Case study

Acceleration test

Abbie Hutty
Spacecraft Structures Engineer,
Airbus Defence and Space

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www.ietfaraday.org/microbit
About this case study

Case studies are useful for learning about practical uses of technology that can improve the day-to-day lives of people. This case study focuses on testing parachute designs to help the ExoMars Rover land on the surface of Mars.

In this case study you will learn:

- why parachutes are important for safe spacecraft landing
- how an accelerometer can be used to assess parachute effectiveness
- how the BBC micro:bit can be used to quickly prototype a new idea
- what the code looks like, and how it works.

Meet the author

Abbie Hutty
Spacecraft Structures Engineer, Airbus Defence and Space

Abbie is currently working as Lead Structures Engineer for the ExoMars Rover Project, Europe’s first Rover mission to Mars.

“We need to make sure our parachute design will get the ExoMars Rover, which is quite fragile, in one piece to the surface.”
About parachute design

The ExoMars Rover has to land on the surface of Mars, via parachute and survive the impact of landing on the Mars surface. Parachutes are designed using a combination of design calculations and Earth-based tests.

We are going to explore how different parachute designs can be assessed.

- The ExoMars Rover will launch in 2020, and will take 6 months to make its journey to the red planet.
- A huge amount of engineering effort has gone into the design of the craft and the mission. Thorough testing is vital, to ensure that the craft is not damaged or lost. A significant base of future scientific results and discoveries could otherwise be put at risk.
- In March 2016, a craft called Schiaparelli was launched. Let's look a bit more closely at the descent sequence, to understand the sheer magnitude of some of the numbers that make a safe landing on the surface of Mars possible:
  - The parachute deploys in less than a second at 11km above the surface, while the craft is traveling at 1,700 kilometres per hour.
  - Two minutes later, the craft should have decelerated to a speed of 240 kilometres per hour and will now be 1.2km above the surface.
  - The parachute is jettisoned, and thrusters are fired for the remaining 30 seconds, with the craft travelling at 10 kilometres per hour when it hits the surface.

Terminology

velocity – measured in metres per second (m/s) - how much distance is travelled in one second of time.

acceleration/deceleration – rate of change of velocity in metres per second per second (m/s/s) - how much does the velocity (m/s) change by, in one second.

The problem

To measure the effectiveness of a parachute design, we need to:

1. time how long the descent takes
2. measure the maximum acceleration in each of three axes
3. measure whether the craft flips upside down or not
4. measure how much the craft spins around.

Our prototype uses the on-board compass to measure how much the craft spins. This compass works by measuring the Earth’s magnetic field.

Other measurement techniques will be required on Mars.

However, spacecraft engineers test their designs on Earth, so it is okay to use the compass as part of this test equipment.

It is very important to choose carefully the landing site for the spacecraft in order to minimise other causes of damage on touch-down.
The solution

Using the product

- The measurement device is fitted into the craft.
- The B button is pressed to arm the measurement system.
- The craft is sealed, and dropped from a height. Free-fall starts the measurement system.
- When it lands and senses no movement for three seconds, the measurement system stops. Then, the user reads out the readings by pressing the B button to cycle through each of the different values.

We’re using the BBC micro:bit’s accelerometer and compass to work out how much acceleration and how much spin our Rover experiences with each version of the parachute.

The accelerometer and compass could accidentally measure movement while fitting and removing the BBC micro:bit in the craft. To prevent this, the user fits the device, then presses the B button to arm the measurement system.

When the BBC micro:bit senses free-fall, it starts taking measurements.

After three seconds of no movement (when it lands), the BBC micro:bit stops taking measurements and subtracts three seconds from the descent time.
Here is part of the code listing for the parachute measurement system. Compare it against the flowchart on the previous page and see if you can spot where this code slots into our flowchart.

```
| Take measurements |
| var now := input → running time |
| var x := math → abs (input → acceleration (x)) |
| var y := math → abs (input → acceleration (y)) |
| var z := input → acceleration (z) |
| Calculate differences |
| var x diff := math → abs (last x - x) |
| var y diff := math → abs (last y - y) |
| var z diff := math → abs (last z - z) |
| var bearing := input → compass heading |
| var bearing diff := math → abs (last bearing - bearing) |
| Assess readings |
| if x > maxx then |
| | maxx := x |
| else add code here end if |
| if y > maxy then |
| | maxy := y |
| else add code here end if |
| if (last z ≤ 0 and z > 0) or (last z > 0 and z ≤ 0) then |
| | The craft has flipped over |
| | zflips := zflips + 1 |
| else add code here end if |
| update spin based on compass movement in last loop period |
| if bearing diff > spin threshold then |
| | spins := spins + 1 |
| else add code here end if |
```

See the full program listing by following the links at the end of this booklet.

Now that you have worked through this case study booklet and tried the program for yourself, test how much you have remembered with our quiz! You can also look up the answers at the bottom of page 11.

**Q** How long will the Mars descent take with a parachute deployed?

**Q** What speed has the craft reached by the time it touches down on the surface of Mars?

**Q** Why do engineers do Earth-based tests before sending a craft into space?

**Q** How does the prototype device prevent false readings while being fitted and removed?

**Q** What might you change about how this program works?

**Q** What feature might you add to this program to make it even better?

**Q** Why do you think you might enjoy a career as an engineer?
More information

If you want to read more about the topics covered in this case study, why not take a look through some of these suggested websites and additional resources?

Acceleration test
- Program code
  www.microbit.co.uk/nwwewb
- Downloadable eBooklet and video
  www.ietfaraday.org/microbit-casestudies

Information about Mars space exploration
- ExoMars Rover Programme information
- ExoMars Rover fact sheet
  www.esa.int/Our_Activities/Space_Science/ExoMars/ExoMars_Factsheet
- Wikipedia page about ExoMars programme
- Wikipedia page about the ExoMars Rover
- Descent calculations for ExoMars 2016 Schiaparelli
  http://exploration.esa.int/mars/57464-exomars-2016-schiaparelli-descentsequence
- Airbus Defence and Space
  www.space-airbusds.com
- Jet propulsion laboratory parachute design activity
  www.jpl.nasa.gov/edu/teach/activity/parachute-design

About IET Faraday

How can I get involved?

The IET Education team will be working on this exciting project in three main areas:

1 Teaching resources
   The IET Education team have developed a new suite of resources covering 13 separate topics to help you to introduce the BBC micro:bit to your students. Each of these free resources includes a starter/introduction, main and extension activity as well as video clips to contextualise the information provided. For more information and to view the resources: http://faraday.theiet.org/stem-activity-days/bbc-microbit/resources/index.cfm

2 Faraday Challenge Days
   162 events taking place between October 2016 and June 2017 aimed at Year Eight students in England and their equivalents across the whole of the UK. These off-timetable STEM activity days aim to encourage creativity, team working, problem solving and the application of the technology to real-life situations.

3 BBC micro:bit classroom poster
   This poster is free to download or order direct from the IET Education team. It provides a quick look at the individual components of the BBC micro:bit and how you can use it in your classroom.

For more information please visit
www.ietfaraday.org/microbit

or contact faraday@theiet.org
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Please visit our website for more information:

www.theiet.org/education