# Land Yacht Speed Record Project –Tire Research

**Edward Stilson, Luke Yoder**
**Mechanical Engineering and Mechanics**

## Project Overview

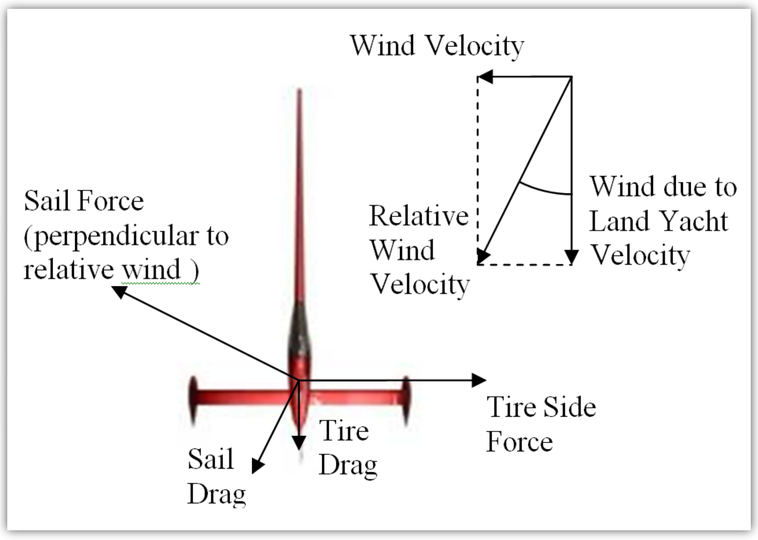
The goal of the Land Yacht Speed Record Project is to design and fabricate a vehicle capable of traveling as fast as possible using only wind power, setting a new land speed record. These vehicles, called land yachts, have evolved over the years into slender, streamlined racing machines, harnessing the power of the wind with tall rigid wing-like sails. With wind speeds of just 20 to 30mph, some land yachts are able to travel over 100mph, with the present record set at 126.1mph by Richard Jenkins, a British engineer.

"Greenbird," the current World Record Holder.

## The Physics Behind a Land Yacht

Although aerodynamics are vital to the effectiveness of a land yacht, tire performance is surprisingly important as well.

The figure below shows the basic forces that act on a land yacht.



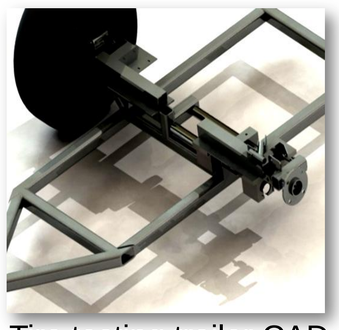

At high speeds, the vectors shown can be used to prove this equation (Eq. 1)

$$\frac{1}{\dfrac{\text{Land Yacht Velocity}}{\text{Wind Velocity}}} = \frac{1}{\dfrac{\text{Sail Lift}}{\text{Sail Drag}}} + \frac{1}{\dfrac{\text{Tire Side Force}}{\text{Tire Drag}}}$$

With the goal of achieving maximum speed, This equation shows that the aerodynamic performance, defined by the sail lift/drag ratio, is equally as important as the tire performance, defined by the tire side force/drag ratio. The sail lift/drag ratio of many wings can exceed 60, while the side force/drag ratio that tires produce is much lower. Therefore, a land yacht's tire performance, rather than its aerodynamic performance, is the limiting factor in achieving high speeds.

## Measuring the Forces Acting on a Tire

With the physics behind a land yacht in mind, a tire testing trailer was developed to measure the loads developed by tires while being pulled behind a tow car.



Tire testing trailer CAD

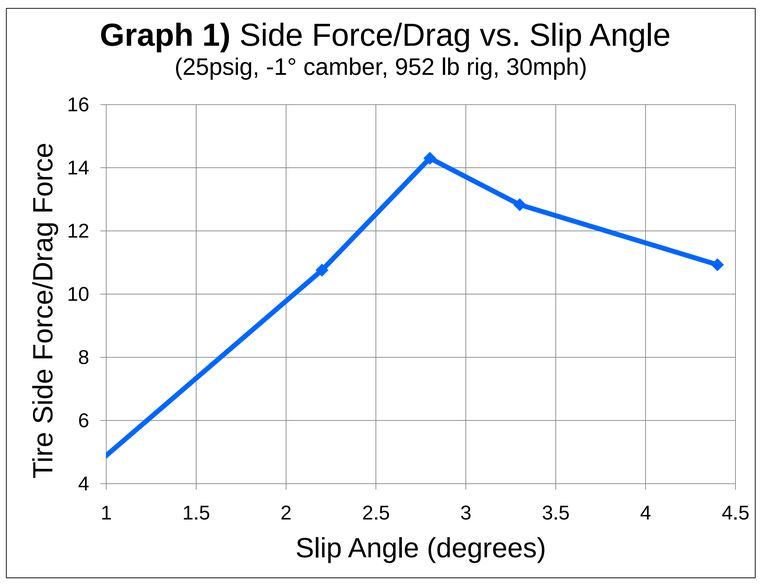
Tire testing trailer behind tow car

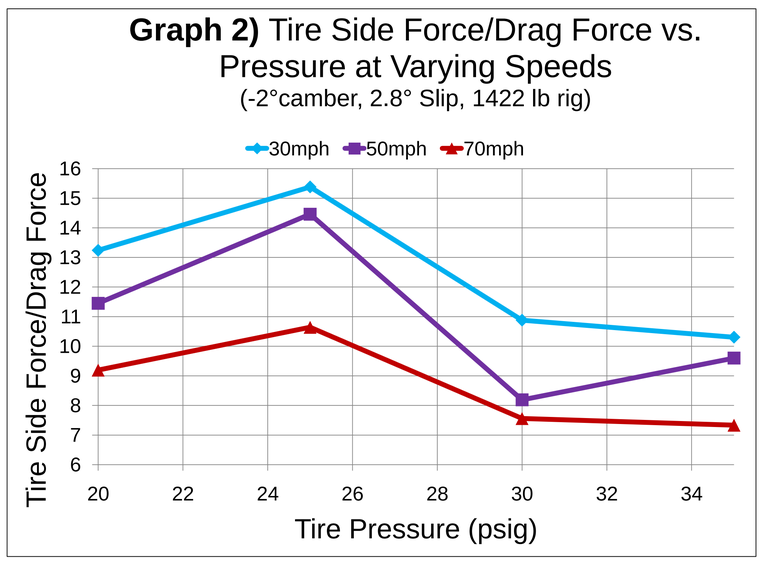
Its features Include:

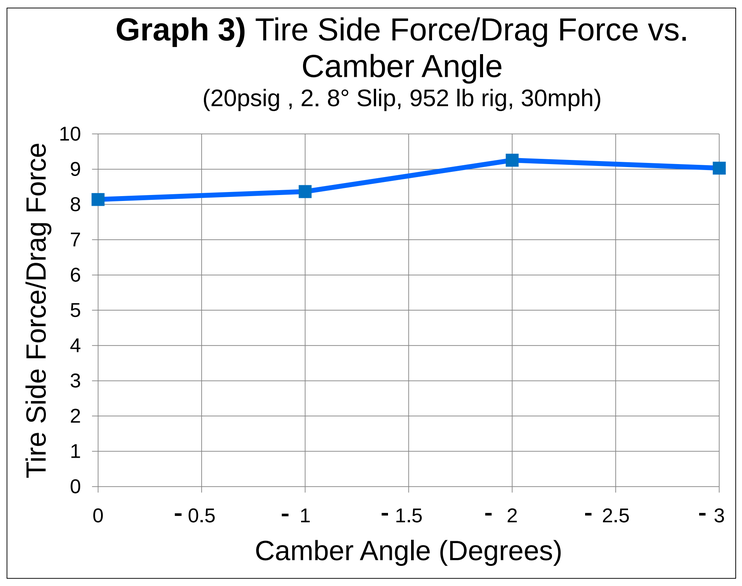
- Sensors that measure tire's side force and drag force—sent in real time to computer in the tow car.
- Wheels that are adjustable to extreme angles of toe—to simulate the slip angle tires will develop under side loading.
- Variable weight and tire camber angle

## Data From Nevada Research Trip

In March 2009, the tire testing trailer was shipped to Lake Ivanpah, Nevada, where the speed record attempt will take place. Several tires were tested while varying slip angle, tire pressure, camber angle, down force, and speed. The data shown below is from the best performing tire, the Toyo R880.



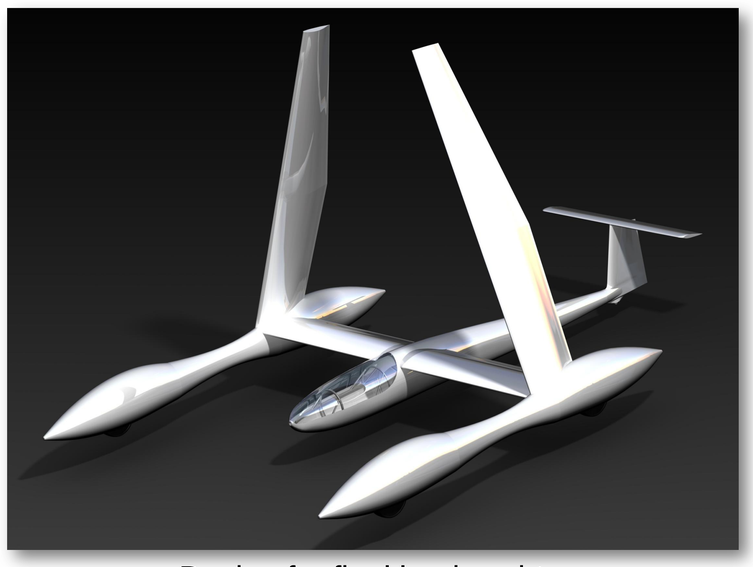




Variables such as tire temperature and the desert's surface roughness had a significant impact on tire performance, yet were out of our control. These variables were assumed to be constant only during each individual test. Because of this, data within each test was used to optimize tire performance, yet data could not be compared between tests.

## Impact on Final Design

Graphs 1-3 clearly show that with the Toyo R880 tire, a maximum tire side force to drag ratio can be achieved by setting the tire at a camber angle of 2°, at a pressure of 25psig, and by designing the craft to operate at a slip angle of roughly 2.8°.



Design for final land yacht

Over the course of our study, a tire side force/drag ratio of 15 was consistently achieved. Under our budget and time constraints, we might assume an aerodynamic lift/drag ratio of 15 for our final land yacht. With a wind speed of 30mph, Eq. 1 gives a maximum land yacht velocity of 225mph. Although this maximum theoretical speed is not our projected speed due to the huge assumptions made, the tire performance that we achieved as result of this study could lead to a record breaking maximum speed.

## References

**Professor Jochim L. Grenestedt**
email: jog5@lehigh.edu
**Bill Maroun**
email wjm2@lehigh.edu

Grenestedt J.L. "Sailing and Equilibrium Equations." 2/11/2008.