaceplane can be overcome. But he feels that real progress will come only if enthusiasts have a clear goal at which they can drive their technology programmes. "We need to stop and ask ourselves: 'What are we trying to do?'" he says. ■

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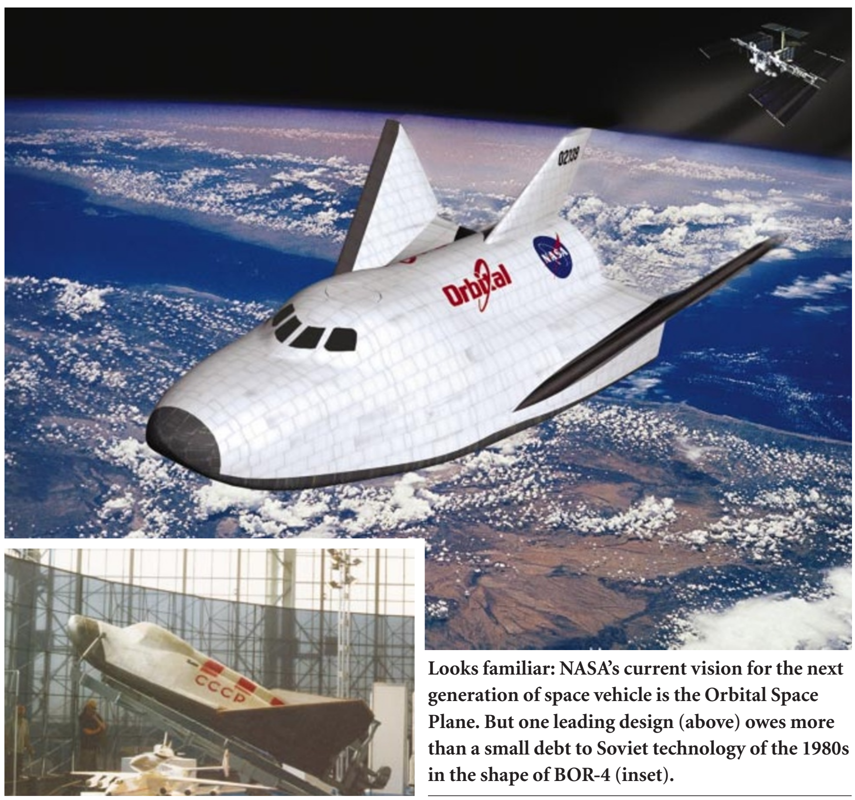
NASA's Space Launch Initiative
www.slinews.org



NORTHROP GRUMMAN/ORBITAL SCIENCES

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Looks familiar: NASA's current vision for the next generation of space vehicle is the Orbital Space Plane. But one leading design (above) owes more than a small debt to Soviet technology of the 1980s in the shape of BOR-4 (inset).