Mission Space Lab Phase 4 report

Team name: ToucanPi

Chosen theme: Life on Earth

Organisation name: Self-organised

Country: Spain

1. Introduction

We are three students in year 6 and have not studied the earth's gravity and magnetism in detail. However, our general knowledge has indicated to us that both extend far away from the surface of the earth. During our brainstorming sessions, we have noticed a discrepancy; the astronauts are floating in space and are told to be in "microgravity" which should imply that the gravity is negligible there. The word "micro" caught our attention here which was used instead of "zero" which led to discussions with our mentor and our families.

We heard during these discussions that in 1915 Albert Einstein formulated the theory of General Relativity which says that gravity is equal to acceleration. If the ISS is not accelerating, then the people who designed the ISS must be perfectly balancing the gravitational field of the Earth.

We now understand that the gravitational pull of the earth at the ISS is quite high (~88% percent of that on the earth) and it is near zero (hence "micro") due to ISS' own motion[1]. So this is the starting point for our experiment for the AstroPi onboard the ISS. We want to learn important lessons on gravity, magnetic fields, how a satellite works, scientific method and carry out an experiment testing whether the theory and real-life approximate each other well or not within the limitations of our tools.

2. Method

We have logged the position of the ISS and the IMU sensor data every five seconds. Photos were taken every twenty-five seconds. The resulting data-file (csv) was analysed by (i) plotting data over time as individual components and as the total magnitude, (ii) plotting the position of the ISS over the earth, (iii) investigating photos to identify features on earth that could be located, (iv) calibrating the photos to physical distances on earth by comparing the size of features on the photos to those

[1] References are provided in documentation at GitHub repository: https://github.com/ulugeyik/toucanpi/

on Google Satellite imagery, and by (v) carrying out necessary calculations from data and equations from basic physics.

Our hypotheses were:
H1: The sensors on AstroPi can be utilised to separate different directions of acceleration and identify the strength of the earth's gravitational pull on the ISS.
H2: The distance from the earth's core is the main determinant for the strength of gravity which we have calculated to be 8.7 cm^2/sec. It will not depend on the path of the ISS since the height of the ISS is approximately constant throughout.
H3: Similar considerations are true for the magnetic field except that if we end up recording over the South Atlantic anomaly.

Data, codes and documentation are shared online [2].

3. Experiment results

The detailed experimental results are shown in the online notebook[2].

Hypothesis 1: First we show a plot of acceleration (Figure 1) measured which proved that there is indeed "micro-gravity" on the ISS. So we have implemented our risk management plan and calculated the velocity of the ISS by measuring the distance it travelled during a specific time using photos of the surface of the earth. This is illustrated in Figure 2. We looked at photos and a plot of ISS position on the earth during our data acquisition. Once we located it, we used Google Earth to measure its real distance and calculated the velocity of the ISS to be 7.53 km/s which is compared well to the true velocity of 7.66 km/s. From speed, we have used Newton's equations to calculate the gravitational pull that it had to overcome which was 8.1 m/s^2 which is about 80% of that on the earth. Hypothesis one is accepted.

Hypothesis 2: The next question we addressed is whether the gravitational pull changes with position over the earth. However, we could not get the speed we needed since the photos were mostly dark and we did not know its height. We have instead used the logged position of the ISS and the timing to do our best estimation and found out that the speed changes less than a fraction of a percent but is dependent on the position over the earth. We do not have the experimental precision necessary to draw any further conclusions. Hypothesis 2 is partially rejected with the available data. Hypothesis 3 was a similar question about the magnetic field and our findings were also similar.

Overall, our experimental results show that Newton and Einstein were right and the images showing astronauts floating in space are due to ISS motion cancelling the gravitational pull.

[2] References, proposal, codes and analysis notebook are provided at GitHub repository: https://github.com/ulugeyik/toucanpi/
Analysis report is also available as an online Python notebook:
https://colab.research.google.com/drive/13uW6BwmavDIT2WvtGdzgNOYI7ODN56e6?usp=sharing

Figure 1 Three axes of acceleration and the total acceleration over time.

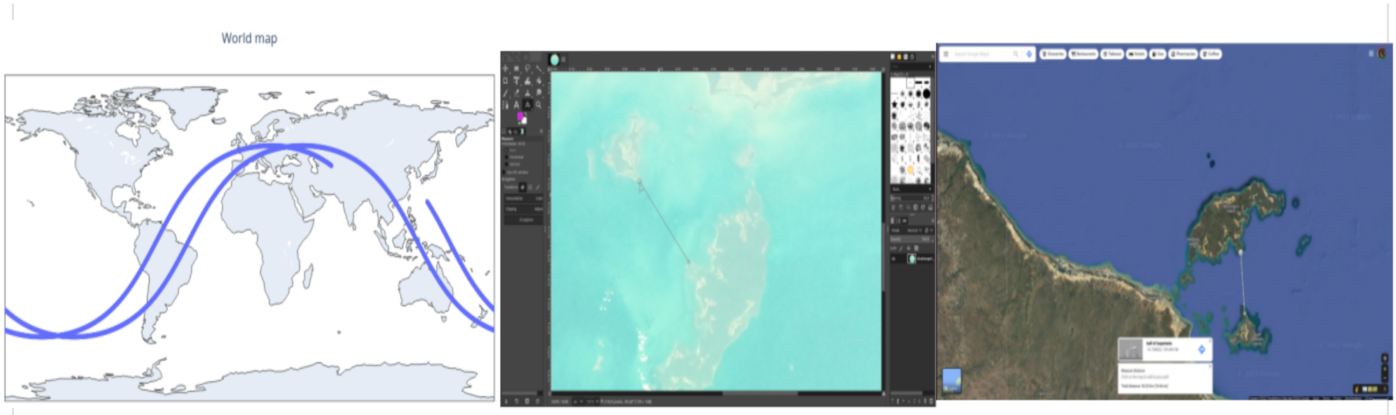

Figure 2 Illustration of how to calculate the speed of ISS. See Ref. [2]

4. Learnings

The team got together because one of the parents sent a message to the class group. Our story has been written in response to a request by Raspberry Pi foundation and is available online[3].

COVID-19 was a challenge. Our age was a challenge but with patience we learned a lot.

We learned how to brainstorm (and agree on a decision!), how to propose a research mission according to its rules, how to write scientific conclusions and hypotheses, how to analyse and interpret data, how to report our results and how to present them to audiences[4]. In fact, our adventure led us to present in our school's STEM centre fair and assembly to the whole school with older kids. We have also learned about gravity and acceleration, about satellites (specially ISS) and about Newton's and Einstein's works. We learned about Raspberry Pi, different sensors, Python programming and how to carry-out experiments. If we want to be specific, we learned how to use experimental data to calculate gravitational

[3] https://github.com/ulugeyik/toucanpi/blob/main/info/ToucanPi%20Story%2003_2022.pdf
[4] https://twitter.com/search?q=%23ToucanPi&src=hash

acceleration!

If we do this again, we would spend more time and find a more entertaining way to approach it.

5. Conclusion

We have found out that a little gadget can be very powerful and measure many things. We had three hypotheses and we were able to answer most of them. In particular, we have found out that the ISS is pulled by the earth quite strongly, about 80% compared to its surface. The gravitational pull may be different at different points above the earth but our experimental precision was not sufficient to answer this conclusively. Our data indicates that it is. As expected, other fields due to earth's dynamics and structure such as the magnetic field also behave similarly.

We have also concluded that the amount of information and data is a lot. We can study how the ISS rotates, we have photos of the CanadaArm2 (one of only two teams!) and see how it moves and how big it is and we have this platform to do other things. We have had a lot of fun doing this experiment and we would definitely do it again.