The Perlan Project combines literal high adventure, extreme science and technology, and the drive to bring educational excitement to the classroom. Taking a unique sailplane to stratospheric altitudes by exploiting far-reaching meteorological phenomena will, so the project team hopes, break aeronautical world records and bring new understanding of our atmosphere.

PROJECT HISTORY
The project began in the offices of the German Aerospace Center, where an image of a very unique mountain wave captured the interest of test pilot Einar Enevoldson. Enevoldson, whose career bridged the U.S. Air Force, NASA, the Empire Test Pilot’s School in England and Grob Aircraft in Germany, wondered if a sailplane could use this type of mountain wave to reach record setting heights.

The image showed a mountain wave crest above Mount Kebebekaise at the Arctic Circle, just west of Kiruna, Sweden. The picture showed what “looked like a mountain wave that extended upward to over 23 kilometers (76,000 feet) of altitude. Its amplitude was over 2km and the wavelength was about 18km. If the wave was sinusoidal, it would take only a moderate wind to create an upward wind velocity component of several meters per second—probably greater than the sink rate of a sailplane at that altitude.”

Enevoldson was soon convinced that a sailplane could soar to these heights, and began looking for sponsors to build a pressurized sailplane. Hannes Linke, a fellow glider pilot, introduced Einar to hotel heir Barron Hilton, an aviation enthusiast. Hilton thought it would be a great project, but did not want to sponsor it. Shortly thereafter, Einar received a phone call. It was Steve Fossett, an American businessman, adventurer and a record-setting aviator. Barron had apparently told him about the project. Steve quickly became convinced that the project was viable, and starting in 1998 he fully funded the project.

Einar and Steve purchased a DG 505-M, a high performance two-seat sailplane, extensively modified it and named it Perlan, the Icelandic word for pearl. They removed the self-launching engine and filled the now-empty engine compartment with dual oxygen tanks, batteries, mounted double-walled canopies to prevent fogging, installed a tail-mounted drogue parachute for emergency descents and added night lighting and high-altitude electronics.

Simultaneously, NASA conducted an informal analysis of the prospects for soaring to extreme altitudes, and supplied the team with two David Clark 1034 full pressure suits, meteorological support and an instrumentation engineer to accompany all campaigns. In return, Perlan I carried NASA instrumentation and provided
NASA with all data collected in flight.

Einar and Steve flew the Perlan I from California City, California reaching over 42,000 feet before shipping it to Oamaru, New Zealand in summer 2002. For the next three winters, Einar and Steve flew Perlan I but were unable to reach the stratosphere. Their attempts may have been too early in the season.

In 2005 they shipped the sailplane to El Calafate, Argentina. Their first attempts were unsuccessful because of unfavorable weather. With improved conditions on August 28, 2006, the team made another attempt. While climbing in a strong lift, Steve’s pressure suit inflated prematurely and excessively, causing them to abort the flight.

On August 29, with weather conditions still favorable and a new pressure regulator on Steve’s suit, they climbed to 50,727 feet (15,460 meters), 17,000 feet into the stratosphere, and established a new world altitude record. This validated the use of the polar vortex to reach the stratosphere. They could have continued higher, but pressure suit expansion made it impossible to fully maneuver the control stick and maintain full control.

This experience led to the conception of Perlan II, a sailplane with a pressurized cabin to eliminate the need for pressure suits. The skills and demonstrated successes of Greg Cole, owner of Windward Performance, lead the team to choose his company to design and build the Perlan II sailplane.

In September 2007, shortly after the structural design of the fuselage and the aerodynamic design of the entire sailplane had been completed, Steve died in a plane crash. With funding lost, the Perlan Project almost came to a halt, with only further meteorological research continuing. Generous donations from Morgan Sandercock, an experienced sailplane pilot from Australia, and Dennis Tito, who funded his own trip into space, allowed the resumption and continuation of the project.

A successful flight will not only set a world sailplane altitude record exceeding the altitude records of all powered aircraft in wing-borne flight – but provide a platform for scientific instruments and experiments in near space, stretching the limits of what is possible.

Following a dedication dinner in April, 2011, Perlan I is on display at The Museum of Flight in Seattle, Washington along with the only other known pressurized sailplane – Robert Lamson’s Alcor wood-en/composite research glider.

**METEOROLOGY**

Soaring a glider to 90,000 feet requires stratospheric mountain waves, which sometimes form when high speed airflow crosses over a mountain range, as shown in figure 2. Air deflected across the top of the mountain range, when descending on the mountain’s lee side, starts an oscillation that continues downwind of the range and propagates upward. A glider uses the upward-moving part of this oscillation to climb.

“Pre-frontal conditions”, the time before a frontal system moves into the region, can generate such winds for eight to fifteen hours depending on how fast the frontal system moves across the area.

Soaring locations having appropriately oriented mountain ranges and these pre-frontal conditions include the Sierra Nevada in California, the Andes in South America, the Southern Alps in New Zealand, mountains in Sweden and Norway, the European Alps, the Rockies in the U.S. and the Urals in Russia.

Mountain waves are usually suppressed at and above the tropopause – the boundary between the troposphere and the stratosphere. However, mountain waves can penetrate the stratosphere when there is a stratospheric wind field that joins and flows in the same direction...
as the wind field at lower altitudes. This allows stratospheric mountain waves to continue upward as an extension of normal tropospheric mountain waves.

This is the case at the North and South poles when the stratospheric polar night jet extends down and joins with the polar jet stream. The polar vortex is a planetary-scale air circulation roughly centered over the North and South poles during the winter of the respective pole. The vortex rotates around each pole and extends down from the upper stratosphere. At its outer edge a narrow band of fast-moving winds – the stratospheric polar night jet – circulates near 100,000 feet altitude. These jet streams can reach more than 260 knots, maintaining the "increasing wind speed with altitude" requirement so waves might propagate upward.

These stratospheric mountain waves develop along a zone of sharp temperature contrasts that occur during long, cold polar nights. Near the northern stratosphere cools by radiating its heat to space, similar to surface cooling of the earth during a clear, calm night. Cooling over several months, the polar vortex and its associated polar night jet form in the Northern Hemisphere in November, peak in January and dissipate in early April. The Southern Hemisphere's polar vortex begins forming in May, peaks in July and early August and dissipates in October or early November.

From year to year, the southern polar night jet is stronger, lasts longer and may be larger in diameter than in other years. Changing daily, it is sometimes round, sometimes more oblong, sometimes a circular repeated "S" shape, and sometimes snake-like. It also changes shape vertically, thicker and thinner with altitude.

The Perlan team will need to pick locations beneath probable tracks of the night jet and where pre-frontal conditions generate winds flowing in the same direction as the polar night jet.

Because of its strength and relative ease of forecasting, the southern vortex was chosen over the polar vortex of the Northern Hemisphere. This led to the choice of El Calafate, Argentina. Winds flow from west to east, from ground level up into the stratosphere, and across the Andes, a south-to-north mountain range. Here, Perlan II will attempt to soar into stratospheric mountain waves to 90,000 feet and possibly beyond.

**FLIGHT VEHICLE**

The Perlan II craft will stretch the limits of what is possible, contending with the aerodynamics of high-altitude flight, while protecting its pilots with pressurization and oxygen to overcome the thin atmosphere outside. Accomplishing this in the confines of a high-performance sailplane requires clever packaging.

**AERODYNAMICALLY DIFFERENT**

Most sailplanes rely on winds diverted around and over hills and mountains; thermals, or rising currents of air; and strongest of all – mountain waves. The stratospheric waves of the polar vortex will be a new and unexplored realm of flight, though. Since The Perlan II aspires to such heights, it is a different sailplane.

The Perlan II is 10 meters long, 1.83 meters high at its vertical tail, and 3 meters across at its horizontal stabilizer. It will have a 25.6-meter wing span with a wing area of 24.34 square meters to carry its 773 kg aloft. The Perlan II sacrifices some performance at lower altitudes to gain the higher performance needed at very high altitudes. Specifically, at these altitudes, although the indicated airspeed may be low, the aircraft is in fact flying at nearly the speed of sound. Designing a glider wing that can fly well in the near transonic regime is one of the unique technical challenges being solved. The Perlan II will be in its element at altitudes above 50,000 feet, the unique part of its very specialized mission.

The flight instruments will include both high altitude mechanical altimeters and airspeed indicators along with electronic instruments. Secure global positioning system (GPS) flight recorders will be used as the official documentation for high altitude record claims. Night flying, necessary for the eight-hour flights, will be possible due to specialized instruments and lighting.

**LIFE SUPPORT AND SAFETY**

A variety of life support and safety features are essential.

In Perlan II’s pressurized cabin, pilots, unconstrained by pressure suits, will still have to wear oxygen masks. Pressurization and breathable oxygen are two separate systems. The “breathing loop” is isolated from the cabin atmosphere by the oxygen mask and scrubber system. The cabin air is kept dry, free of CO₂, and kept below a 25% oxygen concentration by separate systems.

In most oxygen systems, pilots inhale oxygen from a mask and exhale a mixture of unused oxygen and carbon dioxide into the cabin. The pilot’s lungs absorb only a small fraction of the inhaled oxygen. The Perlan II breathing system, however, is unique and more similar to those used by scuba divers. Exhaled oxygen is captured, recirculated and breathed again by the pilots, allowing use of a smaller oxygen bottle and keeping the oxygen out of the cabin. A calcium carbonate scrubber removes CO₂ from the exhaled air. Oxygen from a separate high pressure bottle is added to the pilot’s breathing loop to replace only the oxygen actually metabolized (see figure 3). The Perlan II’s system must also prevent exhaled water vapor from entering the cabin because its 100% saturated humidity would condense and freeze on cabin walls and windows, limiting visibility.

With increased altitude, the atmosphere’s pressure decreases, and the boiling tem-
perature of water decreases too. From sea level to 62,000ft, the boiling point drops from 100°C to 37°C – the temperature of the human body. At 62,000ft and beyond, the pilot’s sweat, saliva, tears and liquids lining the inside of the lungs will all boil instantly. No amount of oxygen, in whatever manner delivered, will sustain consciousness more than a few seconds – or life for more than a few minutes. But even at a lower altitude, down to 50,000ft (15,240m), before the boiling problem were to occur; even if breathing pure oxygen through a mask in an unpressurized cabin, the air pressure is so low that the oxygen does not exert enough pressure on the lungs to be absorbed properly. To compensate for both the low boiling point temperature and the low oxygen pressure in the lungs, the cabin will be pressurized.

Before takeoff, the pilots will close all vents and activate the pressurization system. This system will hold the hatches shut with a small differential pressure. As Perlan II climbs, cabin air pressure drops to the equivalent pressure found at 15,000ft and the pressurization system automatically maintains this pressure as the sailplane climbs to 90,000ft. The cabin is intended to be leak-free, although there are allowances for losing up to one liter per minute. After eight hours, residual compressed air can be released into the cabin to compensate for a small leak. Once on the ground, the pressurization must be turned off to equalize cabin pressure with outside pressure so that the hatches can be opened.

An emergency drogue parachute stored in the tail cone allows a descent from 90,000ft to 45,000ft in less than two minutes. A massive ballistic rescue parachute will open at lower altitudes if there is a catastrophic structural failure.

NEXT STEPS

The Perlan II aircraft construction is moving along in Bend, Oregon, at Windward Performance. The first test flights are planned for the fall of 2012. Additional test flights will take place at Minden, Nevada and over the California Sierras.

The goal is to ship the plane to Argentina by August 2013 where the team may find a fortunate confluence of weather, readiness and skill to glean the 90,000 foot prize. Nevertheless, as the team found in 2005, the weather does not always cooperate and it may take two years or more to attain the goal.

The Project has raised $3.2 million to fund research and the construction of the Perlan II. Another $1.8 million is needed to accomplish the team’s goals, which include inspiring students to study math and science. It highlights the many explorations still to be made and the technical mastery necessary for them to be successful.  

See the Perlan Project web site, perlanproject.org, for details on how to donate or become involved or contact the Project CEO Ed Warnock at ewarnock@cumulusllc.com.