**Memorandum 1**

**From:** Justin Pajak, Patrick Creaven, Carter Goldman, Raytheon Preternship Team

**To:** Dr. Matthew Morrison, Assistant Teaching Professor, Department of Computer Science and Engineering, University of Notre Dame

**CC:** John Mallinger, Deputy Chief Engineer, Next Gen GPS Ground System, Raytheon Technologies

Below is an overview of what we have done so far with the project, and our plans for the future.

**What were the goals for this week?**

1. Schedule an interview with Mr. John Mallinger from Raytheon Technologies
2. Conduct research on satellites and latency and create interview questions
3. Complete the interview and establish future meetings with Mr. Mallinger

**What was accomplished this week?**

We conducted two separate interviews with John Mallinger which are described below.

During our first interview on 10/14, Mr. Mallinger proposed a group of potential projects that we could do. This slightly offset our interview plan and the way we were going to ask our questions. After performing more research on his proposed potential projects, we decided on a project that would model the latency of communications between ground stations and satellites over the course of their orbit. We then conducted a more structured second interview with Mr. Mallinger on 10/18 that allowed us to hone in on what our final project will entail.

The first question of the interview was regarding how we were going to define latency. In a real-world scenario, the bandwidth and the speed at which data is transferred between two nodes plays a small role in the latency of communication. We inquired whether we should include a calculation of that in our overall latency calculation. Mr. Mallinger said that we should just assume that the delay from bandwidth is negligible and to simplify the situation by assuming a fixed value for that part of latency.

Our second question asked: “If the size of the data packets being transferred from a satellite to a ground location has an impact on the latency time, what approach would you recommend using to represent that data in a data structure?” Since Mr. Mallinger stated that we will be simplifying the project so that the size of the data will not be considered, this question became irrelevant in context.

In our next question, we asked if the ground station “source” and “sink” should be assumed to be the same in our calculations. Mr. Mallinger said that, in the beginning to simplify our minimum viable product, we could assume the ground station sending and receiving communication from the satellite is the same. After we get that working, we can look into latency calculations where the source and sink ground stations are different, adding another variable to the equation.

In our next question, we asked about the logistics of programming and how we should represent the parameters of satellites and ground stations. We proposed creating classes that would encompass the basic parameters unique to satellites and ground stations that we could then use to better model interactions. Mr. Mallinger said that this is the same approach he would take, and he suggested creating those and then using other data structures to model the interactions. We followed up by asking if a graph-type data structure where we represent the satellites and ground stations as nodes and the distance/latency between them as the edges would work for modeling the interactions, and Mr. Mallinger agreed that this would be a viable option.

For our next question, we asked about the scope of the overall project. We realized that modeling the latency in a one satellite, one ground station system would not be ambitious enough to fill our month-long project timespan, so we inquired about adding more details to make the project more challenging. Mr. Mallinger suggested that we begin by modeling the one-to-one interaction, then we can expand our horizons by making our project model more realistic communication latency. For example, we could take into account the aforementioned separate source and sink ground stations. We could also model the latency of intersatellite communications with a larger constellation of satellites, with information originating from one ground station, traveling between a number of satellites in a constellation, then ending up at a separate destination somewhere around the world.

Another question we asked was about some of the terminology Mr. Mallinger had used in one of his emails he sent to us. In his most recent email, he stated that we should consider the distance between the ground site and the satellite over the course of its orbit, specifically when a satellite enters and leaves the “visibility” of the ground site. He clarified this statement by saying that “visibility” is in reference to when the satellite passes the horizon of the ground station visible by an observer on the ground. He also stated that he should recognize that latency changes as it passees overhead a ground station.

In our next question we asked if we would assume that we are working with a LEO (Low Earth Orbit) satellite because we want to calculate the latency of communication between a satellite and a ground station as it is moving across the sky? Would a GEO satellite be the wrong choice of satellite? Mr. Mallinger then answered saying that an LEO is more challenging and to start with a GEO, and if we want to challenge and expand the project scope then to move onto an LEO.

In our next question we asked about the usefulness of either a circular or elliptical orbit within the scope of our project, since elliptical orbits, as stated in the “LEO Satellite Communication Networks” paper, are specifically adept at providing coverage for a targeted area. Mr. Mallinger went on to explain that highly elliptical orbits are a shortcut companies use who do not have a large GEO constellation, and that there are most likely too many variants to take into account for the scope of our project.

For the last question, we asked if the purpose of having multiple satellites in a constellation was to allow cross-world communication? If that is the case, is it pointless to have multiple satellites in close proximity to each other? Mr. Mallinger responded saying that the constellations in their final positions are meant to optimize coverage across the entirety of the globe.

**Goals for next week**

1. Conduct further research on communication latency and satellite distance calculations
2. Create the framework for representing the parameters of satellites and ground stations
   1. Build basic class structure for both the satellite and ground station
   2. Create a preliminary link between the two

**Critical dependencies, open problems, or other things to be aware of for next week?**

1. Before we begin coding, we have to fully flush out our project plan by mapping out the flow of our code and the data structures we will implement.

**How many hours were spent on each goal noted above?**

1. Justin Pajak - 3 hours
2. Patrick Creaven - 3 hours
3. Carter Goldman - 3 hours

Very Respectfully,

Justin Pajak

Patrick Creaven

Carter Goldman

Raytheon Preternship Team

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