teach with space

→ **HOW TO COLLECT DATA FROM ASTRO PI**

Using the Sense HAT sensors to collect data from the environment

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During the European Astro Pi Challenge, Astro Pi Ed onboard the International Space Station (ISS) will be collecting a range of data using its sensors.

In this set of activities you will explore life conditions onboard the ISS and compare them with life conditions on Earth using the Sense HAT sensors to sense the space around you.

Figure A1

↑ Astro Pi logo

Equipment

• Astro Pi Kit
• Monitor
• USB keyboard
• USB mouse

Fast facts

Age range: 12-16 years old
Complexity: medium
Location: indoor room
Includes use of:

• Astro Pi Kit;
• monitor;
• USB keyboard;
• USB mouse.

Outline

The students will program Astro Pi to collect temperature and humidity data from the environment. Students will simulate the humidity control system on the ISS and will also collect data from their own environment. Students will take acceleration measurements to detect orientation and to identify the direction of gravity. The objective is to record, analyse, and display data using the Sense HAT sensors and basic code instructions.

Students will learn

• How to use the Python programing language to communicate with the Sense HAT sensors
• To collect temperature and humidity data from the Sense HAT sensors
• To plot and analyse data
• To display data in the LED matrix
• To detect orientation using the Sense HAT accelerometer
• To use an accelerometer to identify the direction of gravity
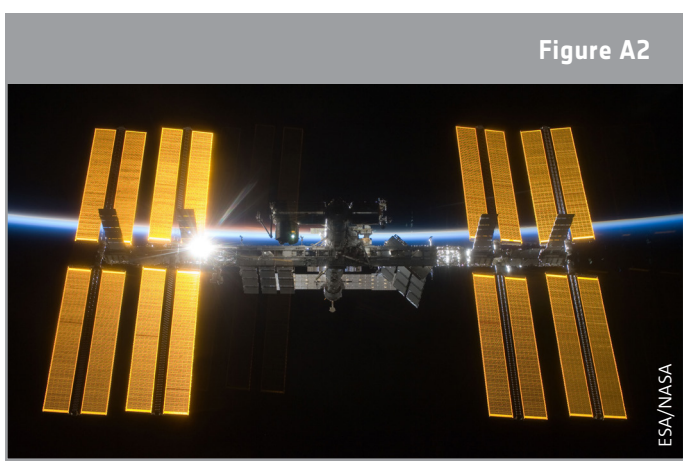• To develop scientific research using computing tools

→ ACTIVITY 1 - STAYING COOL ON THE ISS

It is important for the astronauts that the temperature on the ISS remains at around 24°C, but this is not an easy task. On the sunny side of the ISS, temperatures can reach 121°C, whereas on the dark side they can go as low as -157°C! You are going to use the Sense HAT sensors to measure the temperature in your classroom and compare it with the temperature in the Columbus module of the ISS.

Exercise

1. Why do you think it is important for the temperature on the ISS to remain as close to 24°C as possible?

Figure A2

↑ International Space Station (ESA/NASA)

2. Open Python 3 by clicking on the Raspberry logo at the top of the screen. This will open the Menu. Select Programming > Python 3. This will cause a Python Shell window to appear. Select File > New File, and type the code below in the new window.

Note: The sentences that start with a # are only comments. The program will not run those, and you do not need to write them.

```
File  Edit  Format  Run  Options  Windows  Help
#to allow the program to use the Sense HAT hardware
from sense_hat import SenseHat

#to create a sense object which represents the Sense HAT
sense = SenseHat()

#to collect temperature and store it as temp
temp = sense.get_temperature()

#to round the value of the temperature with two decimal points
temp = round(temp, 2)

print (temp)
```

3. a. Select File > Save As and choose a file name for your program. Select Run > Run module. Write down the recorded temperature.

b. Use another thermometer to record the temperature in your classroom, to test how accurate the Astro Pi is. What temperature does this thermometer read?

4. The temperature in the Columbus module shown in Table A1 below was collected by one of the Astro Pi's onboard the ISS.

Table A1			
Experimental data from Columbus module		**Experimental data from your classroom**	
Temperature (°C)	**Date and time**	**Temperature (°C)**	**Date and time**
27,53	16/2/16 10:45		
27,52	16/2/16 10:45		
27,54	16/2/16 10:45		
27,55	16/2/16 10:45		
27,53	16/2/16 10:45		
27,55	16/2/16 10:45		
27,54	16/2/16 10:46		
27,54	16/2/16 10:46		
27,53	16/2/16 10:46		
27,52	16/2/16 10:46		
27,53	16/2/16 10:46		
27,53	16/2/16 10:46		

↑ A comparison of the temperature on the ISS with the temperature in the classroom.

a) Add a 'while True' loop to your code. This will allow you to continuously collect data from the sensor. Your code should now be similar to the one in the box below.

```
File  Edit  Format  Run  Options  Windows  Help

from sense_hat import SenseHat

#to allow the program to use the time module
import time

sense = SenseHat()

#to repeat the code until a condition is met
while True:
    temp = sense.get_temperature()
    temp = round(temp, 2)
    #_____
    time.sleep(10)

    #the strftime function is used to print the date and time
    print (time.strftime('%x %X'),temp)
```
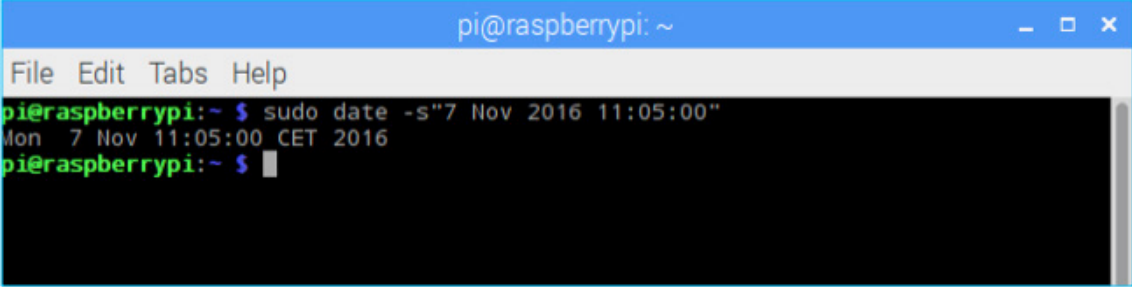
b) Write a comment in your code to explain the command time.sleep(10)

c) Raspberry Pi doesn't have a real-time clock. For you to be able to see the accurate time you need to directly manipulate the system. Open a terminal window by clicking on the terminal icon at the top of the screen. You should be able to see a new window with the following prompt:

pi@raspberrypi ~ $

Type the following command (see example from the print screen below) and press Enter:

sudo date -s "Day Month Year hh:mm:ss"

```
pi@raspberrypi: ~                                    _ □ ✕

File  Edit  Tabs  Help
pi@raspberrypi:~ $ sudo date -s"7 Nov 2016 11:05:00"
Mon  7 Nov 11:05:00 CET 2016
pi@raspberrypi:~ $ ▮
```

Note: You may need to close the terminal window to see the updated time.

d) Return to your editor window and run your code. Complete Table A1 with the data printed. To stop running the program press Ctrl + C.

e) Using the data from Table A1, calculate the average temperature in the Columbus module and the average temperature in your classroom. Are they close to 24°C? Why do you think they vary from this value?

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Extension

Space is a place of extremes. How do you think it is possible to control the temperature inside the ISS? Plan an investigation to determine which materials could be used to keep the astronauts at the right temperature. You can follow the template below.

Plan your investigation template

1. Develop a research question. Then form a hypothesis to investigate.

   Research question:

   Hypothesis:

2. Design a plan to test your hypothesis using your Astro Pi. What other materials do you need?

3. Collect and analyse your data.

4. Draw conclusions and try to answer the research question.

→ ACTIVITY 2 – CONTROLLING HUMIDITY INSIDE THE ISS

Although you might not be able to see it, there is water all around us in the air. Humidity is a measurement of how much water vapour is in the air. It is normally expressed in percentage of relative humidity. 100% relative humidity, at a given temperature, means the air contains as much water vapour as is possible.

In this activity you are going to use Astro Pi to simulate the humidity control system used on the ISS and learn how to share the data collected by the Astro Pi sensors.

Activity 2.1 – Measuring humidity

The humidity level on the ISS is usually maintained at around 60%. This is not an easy aspect to control. Everyday life activities constantly increase the humidity on the ISS. Also, an astronaut consumes around 2.7 litres of water per day through eating and drinking, and part of this water leaves the body as vapour (through the pores or through breathing).

If the humidity level is too high, the ISS life-support system makes sure that the surplus water vapour in the air is collected. In order to do that, humidity is continuously recorded by accurate sensors on the ISS. In this exercise you are going to use the Astro Pi humidity sensor to measure the humidity in your classroom, just like it is done on the ISS.
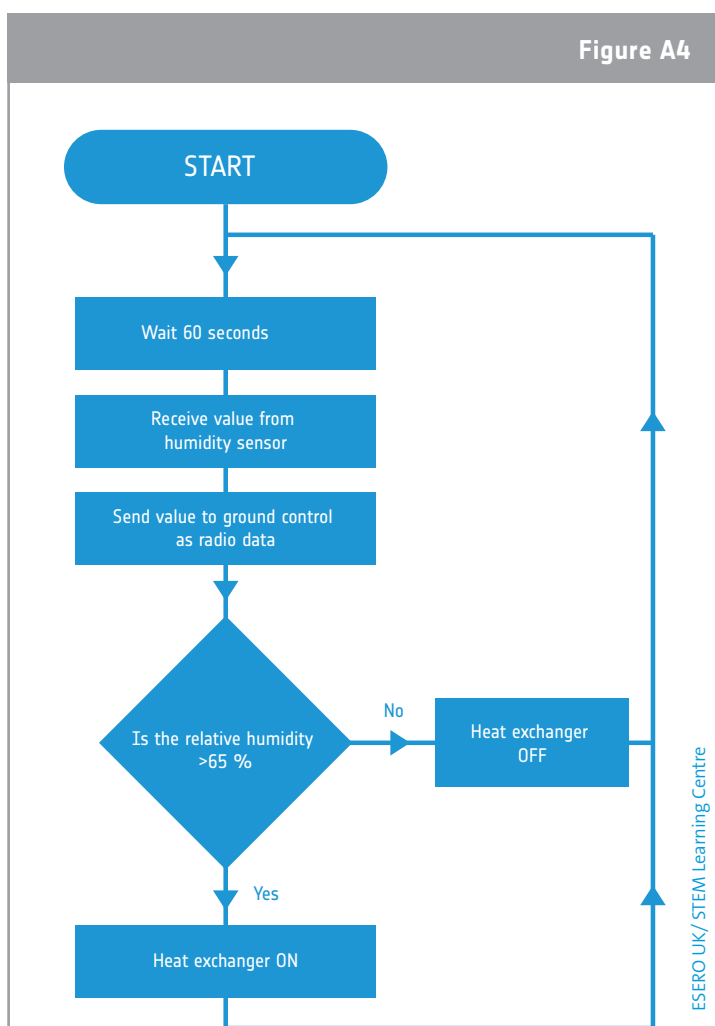

Figure A3

↑ ESA astronaut Alexander Gerst on the International Space Station's fitness bike. Everyday life activities, like exercising, constantly increase the humidity on the ISS. (ESA/NASA)

Exercise

1. Why do you think it is important to control the humidity inside the ISS? Discuss with your peers and give two reasons for using the humidity control system.

2. Figure A4 shows a flow chart representing the humidity control system on the ISS. In the box below, plan/write a short Python program that will run the first three steps of the flow chart.

Figure A4

START

Wait 60 seconds

Receive value from humidity sensor

Send value to ground control as radio data

Is the relative humidity >65 %

No → Heat exchanger OFF

Yes → Heat exchanger ON

ESERO UK/ STEM Learning Centre

↑ Humidity control system. If the relative humidity is higher than 65%, a series of fans and heat exchangers (similar to those found in a refrigerator) cool and dry the air to reduce the water vapour. (ESERO UK/ STEM Learning Centre)

3. Open a new Python 3 window and write your code. Select File > Save As and choose a file name for your program. Then select Run > Run Module. Write down the humidity recorded.

Activity 2.2 - Collecting and sending data

A worldwide network of control centres on the ground support the astronauts living and working on the ISS, including measuring their life conditions onboard the Space Station. For this, it is very important to share the data collected. You are going to recreate step 4 from the flow chart in Figure A4 and send the data collected as a CSV (comma separated value) file that you can share and analyse.

Exercise

1. The data collected on the ISS is sent to the ground as radio data. Write down what you understand by 'radio data'.

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2. The data delivered from the ISS is in CSV format, a format which allows data to be saved in a table structured format and that is easier to be studied and applied by scientists. Open a new Python shell and type in the code below:

```
File  Edit  Format  Run  Options  Windows  Help

from sense_hat import SenseHat
import time
sense = SenseHat()

#to open a file named Datafile in which the program will add the collected data
file = open("Datafile.csv", "a")

#to write in the file the name of the table columns. \n is used to break and to create a new line
file.write("Time, Humidity \n")

print ("Time, Humidity")

for n in range(20):
#repetedly gets data from the humidty sensor until adding 20 lines to the file table
    humidity = sense.get_humidity()
    humidity = round(humidity, 2)

#to write in the file the data collected
    file.write(time.strftime('%X'))
    file.write(",")
    file.write(str(humidity))
    file.write("\n")

    print (time.strftime('%X'),humidity)

    time.sleep(1)

file.close()
```
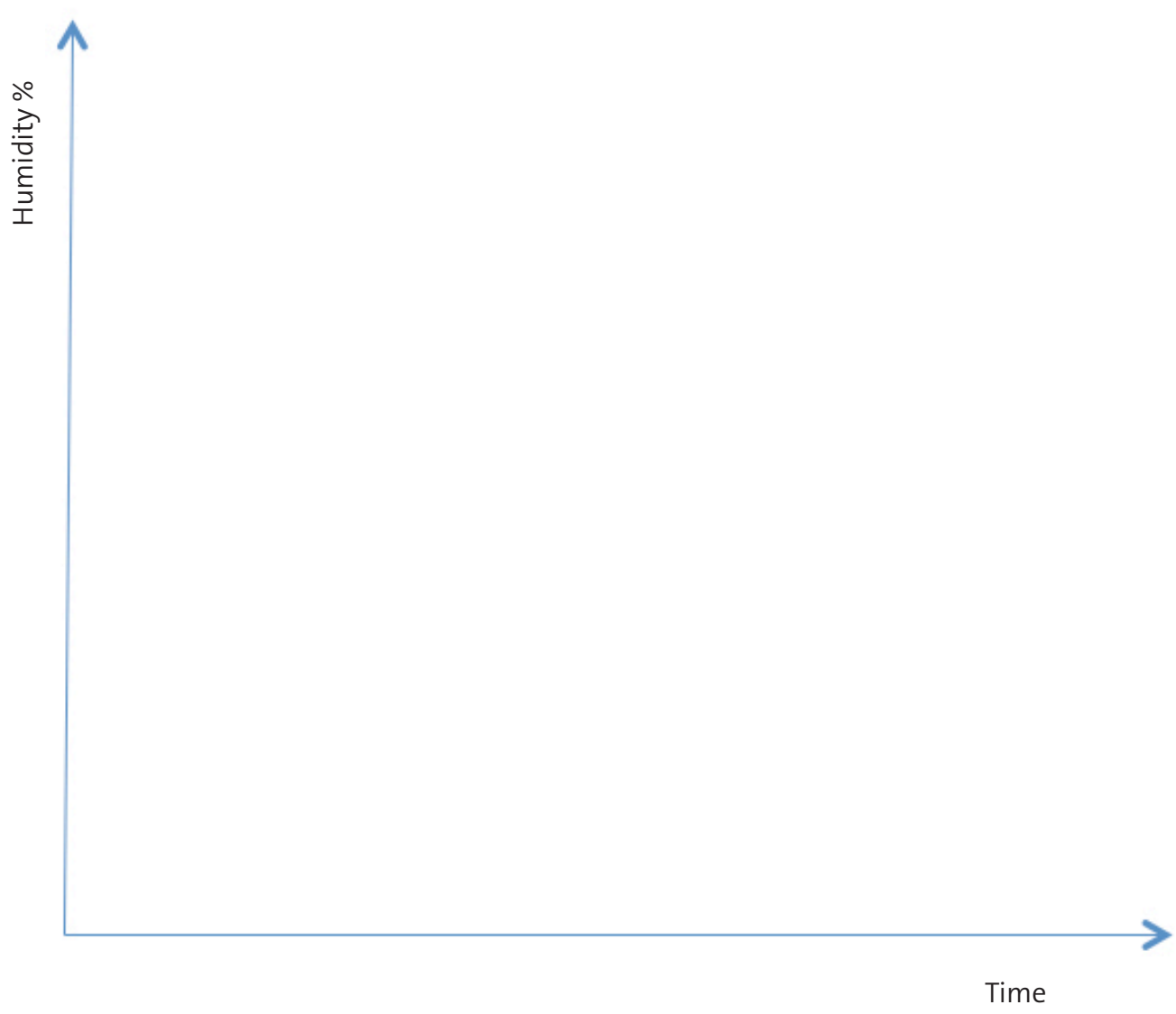
3. Once your data is in a useful format, you will be able to study the data in many possible ways. The data collected from the humidity sensor has been saved in the file manager (you can access it at the top of your desktop) . Open the file and, using the data, plot time vs. humidity on the graph below.

Humidity %

Time

4. Run your code again, but this time blow slowly onto the sensor. Open the data file again. The new data collected has been added to it. Using this new data, plot your new Time vs. Humidity points on the graph above. What can you conclude from comparing the two graphs?

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Activity 2.3 - Displaying data

On the ISS, astronauts are responsible for checking if the equipment is working properly and reporting abnormal conditions to ground control. You are going to recreate step 5 from the flow chart in Figure A4 creating a visual alarm to let the astronauts know when humidity is above 65%.

Exercise

1. Look at the following piece of code. What do you think it will do? Write your answer by editing the comments in the box below.

```
File  Edit  Format  Run  Options  Windows  Help

from sense_hat import SenseHat
import time

sense = SenseHat()

while True:
    humidity = sense.get_humidity()
    humidity = round(humidity, 2)

#_____
    if humidity<65:
        bg = [0,100, 0]

#_____
    else:
        bg = [100,0, 0]

    sense.show_message(humidity,scroll_speed=0.05,back_colour=bg)
```

2. Now copy your code into a new Python window. Select File > Save As and choose a file name for your program, then select Run > Run Module. What happens when you run the code?

_____

Note: To clear the matrix, type the command sense.clear() in the Python shell.

3. The Sense HAT can only display data that it recognises as strings, which are just all the characters on your keyboard. Strings are sequences of characters which can include a letter, a number or a punctuation mark. In a string all the characters are considered as text, even if the characters are numbers. In this example the humidity variable is a number with decimal points. For you to be able to display the humidity value on the Sense HAT you have to convert the humidity to a string. Just before the last line of the code above, add the following line to convert humidity to a string:

humidity = str(humidity)

Run your code again. Did it do what you expected it to do in Exercise 1?

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4. Exhale slowly onto the sensors until you are able to reach a humidity value that is above 65%. What happens to the data displayed in the matrix?

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5. A better way to visualise humidity might be to draw a simple bar chart. Try the code below in a new file.

```
File  Edit  Format  Run  Options  Windows  Help
from sense_hat import SenseHat

sense = SenseHat()

white = (255,255,255)

for height in range (4):
    sense.set_pixel(3,height, white)
    sense.set_pixel(4,height,white)
```

a) What happens if you change the number in range(4)?

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b) What is the largest number you can put in range( ) before you get an error? Explain why this happens.

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6. The humidity can range from 0 to 100. If that value could be scaled down to between 0 and 8, it could be used in the range( ), to produce a chart of the humidity in the air. Dividing the humidity by about 12.5 should do the trick.

a) Can you explain why 12.5?

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_____

b) On the grid below, represent what you expect will be displayed on the LED matrix if you enter the code below (assume that the humidity is the same as displayed in exercise 3). Explain your representation.

```
File  Edit  Format  Run  Options  Windows  Help

from sense_hat import SenseHat

sense = SenseHat()

white = (255,255,255)

humidity = sense.get_humidity()
# int is used to convert data to an integer number
humidity = int(humidity/12.5)

for height in range (humidity):
    sense.set_pixel(3,height, white)
    sense.set_pixel(4,height,white)
```

c) To verify your answer, copy your code into a new Python file. Select File > Save As and choose a file name for your program, then select Run > Run module.

d) Add a 'while True' loop to your code and try that it constantly measures humidity and displays it as a bar chart. Copy your code to the box below.

Extension

Try to create a mini controlled environmental station in your classroom and control temperature, humidity, and pressure using your Astro Pi. You can start your project by investigating the ideal environmental conditions inside a classroom. You can then create an alarm system to let you know whether these conditions are normal or not.

→ ACTIVITY 3 – WHICH WAY IS DOWN?

Everything on Earth is subject to gravity. This is the force that, when you jump, pulls you down continuously. And because of that, it's very easy on Earth to know which way is down. 'Down' is the direction gravity is pulling you to, and 'up' is the opposite direction.

In the International Space Station, there is no up or down. There is no difference between a floor and a ceiling. This disorientation can make astronauts feel sick ('space sickness') until they get used to this strange arrangement.

In this activity you are going to learn how to use the accelerometer sensor to detect orientation.

Exercise

1. The International Space Station orbits the Earth at an altitude of 400km. As gravity become weaker with distance, the gravity at that altitude is about 90% of what it is on the Earth's surface. But if you look at the astronauts on the International Space Station, they seem to be floating around with no sense of up or down. Can you explain why this happens?

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_____

Figure A5

↑ In the ISS there is no up or down (ESA/NASA)

2. The Sense HAT has a movement sensor called an IMU (Inertial Measurement Unit) which is actually three sensors in one:

- A gyroscope (measures rotation and momentum);
- An accelerometer can be used to find the direction of gravity when an object is at rest;
- A magnetometer (measures the Earth's own magnetic field, a bit like a compass)

Accelerometers measure in metres per second squared (m/s^2) or in g-forces (g). g is the symbol for the average acceleration (9,8 m/s^2) produced by gravity at the Earth's surface (sea level). One g-force on planet Earth is equivalent to 9.8 m/s^2.
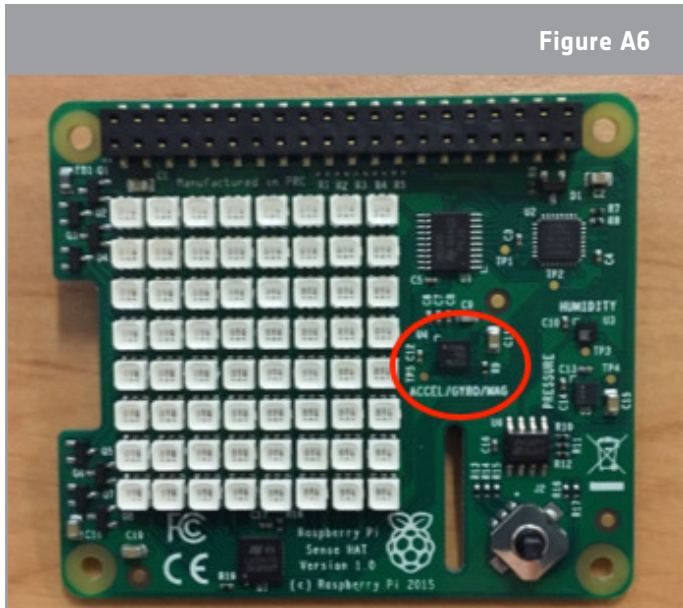

Figure A6

↑ IMU sensor in the Sense HAT

Open a new Python window and type the code below:

```
File  Edit  Format  Run  Options  Windows  Help

from sense_hat import SenseHat

sense = SenseHat()

acceleration = sense.get_accelerometer_raw()

print(acceleration)
```

3. Run your code and write down the measurements from the accelerometer.

4. The Sense HAT accelerometer collects data from 3 axes (or in 3 dimensions). It is not very helpful to read the data in the format that you have just printed. To print the data in a more friendly format, copy and run the following code.

```
File  Edit  Format  Run  Options  Windows  Help

from sense_hat import SenseHat

sense = SenseHat()


acceleration = sense.get_accelerometer_raw()
x = acceleration['x']
y = acceleration['y']
z = acceleration['z']

x=round(x, 0)
y=round(y, 0)
z=round(z, 0)

print("x {0} y {1} z {2}".format(x,y,z))
```

5. Write down the results. In which direction do you think the force of gravity is pointing? Discuss your answer with your peers and with your teacher.

6. Rotate your Astro Pi by 90 degrees. Write down the results and explain the differences from the previous results.

7. Complete the scheme bellow to indicate the directions of the X,Y, and Z axes from your Astro Pi. If you think it's necessary, you can rotate your Astro Pi once more.

Figure A7
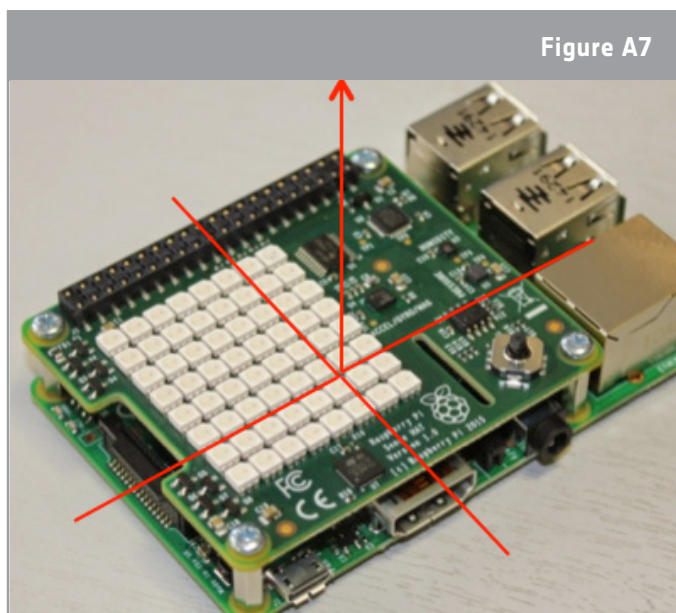
8. Table A2 shows the X, Y, and Z axes accelerometer readings from Astro Pi on the ISS for one work day. Why do you think the accelerometer is reading close to zero? Do you think it can be an anomaly? Try to answer this question by comparing the data collected on the ISS with the data that you have already collected. See your answer to Question 1 from this activity as well. Discuss your answer with your peers and with your teacher.

Table A2 - Accelerometer readings from the Astro Pi on the ISS (in g)			
accel_x	accel_y	accel_z	time_stamp
-0,00057	0,019359	0,014357	10:45:00 AM
-0,00044	0,019405	0,014425	11:45:00 AM
-0,00056	0,019531	0,014597	12:45:00 AM
-0,00056	0,019506	0,014432	01:45:00 PM
-0,00058	0,019464	0,014569	02:45:01 PM
-0,00056	0,01939	0,014578	03:45:00 PM
-0,00053	0,019384	0,014389	04:45:00 PM
-0,00046	0,01926	0,01444	05:45:00 PM
-0,00053	0,019266	0,014568	06:45:01 PM

Extension

1 . The ISS loses 50 to 100 metres of altitude per day. Left unchecked, this would cause the orbit to decay, losing height and putting the ISS in great danger. This happens because even at the altitude of 400 km there is still a tiny amount of atmosphere present. That air creates drag on the ISS, which causes its orbit to slowly decay over time. To avoid this, orbital boosts are provided by rocket engines. Boosts might be staged 3- 4 times each month. What data can be collected by Astro Pi to record these events?

_____

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2. Download here the data collected in the Columbus module from 16/02/2016 to 29/02/2016. Can you guess if any ISS reboots occurred during that period and how long they lasted? Go here for the latest altitude graph; you may be able to correlate this with the data in the file. Write down your conclusions.

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