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NASA Armstrong Fact Sheet: Helios Prototype

The forerunner of 21st century solar-powered "atmospheric satellites"

The solar-electric Helios Prototype flying wing is shown near the Hawaiian islands of Niihau and Lehua during its first test flight on solar power.
Credits: NASA Photo

The Helios Prototype is a remotely piloted flying wing aircraft developed under NASA's Environmental Research Aircraft and Sensor Technology (ERAST) project. The two primary goals of the Helios Prototype development are to demonstrate sustained flight at an altitude near 100,000 feet and flying non-stop for at least 24 hours, including at least 14 hours above 50,000 feet.

In 2001, the Helios Prototype achieved the first of the two goals by reaching an unofficial world-record altitude of 96,863 feet and sustaining flight above 96,000 feet for more than 40 minutes during a test flight near Hawaii. The aircraft is undergoing modifications and upgrades to enable it to accomplish the flight endurance milestone, presently planned for late summer, 2003.

The operational and technical ability to reach these two goals is critical for NASA's ERAST project. Through ERAST, many new propulsion, materials, control, instrumentation, and sensor technologies are being pioneered which could enable the development of a fleet of high-flying uninhabited aircraft that could conduct a wide variety of Earth and atmospheric science missions. Flying autonomously with mission-oriented payloads and instrumentation, these ultra-high flyers could carry out storm tracking studies, atmospheric sampling, spectral imaging for agricultural and natural resources monitoring, pipeline monitoring, and also serve as relay platforms for telecommunications systems.

Developed by AeroVironment, Inc., of Monrovia, CA, with the assistance of NASA's Dryden Flight Research Center, the Helios Prototype is one of several remotely piloted aircraft that have been involved in NASA's ERAST project. It is an enlarged version of the Centurion flying wing, flown at Dryden in late 1998 to verify the handling qualities and performance of a lightweight all-wing aircraft of more than 200-foot wingspan. It was renamed the Helios Prototype to reflect its role as a forerunner of the eventual Helios production aircraft, which will be designed to fly continuously for up to six months at a time on science and commercial missions.

Aircraft Description

The Helios Prototype is an ultra-lightweight flying wing aircraft with a wingspan of 247 feet, longer than the wingspans of the U.S. Air Force C-5 military transport (222 feet) or the Boeing 747 commercial jetliner (195 or 215 feet, depending on the model), the two largest operational aircraft in the United States. The electrically powered Helios is constructed mostly of composite materials such as carbon fiber, graphite epoxy, Kevlar®, styrofoam, and a thin, transparent plastic skin. The main tubular wing spar is made of carbon fiber. The spar, which is thicker on the top and bottom to absorb the constant bending motions that occur during flight, is also wrapped with Nomex® and Kevlar for additional strength. The wing ribs are also made of epoxy and carbon fiber. Shaped styrofoam is used for the wing's leading edge and a durable clear plastic film covers the entire wing.

The Helios Prototype shares the same eight-foot wing chord (distance from leading to trailing edge) as its Pathfinder and Centurion predecessors. The 247-foot wingspan gives the Helios Prototype an aspect ratio of almost 31 to 1. The wing thickness is the same from tip to tip, 11.5 inches or 12 percent of the chord, and it has no taper or sweep. The outer panels have a built-in 10-degree dihedral (upsweep) to give the aircraft more lateral stability. A slight upward twist at the tips of the trailing edge helps prevent wingtip stalls during the slow landings and turns. The wing area is 1,976 sq. ft., which gives the craft a maximum wing loading of only 0.81 lb./sq. ft. when flying at a gross weight of 1,600 lb.

The all-wing aircraft is assembled in six sections, each about 41 feet long. An underwing pod is attached at each panel joint to carry the landing gear, the battery power system, flight control computers, and data instrumentation. The five aerodynamically shaped pods are made mostly of the same materials as the wing itself, with the exception of the transparent wing covering. Two wheels on each pod make up the fixed landing gear—rugged mountain bike wheels on the rear and smaller scooter wheels on the front.

Helios Prototype flying wing is shown moments after takeoff, beginning its first test flight on solar power from the U.S. Navy's Pacific Missile Range Facility on Kauai, HI.
Credits: NASA Photo

The Helios Prototype is powered by 14 brushless direct-current electric motors mounted across the wing's entire span. The motors are rated at 2 hp. (1.5 kW) each, and drive lightweight two-blade propellers of 79-inch diameter. The propellers are made from advanced composite materials and a laminar-flow design for efficiency at high altitudes.

The cruising speed of Helios ranges from 19 to 27 mph, with takeoff and landing equating to the average speed of a bicycle.

For the initial flight tests at Dryden in 1999, the Helios Prototype was powered by lithium battery packs carried in the underwing pods. More than 62,000 solar cells were installed on the entire upper surface of the wing during 2000. For eventual long duration missions, the solar cells will be assisted by an on-board fuel-cell based energy storage system now in development that will power the motors and aircraft systems through the night.

The only flight control surfaces used on the Helios Prototype are 72 trailing-edge elevators that provide pitch control. Spanning the entire wing, they are operated by tiny servomotors linked to the aircraft's fight control computer. To turn the aircraft in flight, yaw control is applied by applying differential power on the motors—speeding up the motors on one outer wing panel while slowing down motors on the other outer panel.

The Helios Prototype weighs in at only 1,322 lb empty. During the 1999 development flights, the aircraft carried payloads of up to 626 lb; —a combination of ballast and instrumentation, with the amount on each flight determined by the flight objectives. During the 2001 flights, the Helios Prototype flew at a weight of about 1,600 lb, including its flight test instrumentation. The ultimate objective of the Helios design is to carry a payload of scientific instruments or telecommunications relay equipment averaging about 200 lb to high altitudes for missions lasting from several days to several months.

The Helios Prototype is controlled remotely by a pilot on the ground, either from a mobile control van or a fixed ground station that is equipped with a full flight control station and consoles for systems monitoring. A flight termination system, required on remotely piloted aircraft flown in military restricted airspace, includes a parachute system deployed on command, plus a homing beacon to aid in the aircraft's location. In case of loss of control or other contingency, the system is designed to bring the aircraft down within the restricted airspace area to avoid any potential damage or injuries to fixed assets or personnel on the ground.

Helios Prototype Development Path

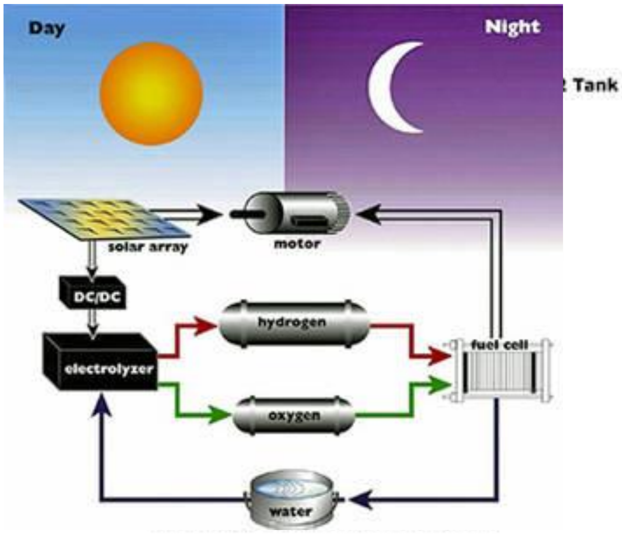
AeroVironment initiated its development of full-scale solar-powered aircraft with the Gossamer Penguin and Solar Challenger vehicles in the late 1970's and early 1980's, following the pioneering work of Robert Boucher, who built the first solar-powered flying models in 1974. The Helios Prototype is the fourth generation of all-wing aircraft designed and built by AeroVironment at its Design Development Center in Simi Valley, CA as technology demonstrators for future solar-powered high-altitude aircraft platforms for science and commercial missions.

The first generation was the Pathfinder, developed as the HALSOL aircraft in the early 1980's with a wing span of 98.4 feet. Its eight electric motors —later reduced to six —were first powered by batteries. Two underwing pods contain the landing gear, batteries, instrumentation system, and flight control computer. By the time the aircraft was adopted into the ERAST project in late 1993, solar cells were being added, eventually covering the entire upper surface of the wing. Pathfinder set a solar-powered altitude record of 50,500 feet at NASA Dryden on Sept. 11, 1995.

After further modifications, the aircraft was moved to the U.S. Navy's Pacific Missile Range Facility (PMRF) on the Hawaiian island of Kauai. On one of seven flights there in the spring of 1997, Pathfinder raised the altitude record for solar-powered aircraft —as well as propeller-driven aircraft —to 71,530 feet. During those flights, Pathfinder carried two lightweight imaging instruments to learn more about the island's terrestrial and coastal ecosystems, demonstrating the potential of such aircraft as platforms for scientific research.

Pathfinder Plus was the next step leading to Helios. It used four of the five sections from the original Pathfinder wing, but substituted a longer center section that increased the span to 121 feet, increasing the area available for solar cells on the upper wing surface. The number of electric motors was increased to eight. The Pathfinder Plus development flights flown at PMRF in the summer of 1998 validated power, aerodynamic, and systems technologies for its successor, the Centurion, which at that time was being designed to reach 100,000-foot altitude on solar power. On Aug. 6, 1998, Pathfinder Plus proved its design by raising the world altitude record to 80,201 feet for solar-powered and propeller-driven aircraft.

Centurion, originally built for the 100,000-foot altitude milestone specified by the ERAST project, was the third generation. Its wing incorporated a redesigned high-altitude airfoil and the span was increased to 206 feet. The number of motors was increased to 14 and the number of underwing pods to carry batteries, flight control system components, ballast, and landing gear rose to four. Centurion flew three development test flights on battery power in late 1998 at low altitudes at NASA Dryden Flight Research Center at Edwards, CA, verifying the design's handling qualities, performance, and structural integrity.



Helios Warm Box diagram.
Credits: NASA Illustration

The Centurion was then modified into the Helios Prototype configuration by adding a sixth 41-foot wing section and a fifth landing gear and systems pod, becoming the fourth configuration in the series of solar-powered flying wing demonstrator aircraft developed by AeroVironment under the ERAST project. The larger wing on the Helios Prototype accommodates more solar arrays to provide adequate power for the sun-powered development flights that followed.

Using the traditional incremental or stair-step approach to flight testing, the Helios Prototype was first flown in a series of battery-powered development flights in late 1999 to validate the longer wing's performance and the aircraft's handling qualities. Instrumentation that was used for the follow-on solar-powered altitude and endurance flights was also checked out and calibrated during the initial low-altitude flights at NASA Dryden.

Solar panels were then installed in 2000 for further development flights flown during the summer of 2001 over the Pacific Ocean near Hawaii. On Aug. 13, 2001, the Helios Prototype reached an altitude of 96,863 feet, a world record for sustained horizontal flight by a winged aircraft. The altitude reached was more than 11,000 feet —or more than two miles —above the previous altitude record for sustained flight by a winged aircraft.

Round-the-clock Operation

Flying the solar-electric Helios Prototype at night when no sunlight is available will require a supplemental electrical energy source to provide power to operate the motors, avionics and experiment payloads. The number of ordinary rechargeable batteries of the NiCad or Lithium families that would be required to successfully power the aircraft through an entire night would be too heavy to meet either altitude or endurance goals. Therefore several years ago, the Helios Team turned to proton-exchange membrane fuel cell technology as the best option to give the Helios Prototype full day-and-night flight capability. Proton-exchange membrane, —also known as polymer electrolyte—technology, has advanced significantly in recent years due to the large interest and investment in alternative energy research, primarily by the automotive industry.

Helios day and night diagram.
Credits: NASA Illustration

The premise of a fuel cell-based system is that oxygen and hydrogen are combined to produce electric power, heat and water. As long as these gases are supplied, the unit continues to produce power. Not only are these systems attractive from an environmental standpoint, but since they have very few moving parts, these systems have the potential of very high reliability.

The Helios Team—, including NASA, AeroVironment and several subcontractors, —has tested a number of different fuel cells and investigated a variety of fuel cell-based power systems, with the goal of developing a system which would be significantly lighter than conventional energy storage systems. The Helios Team is currently building a fuel cell-based system which will be installed and flown on the Helios in 2003 to achieve a NASA milestone of flying for at least 14 hours above 50,000 feet altitude. This will double the amount of time the Helios is able to operate above 50,000 feet altitude. In the future, a more sophisticated regenerative energy storage system is expected to provide night-time power for Helios derivatives on flights lasting from several weeks to several months. Developmental versions of both systems are undergoing operational testing at AeroVironment laboratories.

Differential Thrust for Pitch Control

A major test during the initial flight series was the evaluation of differential engine power as a means of pitch control. During normal cruise the outer wing panels of Helios are arched upward and give the aircraft the shape of a shallow crescent when viewed from the front or rear. This configuration places the motors on the outer wing panels higher than the motors on the center panels. Speeding up the outer-panel motors caused the aircraft to pitch down and begin a descent. Conversely, applying additional power to the motors in the center panels caused Helios to pitch up and begin climbing.

If AeroVironment engineers feel that the procedure provides adequate and safe pitch control for all flight operations, the elevator servo motors and all of their electrical wiring could be removed from a follow-on production Helios design, giving it an additional 25 to 30 pounds of useful payload on future flights. The wing space now being used by the elevators could also be covered with solar arrays for additional power.

Flight Test Venues

The initial Helios Prototype development flights were conducted at the NASA Dryden Flight Research Center at Edwards, CA, where NASA's ERAST project is managed. The subsequent development flights on solar power which led to the world altitude record flight in the summer of 2001 were flown from the U.S. Navy's Pacific Missile Range Facility on the Hawaiian island of Kaua'i. That site was chosen due to its more equatorial latitude, minimal air traffic, and restricted test range airspace over the Pacific Ocean.

ERAST Project Management

Overall management of the ERAST aeronautical technology project is managed by NASA's Dryden Flight Research Center, Edwards, CA.

A parallel effort is the development of lightweight, microminiaturized sensors that will be used to carry out the environmental research and Earth monitoring. This effort is led by NASA's Ames Research Center, Moffett Field, CA. Also contributing to the ERAST project in the areas of propulsion, energy storage systems, structures, and systems analysis are NASA's Glenn and Langley Research Centers.

NASA is also working closely with the Federal Aviation Administration to develop "detect, see and avoid" systems; over-the-horizon command and control technologies and operational plans so remotely operated aircraft can be safely flown in national airspace.

The ERAST project supports the Revolutionary Vehicles element of NASA's Aerospace Technology Enterprise' Aeronautics Blueprint by creating environmentally compatible aircraft with revolutionary capabilities for unprecedented levels of performance and safety. The Helios Prototype development is in line with the goal of developing efficient electric propulsion with advanced fuel cell technology and highly integrated airframe and propulsion designs to enable quiet, low-emission aircraft.

Aircraft Specifications

Wingspan: 247 ft
Length: 12 ft
Wing Chord: 8 ft
Wing Thickness: 11.5 in. (12 percent of chord)
Wing area: 1,976 sq. ft.
Aspect Ratio: 30.9 to 1
Empty Weight: 1,322 lb
Gross Weight: Up to 2,048 lb, varies depending on power availability and mission profile.
Payload: Up to 726 lb, including ballast, instrumentation, experiments and a supplemental electrical energy system, when developed.

Electrical Power: 62,120 bi-facial solar cells covering upper wing surfaces. Cells are silicon-based, and are about 19 percent efficient in converting solar energy into electrical power. Lithium battery pack backup power to allow limited operation after dark.
Propulsion: 14 brushless direct-current electric motors, each rated at 2 hp. (1.5 kW), driving two-blade, wide-chord, 79-in. diameter laminar-flow propellers designed for high altitude.
Airspeed: From 19 to 27 mph cruise at low altitudes, up to 170 mph ground speed at extreme altitude.
Altitude: Designed to operate at up to 100,000 ft., typical endurance mission at 50,000 to 70,000 ft.
Endurance: With solar power, limited to daylight hours plus up to five hours of flight after dark on storage batteries. When equipped with a supplemental electrical energy system for nighttime flight, from several days to several months.
Primary Materials: Carbon fiber composite structure, Kevlar®, Styrofoam leading edge, transparent plastic film wing covering.

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