# A step to the moon

## DC-X experimental lander set up Boeing for future NASA work

By Ed Memi

You probably remember the Apollo lunar lander from the 1960s. But did you know that Boeing has more recent experience with this type of space vehicle? McDonnell Douglas, a Boeing predecessor company, built the Delta Clipper–Experimental DC-X, a prototype experimental lander, and the more-advanced Clipper Graham DC-XA vehicle. Boeing will put that expertise to good use when it competes to build the United States' next lunar lander in 2011 or 2012.

The DC-X program was an unmanned prototype of a reusable single-stage-to-orbit launch vehicle. The one-third-scale DC-X was never designed to achieve orbital altitudes or velocity. Instead, it was meant to demonstrate various flight concepts, such as vertical takeoff and landing and responsive operations.

McDonnell Douglas received its DC-X contract on Aug. 16, 1991, from the U.S. Department of Defense's Strategic Defense Initiative Office; the contract was taken over by NASA's Marshall Space Flight Center when it became the DC-XA program.

The cone-shaped 42-foot (12.8-meter) DC-X and DC-XA vehicles were assembled in Huntington Beach, Calif., with test flights taking place at the White Sands Missile Range, N.M. The DC-XA was a lighter-weight version of the DC-X that relied on the use of more-advanced technologies to provide improved performance.

### 'VERY COMPLEX SYSTEMS'

The DC-X conducted its first of eight test flights on Aug. 18, 1993, while another four flights were flown under the DC-XA program. The flights lasted from 59 to 142 seconds, and the highest altitude was 10,300 feet (3,140 meters).

"Rocket-powered vertical landers are very complex systems, and we have a really deep understanding of how those systems work," said James Ball, who was on the original DC-X proposal team and eventually went on to lead the DC-XA software team. Ball, now a Boeing manager for the flight function at Huntington Beach, noted that the lunar lander was a simpler vehicle than the DC-X; for example, the DC-X featured four engines, while previous landers had just one.

The DC-X demonstrated that aircraft-like operations are possible using rocket-powered reusable vehicles. "The vehicle flew forward, backward, sideways and could hover. Most vehicles don't do that," said Dan Nowlan, a Boeing technical fellow who was the DC-X guidance, navigation and control lead.

There were also a host of performance requirements for the vehicle, which used innovative fuel-tank technologies such as lightweight composite tanks, lines and valves. The DC-X program featured new propulsion technologies such as gaseous oxygen and hydrogen roll-control thrusters. Other innovations included an autonomous checkout to include leak detection and isolation. These technologies can be directly applied to future lunar lander designs.

One of the objectives of the test program was to demonstrate that the DC-X had a robust, adaptive vehicle design. During the fifth test flight, a portion of the side of the vehicle was damaged, but the design was so robust that the vehicle was able to land safely. Lt. Col. Jess Sponable, Single Stage Rocket Technology program manager for the Ballistic Missile Defense Organization, was quoted in a company press release saying, "This anomaly resulted in successful demonstrations of several important firsts: executing the autoland sequence demonstrating an 'aircraft-like' abort mode; landing on the gypsum (desert ground), demonstrating the ability to land future vehicles virtually anywhere; and demonstrating the system's toughness and robustness, since the DC-X continued to fly despite the aeroshell damage."

During another test flight, a vehicle fire destroyed a control flap, but the vehicle was repaired in time for its next test flight. On test flight three, the vehicle survived a propellant helium bubble during liftoff and autonomously recovered

The McDonnell Douglas DC-X blasts off from the desert at White Sands Missile Range, N.M. The DC-X needed only two years from contract award to first flight.

MCDONNELL DOUGLAS PHOTO

control, demonstrating the equivalent of an engine-out capability. "This showed how the DC-X's highly adaptive flight-control system could adjust to an unplanned maneuver and save the vehicle," Ball said.

### 'FLY A LITTLE, BREAK A LITTLE'

The DC-X was designed for reliability, maintainability, supportability and operability. Given the uncertainties of the design, the plan was to produce a deliberately simple test vehicle and to "fly a little, break a little" to gain experience with a fully reusable quick-turnaround spacecraft. Demonstration objectives included a 7-day turnaround between flights with a 3-day goal and use of 50 or fewer on-vehicle maintenance personnel. The program achieved a 26-hour turnaround with 10 maintenance personnel.

"My heroes during the flights were the operations and maintenance folks. They did amazing things in turning this vehicle around in terms of repairs and doing things quickly," Nowlan said. The DC-X program flew with a total field-support team of only 25 engineers and technicians.

The DC-X used fast-track management rules for the $60 million contract. Nowlan said one of the reasons for success was the reliance on system-level, end-to-end testing to spot problems before each flight. Independent reviewers were impressed with the speed with which problems were addressed and resolved. "The reason DC-X was successful was because of our customer commitment to rapid prototyping principles and our internal program management," Nowlan said.

Even with these achievements in flight, prototyping and program management, one of the program's most significant technical advances was its streamlined software-development process. This helped increase efficiency over previous systems and greatly cut support-infrastructure requirements during test flights. "We literally could turn around software in small fractions of what it takes to launch current systems," Ball said. Echoed Don Barnes, a Boeing Ares I engineer who was a DC-XA stress engineer for the first use of a composite hydrogen tank in the spacecraft: "We did not have much in way of paperwork—which I liked, since it was such a fast-paced development program." ■

*edmund.g.memi@boeing.com*

## Tale of the tape: *DC-X*

**Height:** 42 feet (12.8 meters)

**Diameter:** 13 feet 4 inches at base (4.06 meters), conical shape

**Weight empty:** 20,000 pounds (9,072 kilograms)

**Weight with full load of propellants:** 41,600 pounds (18,869 kilograms)

**Propellants:** Liquid oxygen and liquid hydrogen

**Engines:** Four RL-lOA5 rocket engines, each generating 13,700 pounds (6200 kilograms) thrust.

**Reaction Controls:** Four 440-pound-thrust (200-kilogram-thrust) gaseous oxygen, gaseous hydrogen thrusters


**Workers pose under the DC-X following its rollout from the factory floor in Huntington Beach, Calif. The DC-X spacecraft demonstrated that aircraft-like operations are possible using rocket-powered reusable vehicles and pioneered the use of lightweight composite fuel tanks, lines and valves with potential for future lunar landers.**

MCDONNELL DOUGLAS PHOTO