Sensors used in the project

Accelerometer:

* Measures proper acceleration – i.e. the acceleration of a body in its own rest frame
* Piezoelectric accelerometer in smartphones – force due to acceleration applies a stress on microscopic crystal structures, which create a voltage – amount of voltage is measured on each axis.
* 3-axis accelerometer – measures acceleration of the device in 3 axes.
* Kelvin’s data – measurement every 0.01s – i.e. accelerometer has a frequency of 100Hz
* Rollercoaster measurement – accelerometer should have a maximum swing of +/- 2g to 5g
* Larger sensitivity – more noise but more precise readings

Gyroscope:

* Measures rotation in 3 (x, y and z) axes – known as roll, pitch and yaw
* MEMS (microelectromechanical system) gyroscope in smartphones – resonating mass is shifted as the angular velocity of the smartphone changes. Movement is outputted as electrical signals which are read.
* As the sensitivity of the gyroscope increases, the range (i.e. the maximum angular velocity that the gyroscope can read) decreases.
* With a larger range, the resolution of the gyroscope decreases.

GPS:

* GPS on modern smartphones have a range of +/- 0.5m to 5m radius, depending on coverage/foliage/obstacles etc.
* Signal sent from phone to minimum of 3 satellites. Distance from each satellite is known, and 3 rings of coverage are drawn. Where the 3 rings intersect is your exact position – triangulation.
* GPS satellites have atomic clocks onboard for exact determination of time.
* The effects of relativity have to be accounted for:
  + General relativity – time runs slower due to a stronger gravitational pull – i.e. satellite clocks run faster than those on Earth
  + Special relativity – time runs slower on a moving object – i.e. satellite clocks run slower relative to those on Earth.
* Can be useful to define limits of integration for the acceleration and angular velocity data.

Barometer:

* Pressure measurements are used in combination with GPS position measurements to more accurately calibrate elevation (i.e. the positional z-axis)
* Microscopic changes in pressure are detected, again using a MEMS.

Compass/Magnetometer:

* MEMS magnetometer on a smartphone measures the effect of the Lorentz force on a current carrying (microscopic) beam – movement of the beam due to the Lorentz force induces strain on microscopic crystal structures, which induces a voltage which can be measured.
* Alternatively, the frequency shift of mechanical resonance of the beam can also be measured – as the Lorentz force will cause the beam to move/bend and thus alter the resonant frequency.
* This is a very small Hall effect sensor that operates along 3 axes (x, y and z)
* Data from the magnetometer is used in conjunction with the accelerometer to determine the device’s orientation with respect to Earth’s magnetic North.

Microphone:

* Smartphones use a MEMS microphone – formed using a semiconductor rigid backplate that is perforated – i.e. allows air through it, and a membrane that moves in response to the change in air pressure caused by sound waves.
* Sound waves cause the membrane to flex, which changes the amount of capacitance between the backplate and the membrane, which is measured and converted into a sound signal.
* Can be used to convert energy losses in the rollercoaster as sound into positional data.