NASA Facts

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FS-2002-09-045 DFRC

Spacewedge

Spacewedge vehicle decsending with 288 sq. foot parafoil. NASA photo EC 92-04271-4

From October 1991 to December 1996, NASA's Dryden Flight Research Center, Edwards, Calif., conducted a research program known as the Spacecraft Autoland Project to determine the feasibility of the autonomous recovery of a spacecraft using a ram-air parafoil system for the final stages of flight, including a precision landing. The NASA Johnson Space Center (JSC), Houston, Texas, and the U.S. Army also participated in various phases of the program, with the Charles Stark Draper Laboratory developing the software for Wedge 3 under contract to the Army. Four generic spacecraft models (each called a Spacewedge or simply a Wedge) were built to test the feasibility of the concept and also of the use of a parafoil for delivering Army cargo. Technology developed during the program has applications for future spacecraft recovery systems. Spacewedge demonstrated precision flare and landing into the wind at a predetermined location. The program showed that a flexible, deployable system using autonomous navigation and landing was a viable and practical way to recover spacecraft.

Program Development

NASA researchers conducted a flight test program in California to develop and refine the Spacewedge vehicle design. The first test vehicle (Wedge 1) was just four feet long and weighed 120 pounds. It was initially launched from a hillside near Tehachapi to evaluate general flying qualities, including gentle turns and landing flare. Two of these slope soar flights were made on April 23, 1992, with approximately 15-knot winds, achieving altitudes of 10 to 50 feet above the ground. The test program then moved to Rogers Dry Lake at Edwards Air Force Base, and to a sport parachute (Skydive) drop zone at California City.

A second vehicle (known as Inert Spacewedge or Wedge 2) was fabricated with the same external geometry and weight as Wedge 1. It was initially used to validate parachute deployment, harness design, and drop separation characteristics. Wedge 2 was inexpensive, without internal components, and considered expendable. It was first dropped from a Cessna U-206 Stationair on June 10, 1992, during flight three. A second drop of Wedge 2 verified repeatability of the parachute deployment system. The Wedge 2 vehicle was also used for the first drop from a Rans S-12 ultralight modified as a remotely piloted vehicle (RPV) during flight nine on August 14, 1992. Wedge 2 was later instrumented and used for ground tests, mounted on top of a van, and became the primary test vehicle for the Phase II test series.

Thirty-six flight tests were made during Phase I, the last taking place on February 12, 1993. These flights verified the manual control and autonomous landing systems of the vehicle. Eleven of the tests were remotely controlled. Most were launched from the Cessna U-206 Stationair. Only flights nine and 12 were launched from the Rans S-12 RPV.

Phase II of the program ran from March 1993 to March 1995, and encompassed 45 flights. It continued the research for NASA JSC, using a smaller parafoil for higher wing (parachute) loading. For Phase II, NASA Dryden engineers developed a new guidance, control, and instrumentation system.

Phase III, encompassing 34 flights, evaluated the Precision Guided Airdrop Software (PGAS) system using Wedge 3 from June 14, 1995, to November 20, 1996. Researchers used Wedge 3 to develop a guidance system to be used by the Army for precision offset cargo delivery. The Wedge 3 vehicle was four feet long and was dropped at weights varying from 127 to 184 pounds. Unlike Wedges 1 and 2, its flight objectives were not tied to the terminal recovery of a space vehicle, and it was not called a Spacewedge. (There was also a fourth wedge, but it never flew and served only as backup hardware to Wedge 3.)

Wedge 2 under Rans S-12 RPV (EC 92-08148-4), and Wedge 3 being placed in Cessna U-206 (EC 96-43660-3).

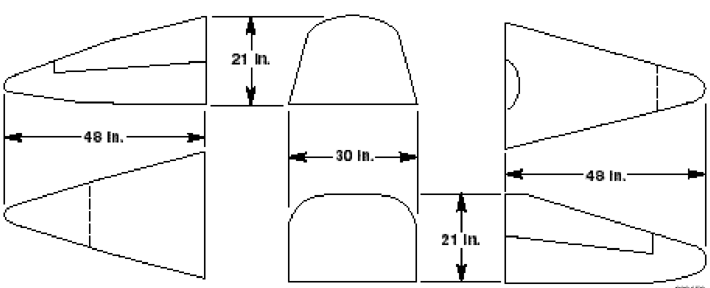
Spacewedge Design

Two Spacewedge shapes, resembling half-cones with a flattened bottom, were used for four airframes that represented generic hypersonic vehicle configurations. Wedge 1 and Wedge 2 had sloping sides, and the underside of the nose sloped up slightly. Wedge 3 and Wedge 4 had flattened sides, to create a larger internal volume for instrumentation. The Spacewedge vehicles were 48 inches long, 30 inches wide, and 21 inches high. The basic weight was 120 pounds, although various configurations ranged from 127 to 184 pounds during the course of the test program. Wedge 1 had a tubular steel structure, covered with plywood on the rear and underside to withstand hard landings. It had a fiberglass-covered wooden nose, and removable aluminum upper and side skins. Wedge 2, originally uninstrumented, was later configured with instrumentation. It had a fiberglass outer shell, with plywood internal bulkheads and bottom structure. Wedge 3 was constucted as a two-piece fiberglass shell, with a plywood and aluminum shelf for instrumentation.

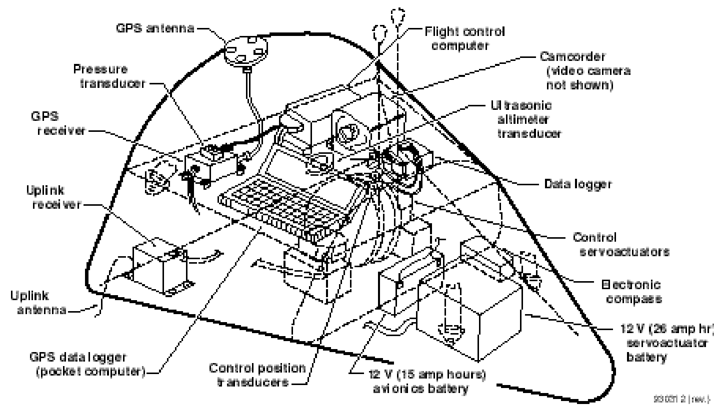
In the manual control mode, the vehicle was flown using radio uplink. In the autonomous mode, it was controlled using a small computer which received inputs from onboard sensors. Selected sensor data were recorded onto several onboard data loggers.

A commercially-available 288 sq. foot ram-air parafoil was selected for Phase I tests. Such parachutes are commonly used by sport parachutists. The docile flight characteristics, low loading factor, and proven design allowed the project team to concentrate on developing the vehicle rather than the parachute. With the exception of lengthened control lines, the parachute was not modified. Its large size allowed the vehicle to land without flaring, and without sustaining damage. For Phase II and III, a smaller (77 sq. foot) parafoil was used to allow for a wing (actually, parafoil) loading more representative of space vehicle or Army cargo applications.

The Spacewedge Phase I and II instrumentation system architecture was driven by cost, hardware availability, and program evolution. (During Phase I, Wedge 2 had an inert payload but was outfitted with instrumentation for Phase II.) The essential items consisted of the uplink receiver, Global Positioning System receiver and antenna, barometric altimeter, flight control computer, servoactuators, electronic compass, and ultrasonic altimeter. Added instrumentation included a video camera and camcorder, control position transducers, a data logger, and a pocket personal computer.



Three-view drawings of Spacewedge shape, Wedge 1 (left), and PGAS Wedge 3 (right).



Schematic showing Spacewedge Phase II instrumentation for Wedge 2.

NASA employees integrated these off-the-shelf components. Wedge 3 instrumentation was considerably more complex to accommodate the PGAS software system.

Spacewedge control systems had programming, manual, and autonomous flight modes. The programming mode was used to start up and configure the flight control computer. Researchers entered the landing coordinates, decision altitudes, and ground wind velocity at the landing site.

The manual mode used a radio control model receiver and uplink transmitter, configured to allow the ground pilot to enter either brake (pitch) or turn (yaw) commands. The vehicle reverted to manual mode whenever the transmitter controls were moved, even when the autonomous mode was selected.

The autonomous mode allowed the vehicle to navigate to the landing point, maintain the holding pattern while descending, enter the landing pattern, and initiate the flare maneuver. There were three decision altitudes: at the start of the landing pattern, at the turn to final approach, and upon flare initiation.

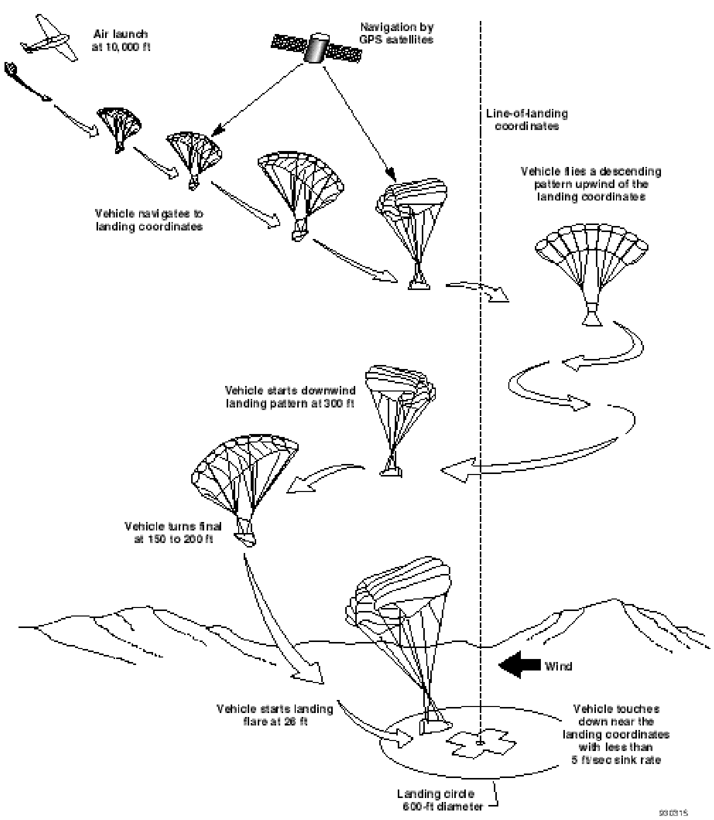
Spacewedge Flight Profile

When at high altitude and offset from the landing point, the vehicle was commanded to fly to the landing point. If the landing point was reached while at or above the first decision altitude (typically set to 300 feet), then the vehicle was commanded to fly a holding pattern until it descended below the decision altitude. The holding pattern was an upwind racetrack aligned with the wind (as input in the programming mode). Each lap of the racetrack pattern consumed approximately 500 feet of altitude. Below the first decision altitude, the vehicle was commanded to enter the landing pattern.

The point to turn to final approach was based on a second decision altitude, typically 150 to 200 feet. This second altitude was a function of the wind and the position relative to the landing point. Once on final approach, the vehicle was commanded to maximum speed, steering commands were locked out, and the ultrasonic altitude sensor was activated.

At a final decision altitude of about 26 feet, the flare was initiated by commanding full brake. Touchdown occurred approximately four seconds later.

Wedge 3 in flight. NASA photo EC 95-43135-1



Key Personnel

Many Dryden employees and partners worked on this project. These included R. Dale Reed, who originated the concept of conducting a subscale flight test at Dryden. He also participated in the flight testing. Alexander Sim managed the project and participated in the flight tests and documentation. James Murray served as the principal Dryden investigator and as lead person for all systems integration for Phases I and II. He designed and fabricated much of the instrumentation for Phase II and was the lead person for flight data retrieval and analysis in Phases II and III. David Neufeld performed the wedge systems mechanical integration for all three phases and served as parachute rigger, among other duties.

From Draper Lab, Philip Hattis served as the project technical director for his organization's significant contributions to Phase III. For the Army, Richard Benney was the technical point of contact, while Rob Meyerson served as the technical point of contact for NASA JSC and provided the specifications for the Spacewedges.

Spacewedge Contributions

NASA is studying a variety of vehicles for use in returning humans and cargo from space to Earth. Although the configuration of these vehicles has not yet been finalized, several capsules and lifting body designs are under consideration.

Potential NASA users for a deployable, precision, autonomous landing system include proposed vehicles with human crews as well as planetary probes and booster recovery systems. Military applications include the use of autonomous gliding parachute systems on aircraft ejection seats, and high-altitude, offset delivery of cargo to minimize danger to aircraft and crews. Such a cargo delivery system could also be used for providing humanitarian aid.

The Spacecraft Autoland Project, or Spacewedge, was an example of the innovative engineering work that is typical at NASA Dryden. Off-the-shelf equipment was used whenever possible in the project to keep costs low and to reduce development time. A relatively inexpensive Rans S-12 ultralight aircraft was modified as a RPV drop aircraft until the less labor-intensive unmodified Cessna U-206 had proved its viability. The four Spacewedge research vehicles are currently in storage at NASA Dryden Flight Research Center, Edwards, Calif.

Spacewedge landing at California City drop zone. NASA photo EC92-06186-2

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