An Investigation into Deep-Space Communications and The Challenges Presented in Transmission

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1 Introduction

The ability to communicate and understand information is what separates man from beast and so its' importance to preserve information in an intelligble state has always been a primary mission of our species. This investigation will delve into what makes a 'good code' and takes a deeper look at how a simple binary message can traverse such great distances of the unknown. From this project's findings, an understanding will be achieved of the elements that challenge the transmission of interstellar communication, the trade-offs a code must make to accommodate the eery buzz of the universe.

The results from this investigation will provide invaluable research into the making of communication codes and will highlight both the history of the field as well as pave paths for deeper learning and improvement of current systems.

2 Project Aims and Objectives

2.1 Aim

Just last month, Voyager 1 elapsed its' 42nd year since launch and, at current (dated 9/10/2019), is a whopping 147.53 astronomical units, or, 13,713,694 miles away from Earth moving at an estimated velocity of 38,026 mph[1]. As our proficiency to explore deep-space evolves, so must the technology used to communicate media back to Earth. In fact, NASA predicts that our "deep space communications capability will need to grow by nearly a factor of 10 each of the next three decades"[2]. This research intends to investigate what makes a 'good code'[3] and to explore effects deep-space presents on communication channels by evaluating both the efficiency of coding information as well as the robustness needed to prevent interference.

2.2 Importance of Research

As humans, we are natural nomadics which gives us a strong curiosity to reach out to the unknown. Currently, the only capabilities we have of interacting with deep-space is through the transmission of media, and so it becomes apparent that our need to continue research in this field is vital. NASA states that overcoming obstacles presented to us in

[1] Voyager - Mission Status. Retrieved 9 October 2019, from https://voyager.jpl.nasa.gov/mission/status/

[2] Deep Space Communications | Science and Technology. (2019). Retrieved 9 October 2019, from https://scienceandtechnology.jpl.nasa.gov/research/research-topics-list/communications-computing-software/deep-space-communications

[3] Hill, R. (1986). A First Course in Coding Theory (1st ed.). Oxford: Clarendon Press.

deep-space provides huge benefits to society, noting space exploration as an "efficient driver for basic science and technology"[4]

Over the last few decades there has been a dramatic change-up in the 'space race'. Once previously fought amongst nations in a battle of pride and accomplishment, the industry now shifts towards a private sector as wealthy persons begin to join the fray. A prime example of this is Elon Musk's venture into SpaceX, a coperation he established in 2002 which boasts over 100 contracted launches[5], providing over 6000 jobs and bringing invaluable information back to Earth to give insight into our universe.

This ambition of space-exploration has produced further development in the deep-space communications field. Just as recently as 19th February, 2019, NASA unveiled its' drive to switch from radio waves to x-rays in deep-space data transmission[6]. In this reveal, NASA displayed its' new-found capabilities to communicate by sending x-ray signals from Earth to the International Space Station to communicate a binary message. NASA stated that a successful demonstration of these new communication techniques would "increase interest in the communications technology, which could permit more efficient gigabits-per-second data rates for deep space missions".

2.3 Objectives

- Explore the mathematical theory behind error-correcting codes and their role in deep-space communication.
- Investigating the challenges communicating through deep-space presents.
- Emulating difficulties faced in deep-space transmission upon communication channels.
- Test a range of coding schemes for their efficiency and robustness.
- Evaluation of what it means to make a 'good code'.
- Proposal of future development within the field of interstellar communication.

[4]International Space Exploration Coordination Group. (2013). Benefits Stemming from Space Exploration [Ebook] (p. Page 3).

[5]SpaceX. Retrieved 10 October 2019, from https://www.spacex.com/about

[6]NASA Set to Demonstrate X-ray Communications in Space. (2019). Retrieved 10 October 2019, from https://www.nasa.gov/feature/goddard/2019/nasa-set-to-demonstrate-x-ray-communications-in-space

2.4 Deliverables

This project plans to give insight into what makes a 'good code', which is to say, to what limits are transmission of codes constrained by and what steps can be taken to overcome them? Research will give insight into the qualities needed for successful data transmission through deep-space which will be emulated through reconstructing the deep-space environment on audio channels. These channels will be used to test messages holding various, different properties to find a code suitable for deep-space communication. Results of this project will emphasise the mathematical theory associated with creating 'good code' and explore the dilemmas faced when transmitting data across an unreliable medium.

3 Preliminary Word

3.1 Data Collection

Data will be received from an emulation of transmitting reliable communications through an unreliable medium. The success of transmission will be measured and a link between the properties of that message, valued against the limitations of the channel, will be compared to the success rate. These results will support the mathematical theories present in long-distance data transmission and help to build an understanding of coding theory and its applications.

3.2 Reading

Initially, reading will be done in areas surrounding Coding Theory. A particularly useful resource is 'A First Course in Coding Theory' by Raymond Hill (1986) which sets the stage for this project. The book delves into what makes a 'good code' and provides mathematical proofs to support its' reasoning. Having this resource available is extremely invaluable, however, its depth will not suffice on its' own and so a few other notable resources will be read to accommodate the understanding of the subject. These will include: 'Coding and Information Theory' by Richard W. Hamming (1986); 'Coding Theory - A First Course' by San Ling and Chaoping Xing; and 'Introduction to Coding Theory Lecture Notes' by Yehuda Lindell at Bar-Ilan University, Israel.

Another area to be explored after establishing what makes a 'good code' is the environment of deep-space. Reading centred around the harsh landscape of deep-space will help to decipher the issues transmitting across deep-space presents. A great way of receiving this information is through NASA who provides numerous articles and journals based on the conditions of space.

3.3 Additional Resources

There are a whole host of space-enthusiatic communities spread across the internet whose discussions could prove useful in discovering the modern-day challenges that data transmission must overcome. Specifically, forums such as the 'NASA Spaceflight Forums'[7], Reddit and a plethora of different websites all dedicated to the discussion.

Another fantastic hub of information is YouTube. YouTube provides simple explanation with easy-to-understand visual representation of key concepts. Furthermore, coding implementation of this project will access tutorials hosted on YouTube (and other online resources) to gain a deeper understanding of the implementation details needed to produce correct and sound results for this project's dataset.

However, it is incorrect to assume that any of the aforementioned resources are reliable, trustworthy resources and so will be taken with a 'pinch of salt'. What the resources will do is map out a path for areas of deeper learning by establishing popular concepts, theories and ideas already prevelant within the field.

4 Development Approach

This project will incorporate the philosophies of Agile development by breaking each task down into sprints with reviews at the end of each sprint (each sprint will be recorded on: https://trello.com/en). The idea behind this is that the project, at current, has much room for deeper understanding and greater development which Agile provides the flexibility needed to meet the requirements. However, the project will not necessarily follow a framework as this project only involves one member.

5 Risks

5.1 Dataset

- Problem: Data will only be collected by one person on a self-designed system.
- Solution: To have the development of the system peer-reviewed and collect enough results such that erroneous results are minimal.
- Problem: Replicating the ever-changing conditions of deep-space may be inaccurate compared to reality.
- Solution: To host a large number of channels all exposing different conditions of space such that each basis is covered in this investigation.

[7]NASASpaceFlight.com Forum. Retrieved 11 October 2019, from https://forum.nasaspaceflight.com/

5.2 Challenges of Topic

- Problem: Discoveries and investigations into deep-space communications is an ever-changing field with a host of experts in the field discovering new findings rapidly that the project's author may lag behind.
- Solution: To keep up-to-date with the topic, connect with peers interested in discussion and to follow news related to space and communications.
- Problem: Being able to implement and test new areas of the field such as NASA's switch from radio wave communications to x-ray communications may prove impossible due to the financial restrictions of this project.
- Solution: To explore any datasets produced by space engineers involving new communications techniques and try to form a comparison based upon this project's result set.

5.3 External Limitations

- Problem: Due to the current political climate surrounding the U.K. it is uncertain as to affect this has on academic research and this project's future.
- Solution: To stay current with political news and potential laws and regulations that may be coming into place post-brexit.
- Problem: Author is constraint with time on this project and so only so much depth can be achieved.
- Solution: To ensure correct time-management throughout the year such that 13 hours or more a week is put into the effort of this project.

6 Milestones

- Explore key concepts associated with deep-space communications.
- Review revered literature within the field to form sound conclusions on the topic.
- Test the transmission of messages through unreliable channels.
- Evaluate the strengths and weaknesses of codes.
- Arrive at sound conclusions dependent on the results of the investigation.
- Present ideas and concepts in a well-formulated report and presentation.

7 Schedule

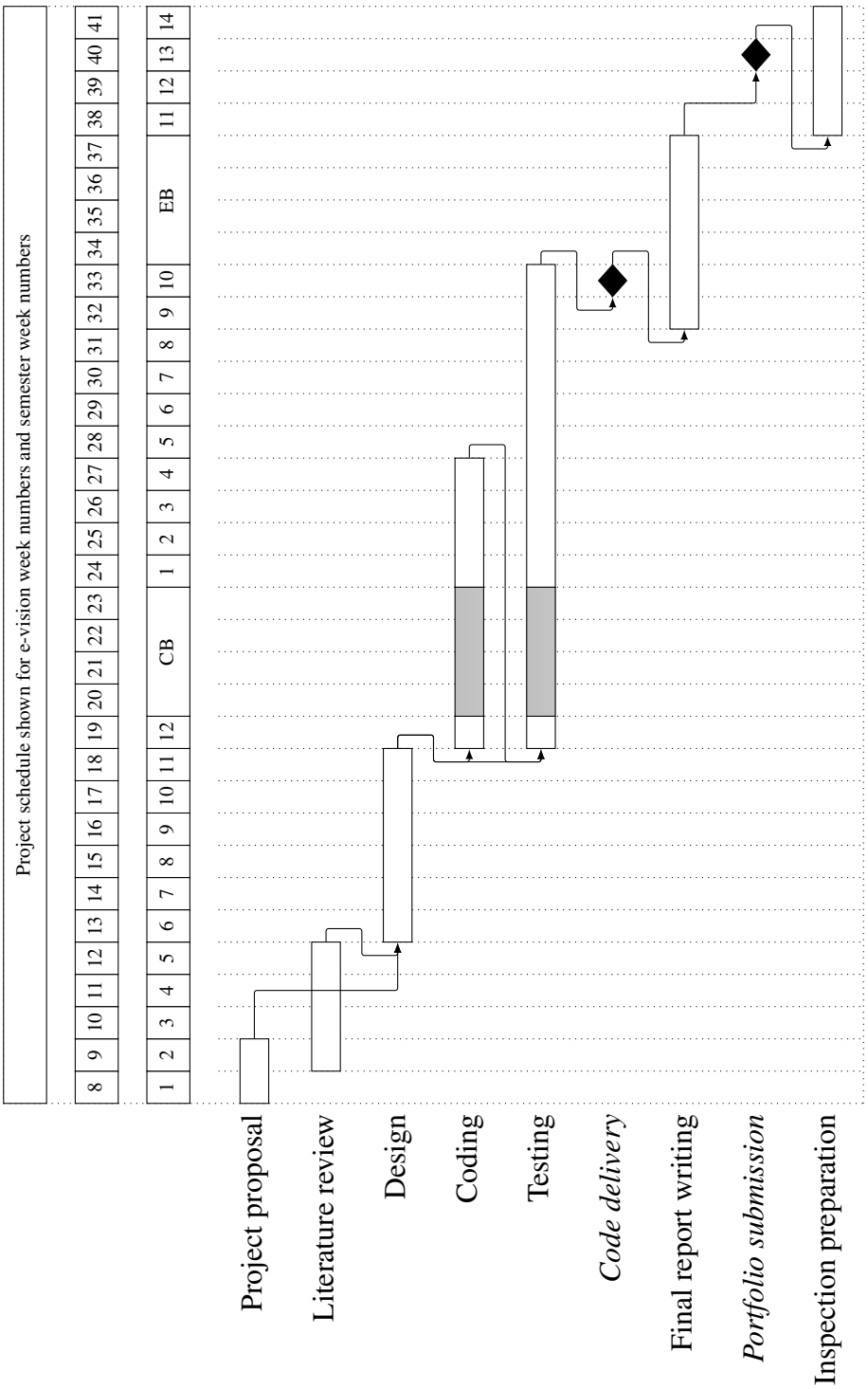

Figure 1: Project Gantt chart

Project proposal

Description of project: aims, motivation, understanding of issues, problems	First	2.1	2.2	3	Fail
Resources, references: evidence of preliminary work to identify key resources, initial reading	First	2.1	2.2	3	Fail
Proposed approaches: relevance, suitability, appropriateness	First	2.1	2.2	3	Fail
Risks: identification, suitable contingency planning	First	2.1	2.2	3	Fail

Quality of writing

Clarity, structure correctness of writing	First	2.1	2.2	3	Fail
Presentation conforms to style	First	2.1	2.2	3	Fail

Workplan

Measurable objectives : appropriate, realistic, timely	First	2.1	2.2	3	Fail
Gantt chart: legibility, clarity, feasibility of schedule	First	2.1	2.2	3	Fail

Comments

Supervisor: Dr. Christopher Greenman

Markers should circle the appropriate level of performance in each section. Report and evaluation sheet should be collected by the student from the supervisor.