Mission Space Lab Phase 4 Report

# Entro PI

Team name: Entro PI

Chosen theme: Life in Space

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## Introduction

Randomness and Random Number Generation (RNG) algorithms have many applications in today's software industry and hence affect many aspects of our everyday life. For example, modern Cryptography and cryptographic algorithms often rely on Randomness.

Random data produced by RNG algorithms is often based on measurements of some natural phenomenon, that is expected to be random, such as the current Temperature, level of Humidity etc. RNG algorithms use that initial values (seed) to perform some mathematical operations and produce their random data. Seed based on measurements of natural phenomena is considered to be a good source of natural entropy and hence hard to predict. To sum up, RNG algorithms produce random data based on a "seed" as a starting point and that seed has to be "random".

In our experiment, we used measurements of natural phenomena as seed to produce long sequences of random data on Earth, as well as in the environment of the ISS. We investigated whether these sequences of random data pass a series of simple statistical tests of Randomness.

Our hypothesis was that random data produced in Space would fail to pass the tests mentioned above, because some types of seed, such as seed based on temperature, are extremely stable in the ISS - in contrast to Earth, that these same values may change significantly in a matter of minutes.

The results seem to confirm our hypothesis.

## Method

Using the Temperature, Humidity, Pressure, Compass, Accelerometer and Gyroscope sensors of the Astro PI, we measured the values of their corresponding natural phenomena once every ~2 seconds.

Each time we completed a measurement, we used its respective value as seed to Python's default RNG algorithm in order to produce a random number between 0 to 9. We, also, produced and saved a random number in that range using the default seed of Python's RNG algorithm (Time), every time we completed a turn of measurements.

After the completion of the process above, we had generated seven sequences of 5233 random numbers, that had been produced having as seed a measurement of natural phenomena. In total, we collected 36631 random numbers in Space.

Following the exact same process, we collected 38878 random numbers, here, on Earth (our classroom), in order to make comparisons.

We manually analyzed the text files we collected using Microsoft Excel in our school's CS Laboratory. Due to the large amount of data and COVID19 restrictions, we only managed to analyze random sequences of numbers generated based on the following values: Temperature, Humidity, Pressure, Compass and Time. As there is no way to determine if a sequence of numbers is truly random, we looked for patterns that would allow some level of predictability and we also did Frequency analysis.

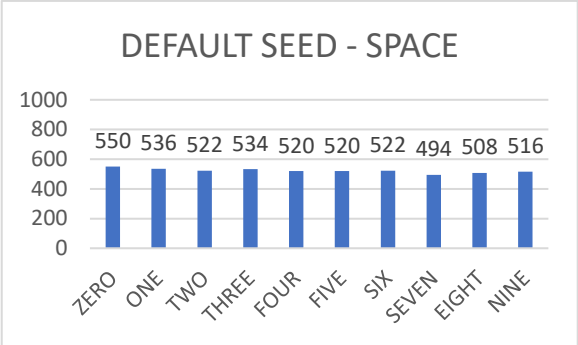
## Results

In regard to unusual frequencies and patterns that would allow predictions, we did not notice any differences between sequences of random numbers generated on Earth and those generated in Space, when we used Python's default seed (system time) in order to produce random data. Both on Earth and in Space, we only noticed two cases that the algorithm returned 4 times in a row the same numbers. In addition, we did not find that many occurrences of the same numbers appearing in a row, that would allow any valid predictability.

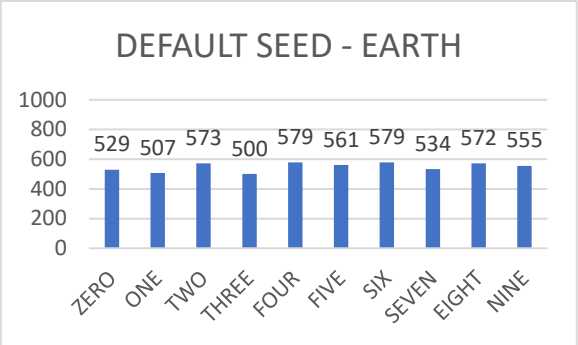
As with Python's default seed, we did not find any unusual frequencies or patterns that would allow predictions in the sequences of random numbers that were produced (both on Earth and in Space) based on the values of Barometric Pressure and the direction of the Magnetic North as their seed.

However, we noticed significant differences between Earth and Space when we produced sequences of random numbers using the values of Temperature and Humidity of the ISS as the algorithm's initial seed. There were three cases that the number "3" came up six times in a row when Temperature was used as seed and we, also, noticed that when a "3" was appearing, another "3" would -most often than not-

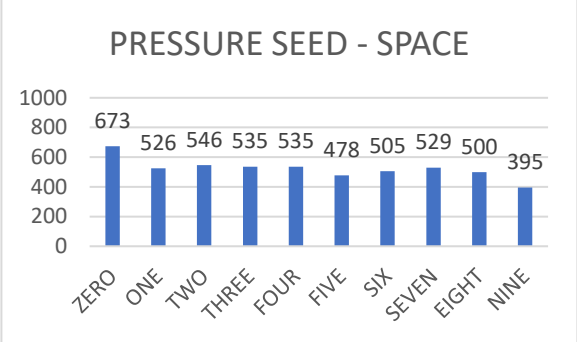
appear shortly after. In addition, out of the 5233 random numbers produced based on Temperature in the ISS, "6" appeared only 15 times, "9" only 3 times and "2" did not appear at all. On the other hand, number "3" appeared 1290 times in total. In regard to the sequence generated having Humidity in the ISS as seed, the results seem to be better in terms of detecting patterns that would allow predictions, as we did not notice cases of numbers taking too long to appear or appearing many times in a row. However, the frequency deviation of the numbers was very high (485), with number "0" appearing 388 times and number "6" appearing 873 times.



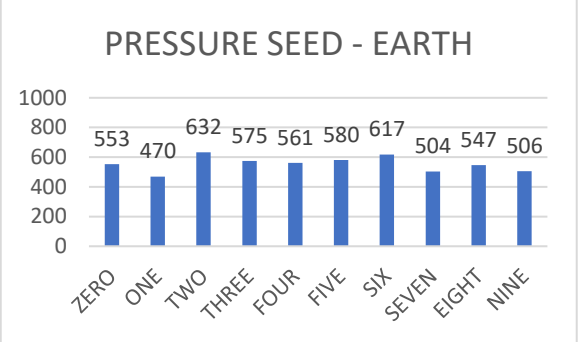

*1 Frequency of random numbers when Time was used as seed in Space.*



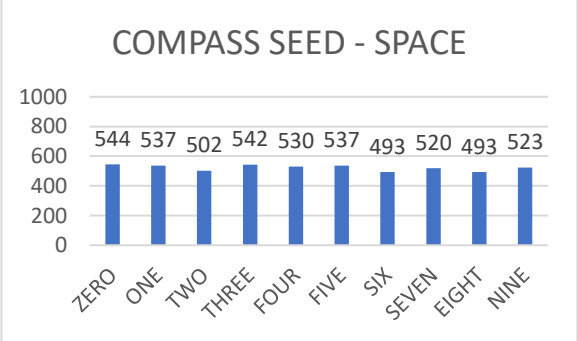

*2 Frequency of random numbers when Time was used as seed on Earth.*



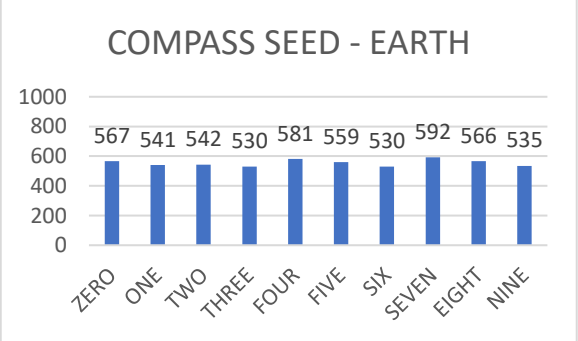

*3 Frequency of random numbers when Barometric Pressure was used as seed in Space.*



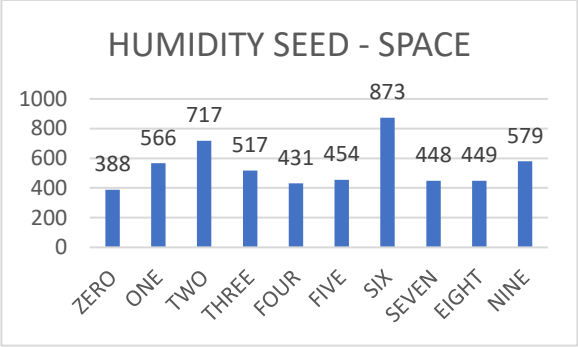

*4 Frequency of random numbers when Barometric Pressure was used as seed on Earth.*



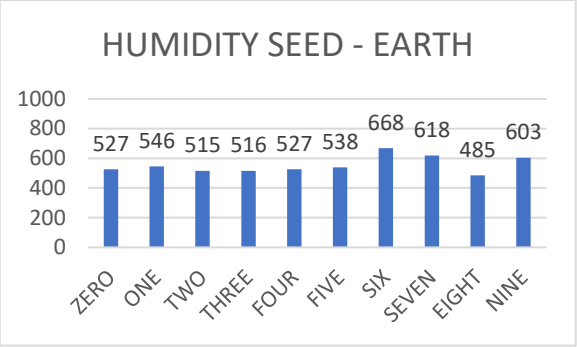

*5 Frequency of random numbers when direction of Magnetic North was used as seed in Space.*



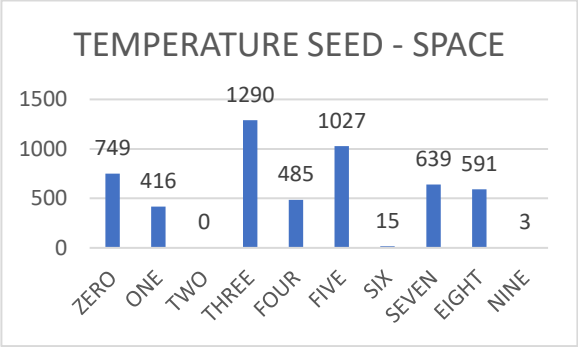

*6 Frequency of random numbers when direction of Magnetic North was used as seed on Earth.*



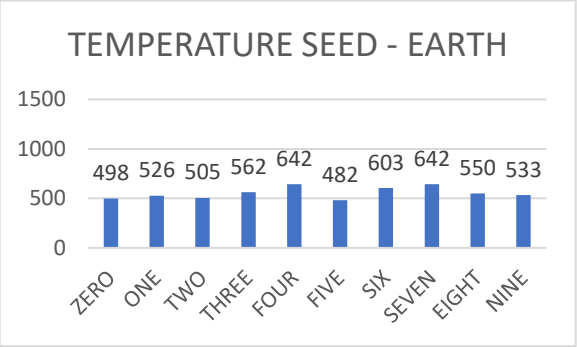

*7 Frequency of random numbers when Humidity was used as seed in Space.*




*8 Frequency of random numbers when Humidity was used as seed on Earth.*




*9 Frequency of random numbers when Temperature was used as seed in Space.*




*10 Frequency of random numbers when Temperature was used as seed on Earth.*

## Conclusion

As our main results show, RNG algorithms produce very "stable" results when they use as seed the value of Time (default seed in Python), not only when they run on Earth, but also, when they run in the controlled environment of the ISS. These sequences of random numbers are considered to be extremely hard to predict.

However, when it comes to using natural phenomena as seed to generate random data, our findings suggest that the values of Temperature and the level of Humidity do not constitute reliable sources of natural entropy, when measured in the environment of the ISS. We were able to find patterns and/or imbalances in the frequency that each number (0-9) appeared, making these sequences "more predictable" and hence "less random". We think that the controlled and relatively stable levels of Temperature and Humidity in the ISS affected the quality of these sequences.

We did not notice any statistical irregularities in sequences of random numbers produced using the values of Pressure and/or Compass as seed, both on Earth or in the ISS. As a matter of fact, the sequence of random numbers produced in Space, using the value of direction of the Magnetic North as seed, had the best randomness evaluation results, slightly better than the sequence produced on Earth, using Time as seed. As a restriction, and a parameter that may have affected some of our findings, it must be noted that the Magnetometer was not calibrated.