BLOODHOUND SSC
ENGINEERING ADVENTURE

How can we make BLOODHOUND travel at 1000 mph?

Dr Tanya Morton, 1st June 2010

How do you make a car reach a thousand miles an hour? The BLOODHOUND engineering team are working to solve this problem with their jet-and-rocket powered car aiming to smash the current land speed record. This British team currently hold the record with the Thrust SSC (SuperSonic Car) that made history by breaking the sound barrier and reaching 763mph. Now they are aiming to go even faster with BLOODHOUND SSC.This series of articles will show you how to use physics and maths to work out what is needed to make BLOODHOUND travel at 1000 mph.

“All models are wrong, but some are useful” is a famous phrase by the statistician George Box. These articles will show you how to progress from a simple mathematical model to a more complex, more useful model. In this first article we start from an inaccurate and not very useful model, which uses basic maths and physics to model the motion of BLOODHOUND. Gradually, we will improve this model to make it closer to the real world, introducing more sophisticated mathematics as we go, until we have a model that is useful. The final model will be very close to the one actually being used today by Ron Ayers, Chief Aerodynamics Engineer, to predict how fast the car will go.

For now, let’s start simple, with Newton’s three laws of motion:

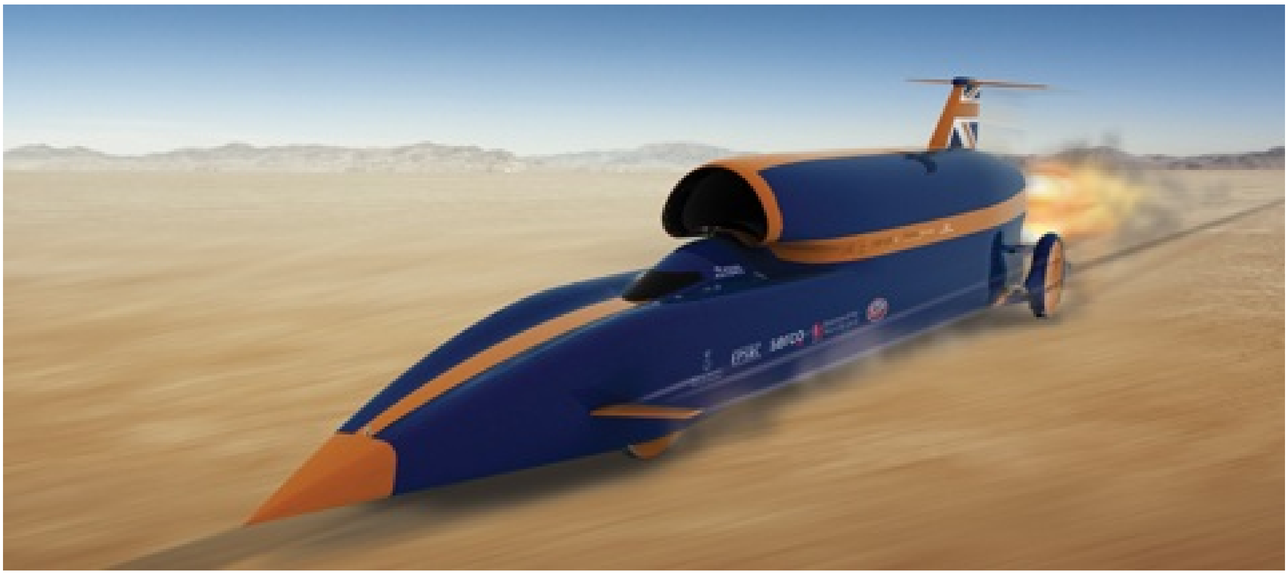
Law 1: An object will remain at rest, or travelling at a constant speed, until acted on by a force

Law 2: Force = mass x acceleration

Law 3: Every action has an equal and opposite reaction

Let’s think about how these laws apply to BLOODHOUND. Picture Andy Green sat in the cockpit of BLOODHOUND on the starting line on the Hakskeen Pan. **Law 1** tells us that he’s not going to move forward, until a force acts on him. Let's start the jet engine! BLOODHOUND has a EUROJET EJ200, a highly sophisticated military turbofan jet engine normally found in the engine bay of a Eurofighter Typhoon.

The jet engine forces air backwards with a maximum force of 90 000 Newtons (N). **Law 3** then says that there must an equal and opposite forward force, called thrust, of 90 000 N.



Putting this force into **Law 2**, along with the mass of BLOODHOUND, 6500 kg (about 6 times the mass of a Ford Fiesta), gives us the equation:

```
90000 = 6500 * Acceleration
```

To help explain the mathematics of BLOODHOUND, we're writing these articles using software called MATLAB that can automatically solve equations and draw graphs. With MATLAB, we use the star symbol to mean multiplication, which is a common convention with spreadsheets and software languages. We want to solve this equation for acceleration using algebra. First, we swap the two sides to put acceleration on the left side.

```
6500 * Acceleration = 90000
```

Then we divide both sides by 6500 to give:

```
Acceleration = 90000/6500
```

$$\text{Acceleration} = \frac{180}{13}$$

In the purple text MATLAB has automatically calculated Acceleration to be 180/13. Can you check that MATLAB has simplified the fraction correctly?

If we prefer to see this fraction as a floating-point number (the kind of number your calculator works with), then we can do this by applying a command called float as follows:

```
float(180/13)
```

13.84615385

To reduce the number of digits shown to 3, we use the following command:

```
float(180/13, 3)
```

13.8

Therefore, to 3 significant figures, our calculation tells us that the acceleration of BLOODHOUND is 13.8 m/s^2.

In the title question, speed is in old-fashioned imperial units, but we have calculated acceleration in metric units. What is 1000 mph in metric units: m/s? Well, there are approximately 1609 metres in a mile, and 60 seconds in a minute, and 60 minutes in an hour, so 1000 miles per hour = 1000/60 miles per minute = 1000/(60*60) miles per second = 1000*1609/(60*60) metres per second. Let's use the software to simplify this fraction:

```
1000*1609/(60*60)
```

$$\frac{8045}{18}$$

Converting this fraction to a decimal with 3 significant figures as before gives

```
float(8045/18,3)
```

447.0

That is, 1000 mph is approximately 447 m/s. By comparison, the highest speed ever recorded by an F1 car is just less than 115 m/s (257mph). At its top speed BLOODHOUND will be up to four times faster than that, travelling further than the length of four football pitches, 447 metres, every second.

In this article we have calculated that the acceleration of BLOODHOUND is 13.8 m/s^2. How can we check if this model is accurate? In the next article, we will see what an acceleration of 13.8 m/s^2 means in terms of the velocity of BLOODHOUND and get closer to answering the question: How can we make BLOODHOUND travel at 1000 mph?

Dr Tanya Morton is Application Engineering Manager at MathWorks. MathWorks products are being used in the control system design and aerodynamic analysis of BLOODHOUND.