# [n]sight

SPRING 2010

## STEM
special issue

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# Welcome...

The theme of this edition is STEM (Science Technology Engineering Mathematics) and, as the Mathematics Specialist at the National STEM Centre, I am very pleased to welcome you to this issue of [n]sight.

Here at the National STEM Centre at the University of York, we are building the UK's largest collection of STEM teaching resources, both contemporary and archive. The collection is growing all the time; teachers are already welcome to visit us to access the resources and from next year a large amount of the material will also be freely available online. We are also coordinating the Government's STEM cohesion programme, ensuring that there is collaboration between the various organisations working on STEM and actively engaging with partners, such as **Texas Instruments.**

This issue of [n]sight starts with an article from **Ian Galloway**, about the attempt to build a supersonic car that will travel faster than 1,000 miles per hour, smashing the land speed record. Included is an activity that enables students to **use TI-Nspire with a data logging device** and investigate some of the issues facing the engineers working on the car. Ian explores how students can access real, accurate data direct from an experiment using handheld technology.

One of the challenges of STEM is to demonstrate to students the strong links between school subjects that they often see as entirely distinct. **Jonathan Powell** has addressed this head-on by taking his students, armed with TI-Nspires, to the beach. **Using GPS technology and temperature probes** attached to their handheld devices they were able to investigate relationships such as the correlation between temperature of sand and distance from the sea. They may have initially found it strange to hear their maths teacher talking about science, but through activities such as this, students gain a much greater awareness of the relationship between the STEM subjects.

Another problem familiar to many teachers is the perennial question of "... but when is this used outside the maths classroom?" One solution to this is to get outside of the maths classroom, literally! **Karen Birnie** did this as part of a STEM project, "Forest to Fire". Using TI-Nspire handhelds, her class investigated the output of a local forest. With the handhelds the students could take measurements, make calculations and record their conclusion whilst in the forest itself, **engaging the students in a very practical application of mathematics.**

All of these are fantastic examples of how technology can allow students to access **realistic problems using genuine data**. This is at the heart of STEM and highlights how Mathematics is fundamental to all the STEM disciplines and how finding Science, Technology or Engineering examples can help motivate students in their study of Mathematics.

I hope you enjoy reading these articles as much as I have and that you can either use some of these examples in your teaching or be inspired to develop some similar ones of your own. We are always keen to hear how teachers are addressing STEM, so please feel free to send your resources to me: **t.button@nationalstemcentre.org.uk.**

Tom Button

Mathematics Specialist, National STEM Centre

NATIONAL STEM CENTRE

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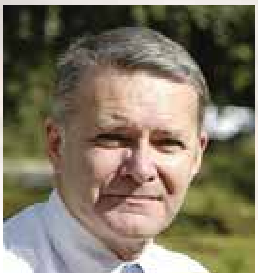
# BLOODHOUND SSC

# The challenge of air resistance



**Ian Galloway** is Education Director for the BLOODHOUND Supersonic Car (SSC) project. Here he describes a classroom activity that will help students understand the challenge that engineers face to reduce air resistance on the car. TI-Nspire is used to investigate the way air resistance changes with speed.

In October 2008 the BLOODHOUND SSC project was launched at the Science Museum London. Lord Drayson, then Minister of State for Science and Innovation, had suggested to Richard Noble that building and driving a car to take the World Land Speed record to 1000 mph (miles per hour) might have a similar effect as the Apollo programme, stimulating young people to take up studies in the STEM (science, technology, engineering and mathematics) subjects. Currently the record stands at 764 mph set by Andy Green in Thrust SSC back in 1997. Pushing the land-speed record up to the headline figure of 1000 mph, exceeding even the current low-level air-speed record, represents considerable engineering challenges.

In the year since the start of the project, the design has begun to take shape using computer fluid dynamics (CFD), a mathematical tool that is sufficiently good to remove the need for wind tunnel testing.

Figure 1 shows computed pressure contours around the car at mach 1.3.

Figure 2 shows Thrust SSC, just as it broke the sound barrier. The shock wave, the line at right angles to the car's motion, is clearly visible in the first such picture ever taken.

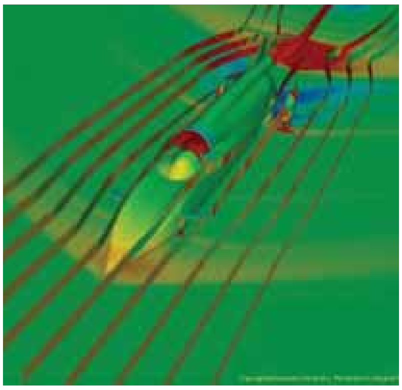


Figure 1

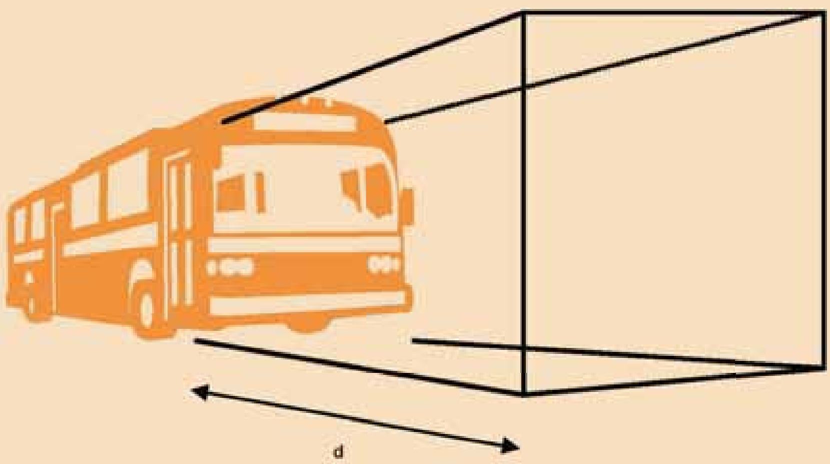
Figure 2

## Air Resistance

Without air, the task of reaching 1000 mph would be simple, just keep on accelerating! The pictures on the previous page show that the air has to be pushed out of the way and this gets increasingly difficult the faster you go. It's like trying to walk fast through a swimming pool at the shallow end.

In order to carry out the CFD above, mathematicians must know how air resistance changes when different variables are altered. In this exercise we will investigate how the air resistance on an object changes with speed. We will rely on the fact that a blunt paper cone will reach terminal speed as it falls a short distance. But first some modelling…

Imagine a slab-fronted vehicle like the bus shown here. Suppose its cross sectional area is A and it is pushing air ahead of itself for a distance d.




At steady velocity, v, the horizontal forces are balanced so that push, F, equals air resistance. But the push has to give kinetic energy to the air in front. So the work done by the push is the work done on the air:

Work done = Energy transformed

$$F\,d = \tfrac{1}{2} A d \rho v^2$$

where $\rho$ is the density of the air.

The distance d cancels, and A and $\rho$ are constants, so very approximately,

$F \alpha v^2$,

i.e. the model predicts that air resistance should be proportional to the square of the velocity.

## Testing with a blunt nose cone

Using TI-Nspire and a motion detector it is possible to carry out an experiment to check if air resistance really is proportional to the square of the velocity. You will also need scissors, card or stiff paper, sellotape, plasticine and a balance.

Firstly make a cone by cutting a circle, removing a small sector and forming the remaining sector into a conical shape.

You should find that the cone will fall to the floor in a reasonably straight line. At this stage we can assume that the cone reaches terminal speed quickly and that, when it does, the forces acting on it are balanced: the weight must equal the air resistance. So by measuring the terminal speed for a number of different weights we can investigate the relationship between terminal velocity and air resistance.

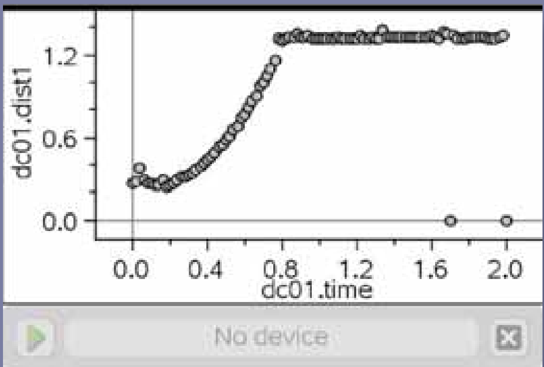
The weight of the cone can be varied simply by adding plasticine. In the example shown here the cone weighed 15g and five balls of plasticine were prepared weighing 5g each.

To measure the cone's terminal speed a CBR 2™ sonic motion detector can be used, connecting it directly to a TI-Nspire handheld. The CBR 2 can be mounted from a shelf or retort stand pointing downwards. Note that distances will increase so that the gradients of the graphs will be positive.

Switch on the TI-Nspire handheld, open a new document and select Data & Statistics. Then plug in the CBR 2. The TI-Nspire page will be divided into two windows: Data & Statistics above and a control console for the CBR 2 below. Press / e to toggle between windows.

The shortest time interval that the CBR 2 can record is 0.02 seconds. Move to the control console and press b , select *Experiment* then *Set Up Collection* and finally *Time Graph*. A window appears asking for time between samples and experiment length. Insert 0.02 and 2 into the appropriate boxes.

The CBR 2 minimum range is about 30 cm, so hold the cone about 30 cm beneath the CBR 2. To start the CBR 2 recording press · on the handheld. When you hear rapid clicking release the cone. Data is automatically stored and displayed as dc01.dist and dc01.time.

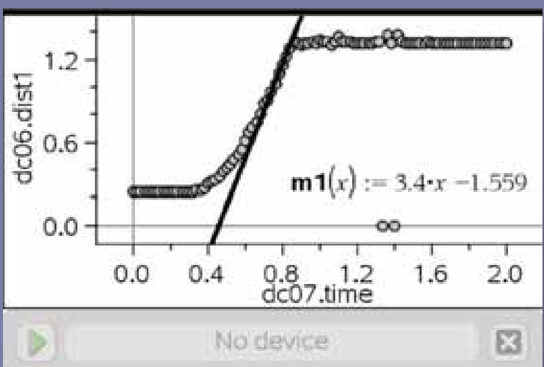



The distance-time graph can be discussed with students, particularly helping them to understand how speeds are represented. What does the horizontal row of dots represent? Why is the graph curved? Where on the graph is the speed greatest? How does that relate to the cone's flight?

The beauty of TI-Nspire is that it is so easy to repeat the process and over-write the previous data or collect another data sample.

To measure terminal speed you can superimpose a movable line on the graph. Return to the Data & Statistics window, press b and select *Analyse* and then *Add Movable Line*. Moving the cursor over one end of the line changes it to a rotate symbol and towards the middle it is a translation symbol. Press / x to change either symbol to a closed hand, allowing the line to be moved using the cursor keys. Press d to release the closed hand.

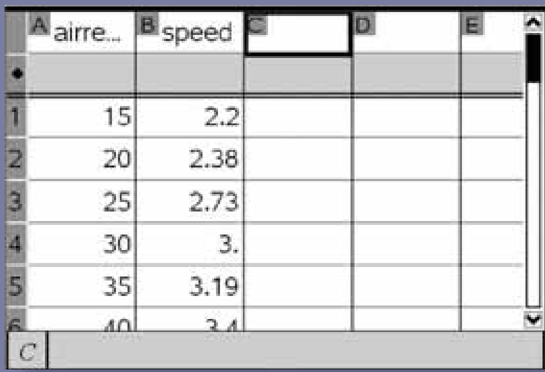
Rotate and move the line until it coincides with the points at the end of the cone's flight where it has certainly reached terminal velocity. It is now easy to read off the gradient of the line, which is the terminal velocity of the cone: 3.4 m/s in the example shown. Here the cone fell only 1.25 m and it is easy to see that a distance of perhaps 2 m would have been preferable.




Collect about six sets of data using the plasticine balls to weigh the cone and so provide different values of air resistance and terminal speed. It is easy to display a graph for each data sample in turn by moving the cursor to the left hand side of the screen and selecting any one of the data sets, dc03.dist for example. The time axis will be the same for all the data sets so this does not need to be changed.

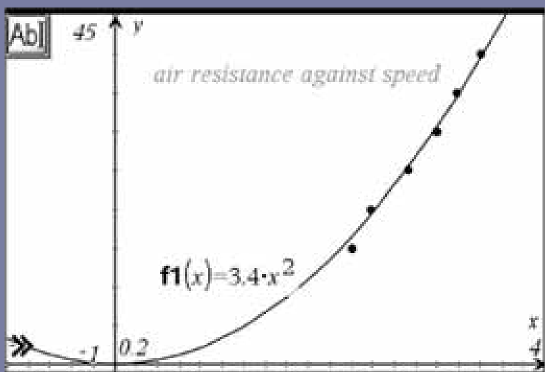
Having collected data for air resistance and terminal speeds it can also be displayed and analysed on the TI-Nspire.

Press c 3 to add a Lists & Spreadsheet page. Enter the weights of the cone plus plasticine in the first column. Remember that for terminal speed this weight is equal to the air resistance. Enter the corresponding terminal speeds in the second column.



| | A airre... | B speed | C | D | E |
|---|---|---|---|---|---|
| 1 | 15 | 2.2 | | | |
| 2 | 20 | 2.38 | | | |
| 3 | 25 | 2.73 | | | |
| 4 | 30 | 3. | | | |
| 5 | 35 | 3.19 | | | |

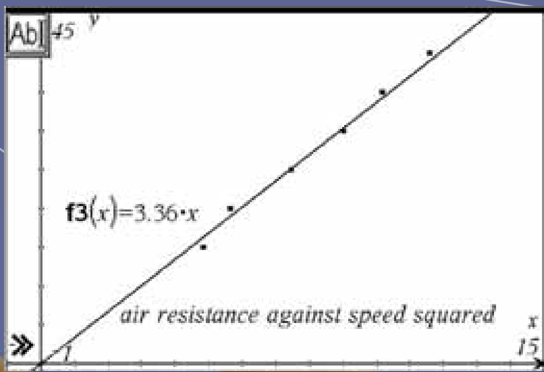
Now we can graph air resistance against speed. Press c 2 to add a Graphs & Geometry page and b 3 4 to select a scatter plot. Choose speed for the x-axis and air resistance for the y-axis.

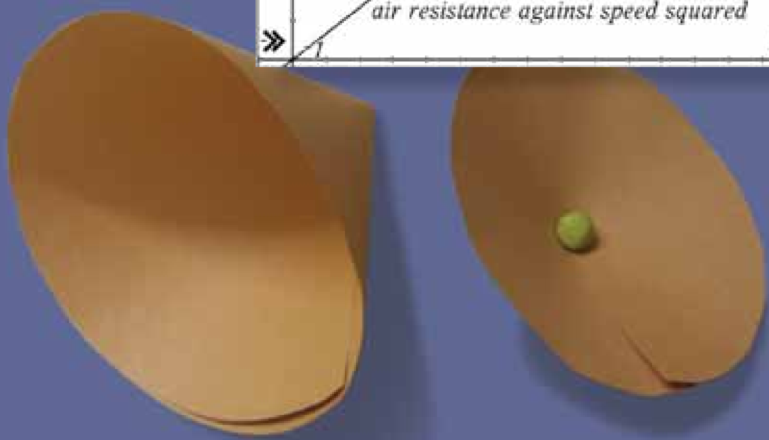



A straight line will fit the data but will not pass through the origin indicating that air resistance is not proportional to the speed. However, a parabola is a reasonable fit suggesting that air resistance might indeed be proportional to speed squared!

Return to the spreadsheet and enter a third column, *squarespeed* and fill down the column.

Insert another Graphs & Geometry page and plot air resistance against speed squared. A straight line through the origin is now a reasonable fit, supporting the physical model, which suggested that air resistance increases as the square of the speed.



## Scaling up to the BLOODHOUND SSC

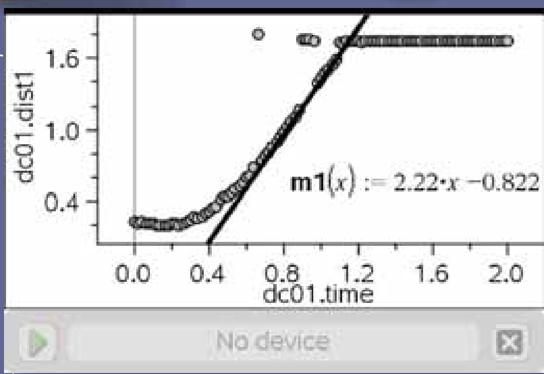
My blunt cone reached about 2 m/s and had a diameter of approximately 10 cm. At terminal speed air resistance equalled its weight (15 g or 0.15 N).

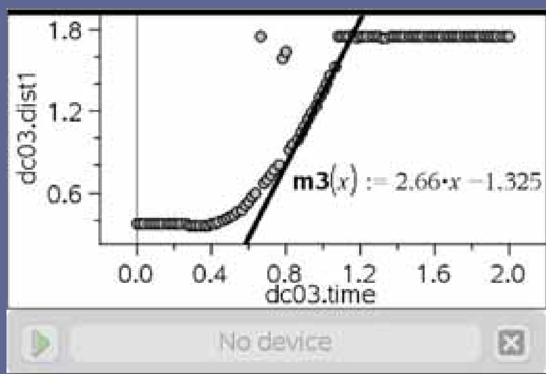
Since air resistance increases as the square of the speed, increasing the speed from 2 m/s to 450 m/s (BLOODHOUND's top speed) would increase air resistance $225^2$ or roughly 50,000 times. That is it would have air resistance of 7,500 N!

Also, my cone's swept area is roughly 300 $cm^2$ or 0.03 $m^2$ whereas the swept area of BLOODHOUND is 1.77 $m^2$. So if my cone were scaled up to 1.77 $m^2$ the air resistance would be 1.77 ÷ 0.03 x 7500 or 442 500 N. However, at top speed the air resistance equals the maximum available thrust, which for BLOODHOUND is 212,000 N, less than half of 442,500 N.

## Streamlining

It is clear that air resistance presents a formidable challenge to the designers of BLOODHOUND! Unlike the cone we have used so far, the nose cone of BLOODHOUND is very long and streamlined. It is possible to investigate the effects of streamlining by constructing paper cones with different cone angles but sweeping out the same area. This means keeping the base of the cone the same area and ensuring the cones have equal weights.




Two cones of equal swept area and equal weights but different cone angle can now be compared to see how streamlining can reduce air resistance. Note: the simple physical model described above no longer applies!

The graph on the left (above) is for the blunt cone which clearly has a smaller terminal speed (2.2 m/s) than the sharper cone shown on the right (2.7 m/s).

## Streamlining works!

# On the beach

## Nspiring activities using geomatics

Geomatics is the discipline of gathering, storing, processing and delivery of geographic or spatially referenced information.

**Jonathan Powell** is Assistant Curriculum Leader for Mathematics at St Thomas More RC High School in North Shields.

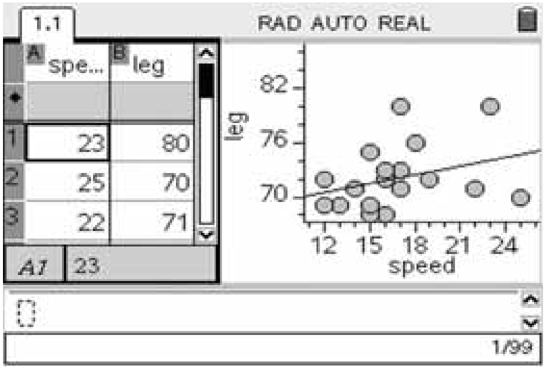
For a whole year, my year 10 class had spent their maths lessons in a freezing-cold mobile classroom. They had been extremely tolerant of the situation and I decided they needed a treat. I told them we were going to the beach! After all the shouts died down, I told them we would be doing maths. After all the groans subsided, I explained that we would be using GPS receivers. They were intrigued!

I am always trying to find different ways of presenting mathematics and I had the Global Positioning System (GPS) receivers on loan from the Newcastle University Geomatics department. Over the past few years I have been taking advantage of their equipment loan schemes with several of my maths classes. Last year, pupils donned reflective jackets and marched onto the school field armed with levels, tape measures and surveyors' staffs. They created a height profile of the field and used Excel to make a 3D map. We have also used theodolites and elementary trigonometry skills to calculate the heights of school buildings. The idea of using GPS receivers in conjunction with TI-Nspire handhelds had intrigued me as well as the students.

## Speed test

The first thing we did when we got to the beach was run around. The GPS receivers could display actual speed and maximum and average speed over a period of time as well as distance travelled. So pupils were challenged to get the highest speed they could on their GPS. There were some novel approaches: running downhill as fast as possible whilst throwing the GPS out in front was one memorable method. Fortunately they are very durable (the units that is!)

All the pupils' speeds could very easily be inserted into a TI-Nspire spreadsheet page and the beauty of having this on handhelds was that pupils didn't need to return to the classroom to do any data analysis. They could do it right there on the beach, in the sunshine. One example of our analyses involved the correlation of inside leg measurement with speed.



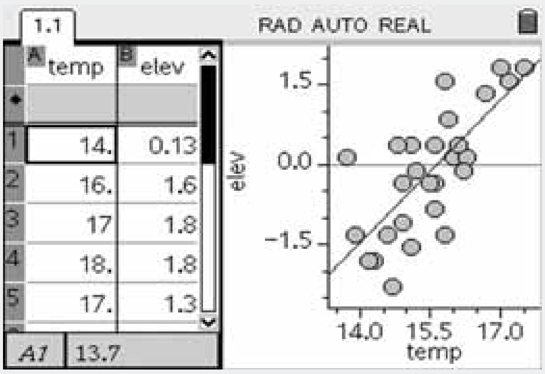

This provoked in-depth discussions on the field trip, without having to wait to return to the classroom: for example, who are the outliers? Tall girls that don't like to run? Short boys with too much energy? How strong is the relationship? What is the average speed? Would the strength of the relationship improve if we removed an outlier? What about the average? What is this equation that links the two variables? So this very simple exercise using GPS and TI-Nspire together yielded many unexpected discussion points.

## Cold sand

With pupils having burnt off some energy, it was out with a temperature probe and on with the second exercise.

I posed this question: “Does the temperature of the sand vary with distance from the sea?” We had a discussion and decided that we would take a series of sand temperatures roughly perpendicular to the tide line. We used the GPS to measure elevation above mean sea level. As we were working on the beach at low tide some of these measurements were negative

The measured temperature and elevation were recorded in a TI-Nspire spreadsheet page as shown below. As you can see, a temperature rise was apparent as we got further above sea level. Pupils hypothesized that “the higher the elevation, the less water it contains and the wetter the sand, the colder it is”.




This provoked a different discussion about why the temperature of the land and the sea are different. The land has a lower specific heat capacity than the sea and so warms up much more quickly than the sea during the day. This is what drives sea breeze: the warm land warms the air above it. The warm air then rises and the pressure drops. The sea, being colder, has higher pressure air above it, which flows towards the lower pressure over the land. At night, the reverse is true.

## The view from the cliff

As a last activity, pupils formed themselves into groups and I set them a challenge: draw an interesting design on a coordinate grid and scale this up to make a huge design on the sand using the GPS receivers. We would then look at their artwork from the cliff top.

Pupils immediately voiced concern about the fact that the GPS device only claimed to be accurate to about 15m. (Accuracy varies depending on the number of satellites in view.). This enquiry promoted a discussion about the difference between absolute position and relative position. The GPS can only give your absolute position on the earth accurate to about 15m, but if you move one metre in any direction the coordinates will change relative to where you were. Pupils immediately started hopping about to verify that their GPS was indeed relatively accurate to about 1m—enough accuracy for this task.

They soon realised that to complete the task in the time given, they would need to work together in teams and various different strategies resulted. One group decided to draw out a grid in the sand and simply plot their points on that grid. They reasoned this would be faster than trying to find each point with a GPS. Other groups opted for a divide and conquer approach: each pupils taken a few points and plots them individually. The activity resulted in some interesting designs viewed from the cliffs, from pacman to a dog relieving itself!

The excursion to the beach was very successful: pupils enjoyed using maths in a different context and location. They also experienced some of the links between mathematics and other subjects such as physics and geography.

## And next summer ... fractals?

Building on this success, I decided to plan a few more activities for future equipment loans next summer. I recently used this as an excuse to take myself out to the beach with a bag full of gadgets. I got quite a few strange looks as I wandered around with my head down looking at a GPS in one hand and an Nspire in the other hand!

My first idea was to use the GPS to automatically record waypoints at a given time interval along a twisting path. I chose the Tynemouth coastline as an experiment and as I walked along the coastline, the GPS recorded my position (as well as lots of other data) every 10 seconds.

I could then use Geobuddy software to transfer the data from the GPS to a computer. There is an option to view the path in Google Earth shown by the green line below. This kind of imagery is a powerful way to capture pupils' interest. I could then export the data from Geobuddy to Excel and finally copy the data into TI-Nspire. Pupils could then use this data to investigate how the length of the path depends on the resolution of data points.

The GPS device outputs waypoints as coordinates in metres (columns A and B in the spreadsheet). By using Pythagoras' theorem to calculate the length between recorded waypoints an approximation of the total length of the path can be calculated. Students could investigate how increasing the number waypoints used gives a more accurate measurement of distance.

| | A x | B y | C d1 | D d2 | E d3 | F d4 | G | H |
|---|---|---|---|---|---|---|---|---|
| ◆ | | | | | | | | |
| 49 | 36478 | 68813 | 113.6 | 213.016 | 330.651 | 363.618 | | |
| 50 | 36463 | 68756 | 57.0088 | 0 | 0 | 0 | | |
| 51 | 36458 | 68741 | 17.72 | 74.7262 | 0 | 0 | | |
| 52 | 36454 | 68729 | 12.6491 | 0 | 87.3613 | 0 | | |
| 53 | 36431 | 68657 | 75.5844 | 88.2326 | 0 | 162.926 | | |
| 54 | 36427 | 68640 | 17.4642 | 0 | 0 | 0 | | |
| 55 | 36421 | 68609 | 31.5753 | 49.0306 | 124.455 | 0 | | |
| 56 | 36407 | 68554 | 56.7539 | 0 | 0 | 0 | | |
| 57 | 36417 | 68530 | 26 | 79.1012 | 0 | 127.769 | | |
| 58 | | | | | | | | |
| 59 | | Sum | 2735.58 | 2627.28 | 2442.33 | 2511.4 | | |

G58

Column C contains a measurement of distance using every waypoint. Column D contains a measurement of distance using every 2nd waypoint and so on. It is clear that the more waypoints used the longer the path – at least in general! (You might like to consider why, for these data, the distance using every 4th waypoint is greater than that using every 3rd waypoint.)

I am sure this activity will provoke questions about approximating the length of curves.

For example:

- What happens to the length of the approximation as we take more data points?
- Does the type of route have any effect on the approximation?
- If we used curves rather than straight lines would the approximation be better?
- What do we actually mean by the "length of the coast line"?
- What if I had walked along the beach and walked into all the caves?
- If I were able to walk into all the tiny nooks and crannies would the total length be any longer?

We are now approaching the notion of a fractal: a complex idea that would require some quite sophisticated maths to fully explore. However, in my experience pupils are fascinated by such notions of infinity and they are well worth exploring. GPS units along with TI-Nspire handhelds will provide an ideal starting point for such exploration.

## Conclusion

A lot of the tasks we conducted on the beach and the resulting discussions could be described as geographical, scientific or mathematical. At first, pupils find it quite strange when their maths teacher starts talking to them about science or geography, but then they start to realise that the subjects they study at school are not distinct.

The data recorded by a GPS device can be used for many different investigations that can lead to some very rich conversations with pupils. Increasingly pupils own sophisticated mobile phones and some of these already have built in GPS receivers. Therefore, many teachers will soon have the technology needed in their classrooms to carry out the exercises described in this article. It is just a matter of utilising it!

## References


Newcastle university geomatics department: http://www.ceg.ncl.ac.uk/

Google earth: http://earth.google.co.uk/

Geobuddy software: http://www.geobuddy.com/

Fractals: http://www.mathsnet.net/fractals.html

# If you go down to the woods today...

**Karen Birnie** is Principal Teacher of Mathematics, Aboyne Academy, Aberdeenshire, Scotland

In 2007, as part of a wider campaign to reduce the use of fossil fuels (gas, oil, coal) and increase the use of renewable fuels, Aboyne Academy became one of the first schools in Scotland to incorporate a biomass boiler into its heating system. This became the focus for a STEM project for S2 students (aged 12-13 years). The big question was: “how much forest is needed to keep the Aboyne Academy boiler going for one year?”

The Forest to Fire project, organised by maths staff with the support of a local forester and research institute, used TI-Nspire handhelds - truly portable technology - that could easily be taken into the forest. TI-Nspire documents could be loaded onto the handhelds and these could include instructions and hints, space to record data and do calculations, pages where data could be analysed and space for students to enter their conclusions. The project was divided into a number of tasks - the first of which was to be completed in the classroom.

## Task A:
## How much woodchip is used each year?

Students were supplied with the necessary information using a Notes page. They used a Calculator page to work out their solutions which they then recorded into another Notes page. It was interesting to see the different ways in which students defined summer and winter, in order to calculate how many loads of chips were required.

1.1 | 1.2 | 1.3 | 1.4 ▶DEG APPRX REAL

**Forest to Fire**

==============================

*Task A*

*How much woodchip is used each year?*

==============================

1.1 | 1.2 | 1.3 | 1.4 ▶DEG APPRX REAL

**Information supplied:**

Each load of chips weighs 7½ tonnes; approximately 30% of the weight is water.

Deliveries are every second or third day in the winter, every third or fourth day in the summer.

1.1 | 1.2 | 1.3 | 1.4 ▶DEG APPRX REAL

© Calculations Page

| | |
|---|---|
| $\frac{7.5}{100}\cdot 30$ | 2.25 |
| $7.5-2.25$ | 5.25 |
| $\frac{\frac{365}{2}}{2.5}$ | 73. |

8/8

1.1 | 1.2 | 1.3 | 1.4 ▶DEG APPRX REAL

**Conclusions:**

Dry weight of one load = 5.25 tonnes

Winter needs 383 tonnes (73 loads)

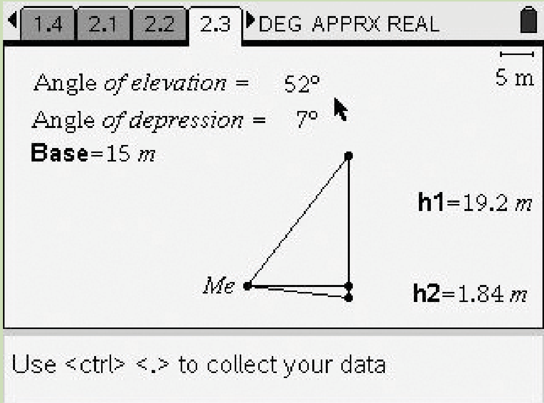
Summer needs 273 tonnes (52 loads)

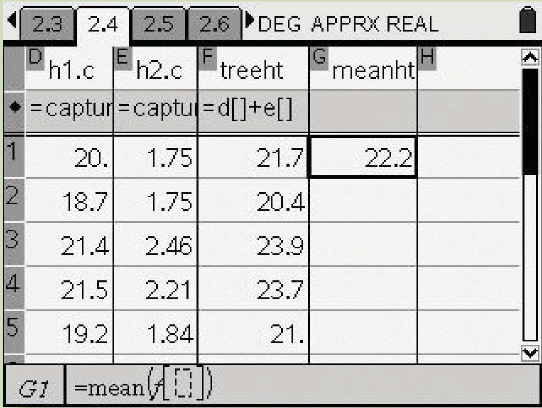
Annual total = 656 tonnes

## Task B:
## How much wood in an average tree?

We assumed that the volume of a Scots Pine tree could be approximated using the formula for volume of a cone. In order to use this formula, students had to gather data on tree height and radius, which required a field trip to a nearby forest and expert input from our local forester and geography department. We also took the handhelds into the forest, which were used to record the data directly into spreadsheets (no more worries about jotters getting wet and dirty and dealing with the difficulties of trying to record data onto paper blowing in the wind).

Before starting the project, students had spent some time in the classroom on scale drawing tasks, using similar geometrical constructions on the handhelds as those required for the project. They therefore understood the mathematics required to calculate the height of the trees and used a clinometer and tape measure to gather the measurements for angle of elevation, angle of depression and base length. They then entered these measurements on the Graphs & Geometry page, observed the corresponding values of height and manually captured the data on a Data & Spreadsheet page.



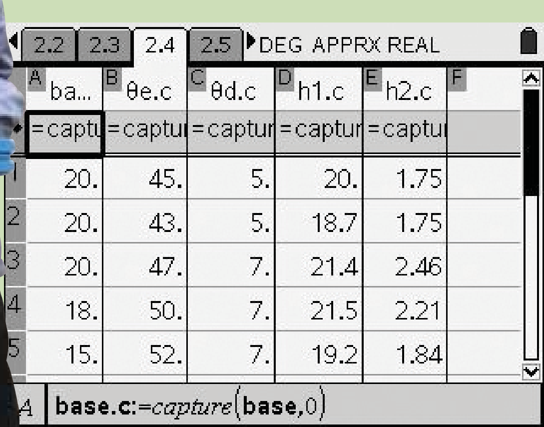



| | D h1.c | E h2.c | F treeht | G meanht |
|---|---|---|---|---|
| ◆ | =captur | =captur | =d[]+e[] | |
| 1 | 20. | 1.75 | 21.7 | 22.2 |
| 2 | 18.7 | 1.75 | 20.4 | |
| 3 | 21.4 | 2.46 | 23.9 | |
| 4 | 21.5 | 2.21 | 23.7 | |
| 5 | 19.2 | 1.84 | 21. | |

G1 =mean(f[])

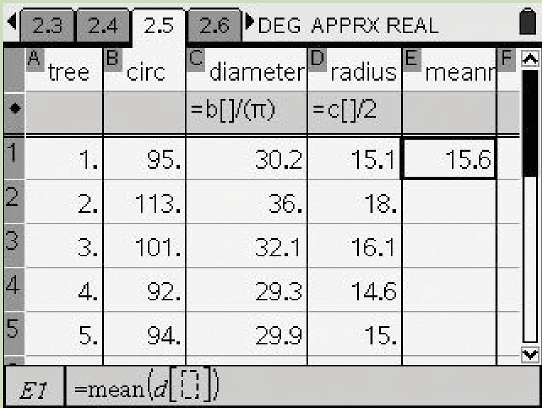
Once the students were back in the classroom, they were then able to use formulae within the Lists & Spreadsheet page to calculate the total height of each tree.

While in the forest, the students also measured and recorded the circumference of the trunk of the trees (at chest height, to avoid the circumference being affected by the spread of the roots) and then once back in the classroom, they were able to use formulae within the Lists & Spreadsheet page to calculate the diameter and then the radius of each tree, and from that calculate the mean radius.



| | A ba... | B θe.c | C θd.c | D h1.c | E h2.c |
|---|---|---|---|---|---|
| ◆ | =captu | =captu | =captur | =captur | =captu |
| 1 | 20. | 45. | 5. | 20. | 1.75 |
| 2 | 20. | 43. | 5. | 18.7 | 1.75 |
| 3 | 20. | 47. | 7. | 21.4 | 2.46 |
| 4 | 18. | 50. | 7. | 21.5 | 2.21 |
| 5 | 15. | 52. | 7. | 19.2 | 1.84 |

A base.c:=capture(base,0)



| | A tree | B circ | C diameter | D radius | E meanr |
|---|---|---|---|---|---|
| ◆ | | | =b[]/(π) | =c[]/2 | |
| 1 | 1. | 95. | 30.2 | 15.1 | 15.6 |
| 2 | 2. | 113. | 36. | 18. | |
| 3 | 3. | 101. | 32.1 | 16.1 | |
| 4 | 4. | 92. | 29.3 | 14.6 | |
| 5 | 5. | 94. | 29.9 | 15. | |

E1 =mean(d[])

Hints, suggestions and helpful information were provided via Notes pages and from this the students were able to use a Calculator page to calculate the dry mass of an average tree and then to record their conclusions in a Notes page.

2.2 | 2.3 | 2.4 | 2.5 | DEG APPRX REAL

**Hints and Suggestions:**

Volume of a cone= $\frac{1}{3}\pi r^2 h$

Use scale drawings to find heights of several trees, then calculate the average height.

Use circumference measurements for find the radii of several trees, then calculate the average radius.

2.4 | 2.5 | 2.6 | 2.7 | DEG APPRX REAL

**Information supplied:**

For Scots Pine, the volume to weight conversion is 0.98 cubic metres per tonne (Table 5.1, Forest Mensuration page 134, published by the Forestry Commission, 2006).

Also, for freshly felled timber, 50% of the weight is water.

2.6 | 2.7 | 2.8 | 2.9 | DEG APPRX REAL

© Calculations Page

| | |
|---|---|
| $avgh:=\text{mean}(tree\_height)$ | 22.2 |
| $avgr:=\frac{\text{mean}(radius)}{100}$ | 0.156 |
| $v:=\frac{1}{3}\cdot\pi\cdot avgr^2\cdot avgh$ | 0.567 |

4/99

2.6 | 2.7 | 2.8 | 2.9 | DEG APPRX REAL

**Conclusions:**

Average tree height is 22.2 m

Average tree radius is 0.156 m

Volume of average tree is 0.567 $m^3$

Mass of average tree is 0.578 tonnes

Dry mass of average tree is 0.289 tonnes

Task C:

## What area of forest is needed for one year?

For this task students needed to estimate the density of the forest, which they did by sampling the number of trees in several 100m² circular plots. The number of trees in each plot was then entered on a Lists & Spreadsheet page from which the density of trees per hectare could be estimated once we were back in the classroom.

As in most real-life projects, further considerations needed to be taken into account, and in this case it was the proportion of the tree trunk that would be used for woodchips. The forester explained that the best wood could be used for sawn timber and not all the trunk is suitable for burning. Students needed to recalculate their solutions accordingly.

2.8 | 2.9 | 3.1 | 3.2 DEG APPRX REAL

**Hints and suggestions:**

Calculate the radius of a circle of area 100m².

Count the number of trees in several circular areas of 100m² to estimate average density of woodland per 100m².

Convert this into average density of woodland per hectare(=100m x 100m).

3.1 | 3.2 | 3.3 | 3.4 DEG APPRX REAL

**Information supplied:**

"If we assume that the boiler is burning sawmill residue then, of the volume of timber that arrives at the mill, 55% becomes usable sawn boards, 5% is bark which we do not burn because it uses a lot of ash and the remainder is residues, ie. chips and sawdust which we can burn." Mr I Ross, Forester

3.2 | 3.3 | 3.4 | 3.5 DEG APPRX REAL

| | |
|---|---|
| mean(*trees*) | 4.57 |
| $4.5714285714286 \cdot 100$ | 457. |
| $457.14285714286 \cdot 0.289$ | 132. |
| $\frac{132.11428571429}{100} \cdot 40$ | 52.8 |
| $\frac{656}{52.845714285716}$ | 12.4 |

1/6

3.3 | 3.4 | 3.5 | 3.6 DEG APPRX REAL

**Conclusions:**

No. of trees in one hectare is 457

Dry mass in one hectare is 132 tonnes

Chips in one hectare is 52.8 tonnes

No. hectares for annual chips is 12.4

## Assessing the project

The whole project expended over eight weeks. However, using the handhelds meant it could be broken down into manageable tasks with new hints/ suggestions/extra information being given at the appropriate stages of the project. The handhelds also meant that students were less concerned about having 'nice' (i.e. well-rounded) answers - this was not some sterile textbook problem and so the answers were never going to be 'nice'.

The students presented their solutions using PowerPoint and they were amazed at the range of answers the different groups had come up with. Their solutions varied depending on their interpretation of summer/winter, on the heights and circumferences they had measured and on the density of the plots they had sampled. Again, this meant that we could discuss with students that there was no single 'correct' solution – another feature of real life.

The project gave students the opportunity to research a sustainable energy option and develop an informed opinion on the use of a biomass boiler. They were able to imagine 12.5 hectares as 25 football pitches - quite a significant area. However, as forestry is a major rural industry in Scotland and woodchips are a co-product of the timber process, they were not overly concerned by the amount of forest required to fuel the Aboyne Academy biomass boiler. They commented, though, that the option of a biomass boiler would become increasingly less manageable if more people opted for one, creating more demand for woodchips.

The project was developed in conjunction with Ross Partnership Forestry (Aboyne) and the Macaulay Land Use Research Institute (Aberdeen) and staff and pupils were supported throughout the project by their expertise.

# STEM loan kit offer

Would you like to try out some of these activities but don't have the kit required? No problem! You can borrow a STEM loan kit from us to use in (or out of) your classroom for up to three weeks.

Simply contact Christopher Rath to discuss your requirements:

**Tel: 01604 663077**

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- **TI-Nspire**™ – the award-winning handheld and software ICT suite for maths and science with additional options:
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- **CBL 2**™, **CBR 2**™, **EasyTemp**™ and **EasyData**™ with support for more than 30 probes and sensors.
- The **TI-84 Plus**™ and **TI-83 Plus**™ family of graphics calculators
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– to support evaluation of our technology and your CPD activities.

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