The Perlan Project

The Perlan Project Newsletter Editor: Stéphane Fymat

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Fuselage Testing

Successful completion

Stéphane Fymat
The Perlan Project

The Perlan team has just wrapped up structural testing of the fuselage. Eight tests were conducted, all were successful.

Hatch Pressurization Test – Last year, a test was done to ensure that the seals that line the entrance hatch to the cockpit could withstand the interior cabin pressurization. They were tested up to 23 psi and held just fine.

Pressure Bulkhead Leak Test: The control stick and rudder pedals inside the pressurized cockpit connect to pushrods and cables that pass through a wall at the back of the cockpit into the unpressurized empennage of the aircraft. There are seals in this wall that prevent air from leaking out of the cabin. Tests were successfully conducted to verify that these seals worked as required.

Bellcrank Temperature Test: The control stick is connected to the ailerons via pushrods. These pushrods are connected to each other via ball joints, called bellcranks. There was a question that in very cold temperatures, these joints might freeze up, the controls would get stuck and the pilot would no longer be able to control the sailplane. A bellcrank was put in dry ice and cooled to -70.1°C. It didn’t freeze.

More on Mountain Wave

Structure and Hazards

Elizabeth Austin
The Perlan Project

Phase two of the Perlan Project is to fly the glider riding mountain waves to an altitude of 90,000 feet, into the stratosphere. In order to accomplish this goal a unique set of meteorological events must occur in conjunction with topographic requirements. In the November 2011 Perlan Project Newsletter the specifics of these requirements were discussed in detail. In this issue, we describe the structure of mountain waves in more detail and discuss some potential hazards.

Mountain waves are a type of gravity wave and they form when stable air flow passes over a mountain or a mountain barrier. Figure 1 is a schematic of mountain waves that are present in the troposphere. On this figure the locations of lenticular clouds (noted as Ac len as their formal name is altocumulus lenticularis) are labeled. Lenticular clouds form in the crest of the mountain waves. However, there can be mountain waves present without the presence of lenticular clouds. Though these clouds remain nearly stationary with respect to the terrain, the airflow is constantly flowing through them.

The Föhn wall is the leeward edge of the orographic stratiform cap cloud as seen from the lee side of the mountain barrier (labeled as ‘Föhn wall cloud’ in Figure 1). This cloud often signifies the occurrence of orographic precipitation over the peaks.

The Föhn gap is a break in an the clouds resulting from the strong sinking motion on the lee side of a mountain barrier during a Föhn (downslope wind storm) or Chinook (which is just the name of the Föhn winds that occur on the eastern side of the Rocky Mountains in the USA. A föhn gap is not always present.
Fuselage Testing

Structural Fuselage Test: Three tests were conducted to make sure that the Perlan fuselage can more than handle the stresses it might encounter aloft.

Torsion Boom Test: The entire fuselage was rotated onto its left side and bolted down at the wing root section. Lead shot was put onto the vertical stabilizer to see how much twist the fuselage can take (Figure 1). In the first test, there was a failure in one of the vertical shear webs (like a spar) in vertical stabilizer. The shear web was repaired and modified to withstand more stress. In a second test, the tail was loaded up to 125% of its limit and passed.

Tail Bending Tests: The fuselage was mounted in a normal position and fixed at the wing section, as shown in Figure 2. The tail was also held down using a lattice structure called a wiffle tree.

Three tests were conducted with 2 times, 4 times and 6 times the maximum design weight of the aircraft. At 6 times, also referred to as 6g, there was 4,475 lbs. of lead in the cockpit (Figure 3), 750 lbs. on the empennage (Figure 4), and 888.6 lbs. on the horizontal stabilizer. The nose of the aircraft deflected downward 5.75" but there was no failure of the fuselage structure.

More on Mountain Wave

Figure 1 also shows other types of clouds besides lenticulars. These are:

- Cirrus clouds, Ci, which look like horses tails and are composed of ice crystals only.
- Cirrostratus, Cs, which are also composed only of ice crystals but are generally thicker and cover a larger area of the sky.
- Fractus, Cu = cumulus clouds (cotton-ball looking clouds) that appear in irregular fragments, as if they have been shred or torn (hence, the term fractus).

Figure 1 also shows ‘clear air turbulence’ or CAT. This term implies turbulence devoid of clouds, however, the term is commonly reserved for high-level wind shear turbulence, even when in cirrus clouds (source: Aviation Weather & Weather Services by Irvin Gleim and Garrett Gleim – 5th edition). CAT is associated with jet streams, mountain wave activity and near developing storm systems.

Figure 1: Fuselage on its left side with vertical stabilizer now in a horizontal position, loaded with weight to verify how much twist the tail can withstand.

Figure 1: Structure of mountain waves
More on Mountain Wave

Figures 2 and 3 show typical lenticular clouds.

Figure 2: Example of lenticular clouds.

Figure 3: Lenticular clouds in Reno, NV.

Lenticular clouds are also visible on satellite images. The NASA Moderate Resolution Imaging Spectroradiometer satellite captured the amazing image of mountain wave clouds over much of the western United States on June 2, 2011 in Figure 4.

Figure 4: Mountain waves seen in a top down view from a satellite image.

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Fuselage Testing

Figure 2: Fuselage mounted at wing root and tail.

Figure 3: Cockpit loaded with lead weight.

Figure 4: Empennage loaded with lead weight.

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Fuselage Testing

Pressurization Leak Test: The cabin was tested under pressure and load to see how the cabin held up. The first test was done without load and at a low 3 psi of cabin pressure, just to see how the structure was behaving. A second test was done at 2g and 23 psi. A third test was done with the intention of taking the fuselage to failure, to see what is its actual limit. At 6 g and 25 psi, the bulkhead blew out. It knocked out the left front lift pin with attaches to the wing to keep it attached to the fuselage. But the load held.

Tow Hook Pull Test: A cable was attached to the tow hook in the nose where the tow rope attaches to the glider. A load of twice the glider’s weight was applied and it performed fine. This means that if the sailplane was being suspended from its nose, the tow hook could withstand at least twice the plane’s weight.

Asymmetrical Horizontal Load Test: With the glider mounted in a normal position, 829 lbs. of weight was put on the right stabilizer and 429 lbs. was put on the left side. This other torsion test passed.

Maximum Horizontal Pulldown Test: 1698 lbs was placed on the horizontal stabilizer, and it held up fine.

Drogue Chute Pull Test: Whereas the tow hook test pulls on the front of the sailplane, the drogue chute pull test pulls on the tail of the plane. 3600 lbs. of force was placed on the tail to simulate the drogue chute deploying, which is twice the 1800 lbs. gross weight of the sailplane. The fuselage passed the test.

This particular fuselage, the “test article”, past all of the test and has demonstrated that it can withstand all of the stresses we anticipate in flight. The test article will be given to a museum for display. We can now proceed to build the actual flying fuselage, the “flight article”. In fact, build activities have already begun. However, we need $398,400 in additional funding to complete building the Perlan II. See details on page 5.

More on Mountain Wave

When mountain waves continue up into the stratosphere, there are two unique dangers: turbulent rotor regions and breaking waves, all of which may cause severe and unexpected turbulence. Large-amplitude waves can also generate regions of CAT.

At lower altitudes, turbulent rotors can usually be spotted and avoided by looking for their associated rotor clouds, if present, or inferring their location, typically right underneath the primary mountain wave just downwind of the mountain range, at or below mountain top level. But with stratospheric mountain waves, rotors also frequently extend up to 35,000 feet. If there is not enough moisture in the air to form rotor clouds then these rotors are not easy to see and avoid.

Breaking waves are another danger. If the wave’s amplitude becomes large relative to its wavelength, the wave steepens to the point where it breaks, similar to ocean waves crashing on the beach. This often occurs in the lower stratosphere where the waves encounter increasing static stability and is also stimulated by the systematic decrease in atmospheric density with altitude. The danger with breaking waves is that they can occur over a wide area, causing significant turbulence. Figure 5 show regions of breaking waves (the dashed lines) and their influences on the flow (streamlines, which are solid lines) (Source: Lee Waves and Mountain Waves by Dale Durran, 2003).

![Figure 5: Breaking waves affecting smooth air flow.](image-url)
**Questions and Answers**

**Q:** What is The Perlan Project?

**A:** The Perlan Project is building an experimental sailplane (glider) that will use the winds that blow up and over the Andes in Argentina to soar up into the stratosphere.

**Q:** Where do these winds come from and where are they?

**A:** Warm air from the equator flows towards the cold areas of the north and south poles. Because of the Earth’s spin, the air flows in a spiral towards each pole, much the same as water spins when going down a drain. This is called the Polar Vortex, and exists at the north and south poles. When the wind hits mountains such as the Andes it is directed upward, creating stratospheric mountain waves.

**Q:** What are the goals of The Perlan Project?

**A:** We have three goals:

1. Break the world altitude record by soaring up to 90,000 feet in altitude and beyond.
2. Perform research to understand the interaction between the polar night jet and the ozone hole.
3. Inspire kids, our next generation, to learn about soaring, flying and aerospace engineering.

**Q:** How will The Perlan Project benefit society?

**A:** The technology and know-how we develop will be applicable to improve aircraft of all types. Better understanding our atmosphere helps us better understand and respond to climate change. Inspiring kids to learn about aviation, weather and aerospace helps ensure that we continue to have a highly skilled workforce in America.

**Q:** When will you fly?

**A:** Test flights will begin in March 2012 and we are currently planning our first expedition to Argentina in August 2012.

**Q:** What have you accomplished so far?

**A:** On August 30th, 2006, Steve Fossett and Einar Enevoldson set a world-record altitude for gliders of 50,671 feet (15,447 m) in the Perlan I, reaching the stratosphere. This has provided valuable information for building Perlan II.

**Q:** How can I help?

**A:** We have raised $3.2M to fund the research and construction of Perlan II. We need another $1.8M to accomplish our goals. Sponsorships and contributions are welcome. In addition, we welcome your in-kind donations and your interest to volunteer your time or expertise. Feel free to contact us.