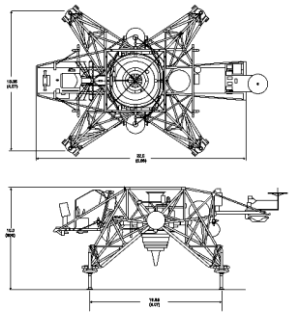


Bell Aerosystems Lunar Landing Research Vehicle (LLRV)

The **Bell Aerosystems Lunar Landing Research Vehicle (LLRV)** was an Apollo Project era program to build a simulator for the Moon landings. The LLRVs, humorously referred to as "flying bedsteads", were used by the FRC, now known as the NASA Dryden Flight Research Center, at Edwards Air Force Base, California, to study and analyze piloting techniques needed to fly and land the Apollo Lunar Module in the moon's low gravity environment.

Success of the two LLRVs led to the building of three **Lunar Landing Training Vehicles** (LLTVs) used by Apollo astronauts at the Manned Spacecraft Center in Houston, Texas, predecessor of NASA's Johnson Space Center.
The final phase of every Apollo landing was manually piloted by the mission commander. Because of navigational problems, Neil Armstrong, Apollo 11 commander, said his mission would not have been successful without extensive training on the LLRVs and LLTVs.

Built of aluminum alloy trusses, the vehicles were powered by a General Electric CF700-2V turbofan engine with a thrust of 4,200 lbf (19 kN), mounted vertically in a gimbal. The engine lifted the vehicle to the test altitude and was then throttled back to support five-sixths of the vehicle's weight, simulating the reduced gravity of the moon. Two hydrogen peroxide lift rockets with thrust that could be varied from 100 to 500 lbf (440 to 2,200 N) handled the vehicle's rate of descent and horizontal movement. Sixteen smaller hydrogen peroxide thrusters, mounted in pairs, gave the pilot control in pitch, yaw and roll. As safety backups, six 500 lbf (2,200 N) thrust rockets could take over the lift function and stabilize the craft for a moment if the jet engine failed. The pilot had an ejection seat for safety.

After conceptual planning and meetings with engineers from Bell Aerosystems, Buffalo, N.Y., a company with experience in vertical takeoff and landing (VTOL) aircraft, NASA issued Bell a $50,000 study contract in December 1961. Bell had independently conceived a similar, free-flying simulator, and out of this study came the NASA Headquarters' endorsement of the LLRV concept, resulting in a $3.6 million production

contract awarded to Bell on February 1, 1963, for delivery of the first of two vehicles for flight studies at the FRC within 14 months.

The two LLRVs were shipped from Bell to the FRC in April 1964, with program emphasis on vehicle No. 1. It was first readied for captured flight on a tilt table constructed at the FRC to test the engines without actually flying. The scene then shifted to the old South Base area of Edwards. On the day of the first flight, 30 October, 1964, research pilot Joe Walker flew it three times for a total of just under 60 seconds to a peak altitude of ten feet (3 m). Later flights were shared between Walker; another Dryden pilot, Don Mallick; the Army's Jack Kluever; and NASA Manned Spacecraft Center pilots Joseph Algranti and H.E. "Bud" Ream.
NASA had accumulated enough data from the LLRV flight program at the FRC by mid-1966 to give Bell a contract to deliver three LLTVs at a cost of $2.5 million each.
In December 1966 vehicle No. 1 was shipped to Houston, followed by No. 2 in January 1967, within weeks of its first flight. Modifications already made to No. 2 had given the pilot a three-axis side control stick and a more restrictive cockpit view, both features of the real Lunar Module that would later be flown by the astronauts down to the moon's surface.

After testing at the FRC, the LLRVs were sent to Houston, where research pilots learned to become LLTV instructor pilots. In December 1967, the first of the LLTVs joined the LLRVs to eventually make up the five-vehicle training and simulator fleet. In all, NASA built five LM trainers of this type. During training flights at Ellington AFB near Houston, Texas, three of the five vehicles were destroyed in crashes. Two were an early version called the Lunar Landing Research Vehicle or LLRV. Neil Armstrong was flying LLRV-1 on May 6, 1968 when it went out of control. He ejected safely and the vehicle crashed. A later version was called the Lunar Landing Training Vehicle or LLTV and three were built. Two of these were lost in crashes on December 8, 1968 (piloted by Joe Algranti) and January 29, 1971 (piloted by Stuart Present). The other pilots also ejected safely from the crashing LLTV's.

Lunar Sim Mode

Test pilot Stuart Present ejects safely from crashing LLTV (NASA), 29 January 1971.

There were two distinct modes of flight for the LLTV. The basic mode was with the engine gimbal locked. But in the gimbaled lunar sim mode, the engine was kept pointed downward which allowed the vehicle to tilt at the greater angles necessary in the reduced lunar gravity to achieve similar rates of translation. Despite its ungainly appearance, the LLRV was equipped with an astonishingly sophisticated array of early sensoric and computational hardware. The system had no specific name, but the effect it produced was called "Lunar Sim Mode". This was the highest degree of hardware-based simulation, and was the purpose of the whole project. This was not a system to unburden the pilot, such as an autopilot does, nor was it meant to introduce any sort of safety or economy. The system's sole intention was to project the illusion of piloting the Lunar Module. So 'Lunar Sim Mode' can be thought of as a mixture of stability augmentation, recalculation of vertical acceleration according to the lunar gravity constant, all followed by accompanied instantaneous corrective action. The LLRV's Lunar Sim Mode even was able to counter-correct wind gusts within milliseconds, as they definitely would have disturbed the impression of a missing atmosphere. Sensoric source of the Lunar Sim Mode was the Doppler radar. The visually significant sign of an engaged Lunar Sim Mode was the free-gimbaled turbofan, always strictly pointing to the center of gravity, regardless the LLRV's current attitude. This unique aircraft represents one of the few hardware simulators that ever became airborne.

Donald "Deke" Slayton, then NASA's chief astronaut, later said there was no other way to simulate a moon landing except by flying the LLRV.
LLRV No. 2 was eventually returned to Dryden, where it is on display as a silent artifact of the Center's contribution to the Apollo program.

Specifications (LLRV)

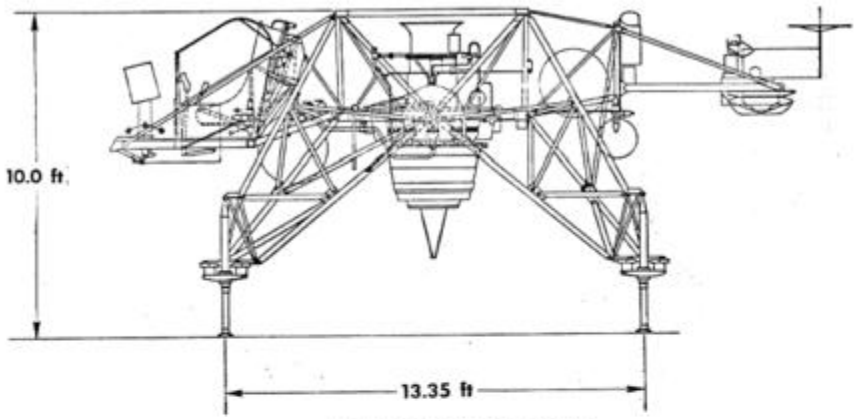
General characteristics

Crew: one, pilot
Length: 22.5 ft (6.85 m)
Wingspan: 15.08 ft (4.6 m)
Height: 10.0 ft (3.05 m)
Empty weight: 2,510 lb (1,138 kg)
Loaded weight: 3,775 lb (1,712 kg)
Max takeoff weight: 3,925 lb (1,780 kg)
Powerplant: 1× General Electric CF-700-2V jet, 4,200 lbf (19 kN)

Performance

Maximum speed: 40 mph
Service ceiling: 6,000 ft (1,800 m)
Rate of climb: 3,600 ft/min (17.9 m/s)
Secondary Engine: 2 x hydrogen peroxide lift rockets with 500 lbf (2,200 N) each
Endurance: 10 minutes

LLRV PROFILE VIEW



LLRV PLAN VIEW