ASTERIA

Final Report
Android Application Project

Seung Yun Choi (Susan): 997392343
Arjun Subramanian: 1001048895
Jirapat Likitlersuang (Earth): 997279127

April 10, 2014

This document contains 1997 words count for content and 436 words count for apper context section.
This document is also attached alongside with video demo presentation and source code.
- We agree to post our video presentation and source code to public.

Table of Contents

ASTERIA

1.0 Introduction

As a satellite operator at Space Flight Laboratory at University of Toronto Institute for Aerospace Studies, the Apper is heavily involved with the operation of BRITE-Constellation mission. BRITE-Constellation satellites observe the brightness and temperature variations of the star within a set time period. Since we would like to improve the performance of the satellite with more scientific data, observing multiple stars per orbit is considered as a part of the operation plan. Currently, the satellite is observing a target star by fixing its orientation in space. For some portion of the orbit, the first target will be blocked by the earth, but changing the orientation of the satellite to observe a second target will allow for more data to be collected per orbit (figure 1).

The location in space where the satellite is pointing can be determined by a time and space independent coordinate system, specifically the quaternion coordinate system. If the satellite is pointing at the targeted star, usually located several light years from the Earth, then its quaternion coordinates are fixed to that star.

When the satellite is taking its transition path, there are a few things that the operators have to keep in mind. First of all, we would like to avoid the telescope facing the sunlight as it may be damaging its sensors. In addition, estimating the distance and time it takes to transit is necessary to avoid the transition time overlapping with the target visibility window. We would like to be ready to observe the star whenever it is visible by the satellite.

To check this transition path, the operators often use desktop simulation software, but the software requires many inputs and is not very intuitive to use. Also, the Apper was thinking that it would be better to have a physical object which can represent the satellite so that the operators can communicate easily by rotating and moving the physical object around.

From there, the idea of a mobile application Asteria which can show the transition path that the satellite is taking came along. Since the only side on the satellite that we care about is where the telescope and instruments are mounted, we can model the satellite as analogous to a regular phone with a camera (figure 2) so that the phone camera's orientation is the same as the telescope's orientation on board of the satellite in space.

2.0 Overall Design

2.1 Background, challenge and rational of Functionality

In order to satisfy the requirement given in the introduction, an Android application was created that involves three main functionalities that will best suit to the satellite operator.
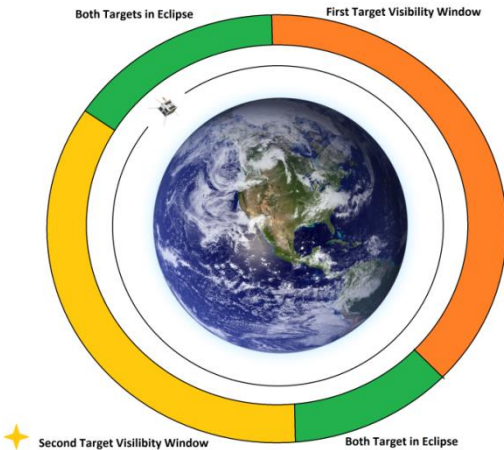
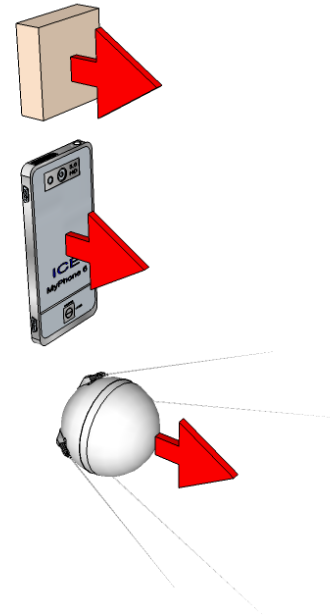**Figure 1**: Visibility windows for two targets in one orbit

Figure 2: Model the satellite as analogous to a regular phone with a camera

2.1.1 Current Quaternion: Display the current coordinates of the phone's orientation

When describing the point of view on the Earth, a compass bearing (Azimuth) and the angular measurement from the ground up (Altitude) can be used, commonly called the Horizontal Coordinate System (figure 3) [1]. However, because the satellite operates at the highest atmospheric layer of the Earth this coordinate system cannot be used as the magnetic bearing changes based on the orbit of the satellite and since there is no horizon, altitude cannot be described. For this reason, the operator must use a fixed coordinate system that is based on a fixed origin of space and is time invariant for describing the point of view of the satellite. The Equatorial Coordinate System assumes a fundamental plane that is aligned with the Earth's equator and pole, which does not rotate with the Earth, but remains fixed against the background stars. This coordinate system has a unit of Declination (DEC), angular distance (in degrees) of an object perpendicular to the equator, and Right Ascension (RA), angular distance (in degrees) of an object eastward along the celestial equator from the vernal equinox. The vernal equinox is the point where the sun is at the centre between North and South Pole (this happens on March 21 of each year) (figure 4) [1]. Satellite operators however use a slightly similar coordinate system called Quaternion Coordinate System. This is similar to RA/DEC but instead describes the position as a unit vector (figure 5) [2]. In this project, the quaternion is our main coordinate system as it is the operator's choice.

In this function, the application reports the quaternion coordinates in real time wherever the phone is pointing. Since the quaternion assumes a fixed origin in space, it will change with time when viewed from the Earth as the earth rotates around the sun. This real-time coordinate reporter will help the operator visualize and understand the coordinates better.
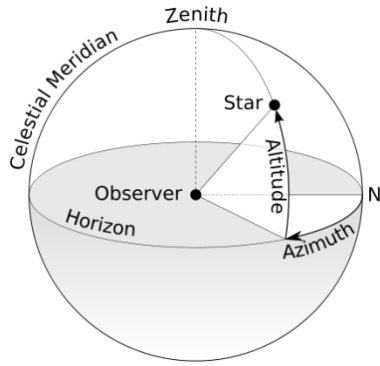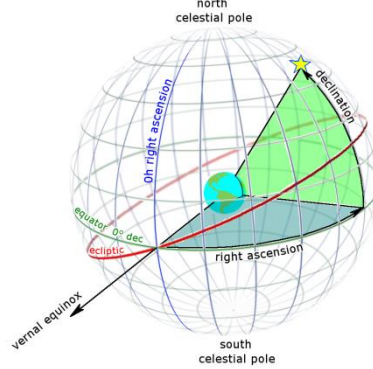
Figure 3: Horizontal
Coordinate System

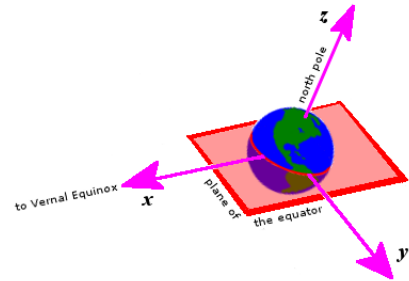**Figure 4**: Equatorial
Coordinate System

Figure 5: Quaternion
Coordinate System

2.1.2 Find Quaternion: Guide user to point to any input coordinates using directional clues

The goal of this function is to allow the operator to point to input coordinates via a guided directional clue. To do this, the phone must be able to convert quaternion inputs into the horizontal coordinate system that the sensor of the phone reports in (see section 2.1.1). In order to know the transition of the satellite, the operator will have to first enter the current coordinates that the satellite points towards and navigate to that point. Afterward, they then enter the coordinates that they wish the satellite to face towards. Thus seeing the initial point of view and the intended point of view will allow operator to visualize the transition path that the satellite has to take to point to the intended region in space (figure 6).
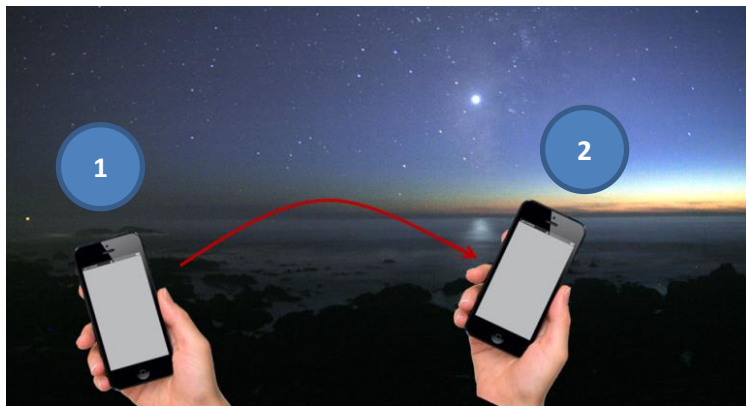
Figure 6: Transition path of the satellite base on two coordinates region

2.1.3 Find Star: Guide user to point to a selected list of stars

In order for the satellite operator to point the phone to the intended star in space they must know the coordinates inputs of the region. Since these coordinates have a fixed origin, each star will have a specific constant coordinates input associated. Therefore, it makes sense to provide the operator with a database of the list of the common stars and the system will guide them to that region containing the star.

2.2 Block Diagram: How it works?

Figure 7: Block diagram that describes how the application works

2.2.1 Current Quaternion (Figure 7 – Path 1)

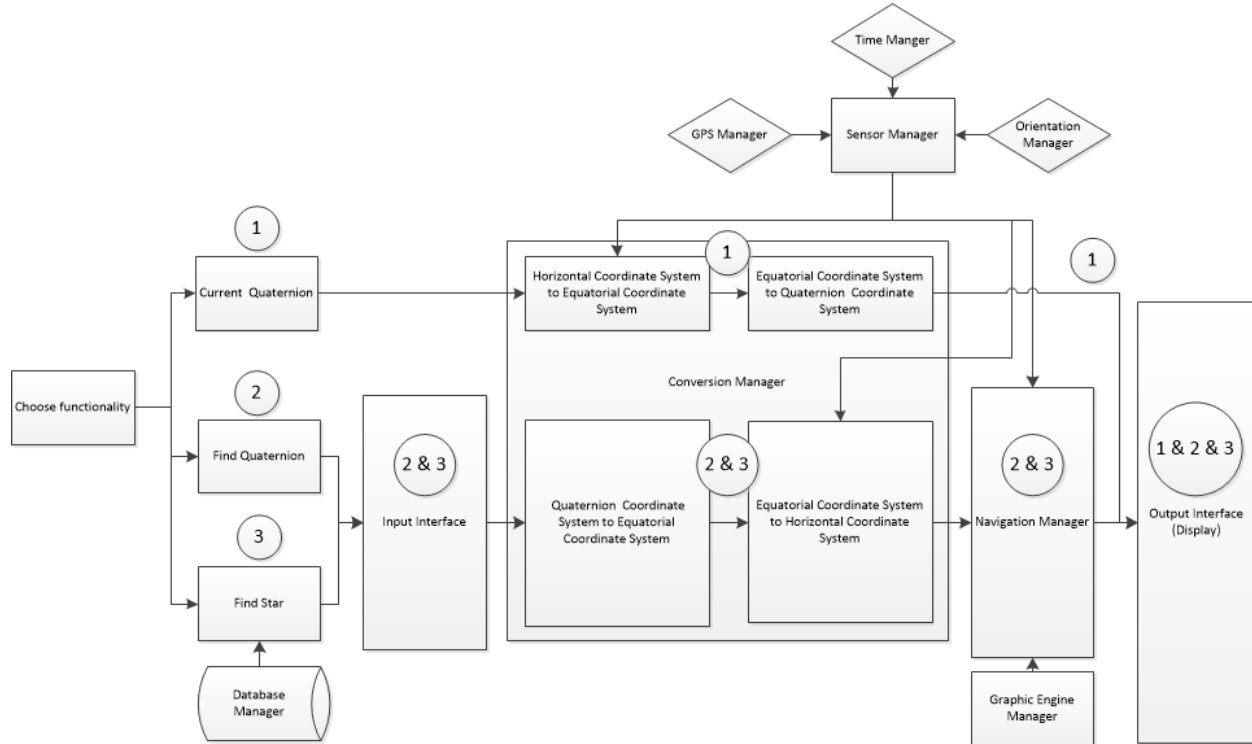When satellite operator selects "Current Quaternion", the system would first get the current horizontal coordinate (i.e. Azimuth/Altitude) from the orientation manager; after which it is converted to equatorial coordinate by using GPS and Time manager, and this is because equatorial coordinate (i.e. RA/DEC) assumes that the Earth is fixed against the background stars. In another word, the GPS and Time manager is used to account for the current position of view point on earth and earth's rotation, so that it is fixed with the fundamental plane used in the equatorial coordinate (see section 2.1.1). After this, the equatorial coordinate is then converted to quaternion coordinate, which is displayed on the screen.

2.2.2 Find Quaternion (Figure 7 – Path 2)

When selecting "Find Quaternion", the system will go into the input interface where user can enter a desired quaternion coordinate. After the input, the system then converts quaternion coordinate to the equatorial coordinate, in which it then will be converted to horizontal coordinate. Similar to converting horizontal coordinate to equatorial coordinate in path 1, GPS and Time manager is used this time to rotate and adjust the point of view to the current view from earth. The converted input of horizontal coordinate is then compared with the current horizontal coordinate reported by the orientation manager. Then the navigation manager generates a directional clue on screen.

2.2.3 Find Star (Figure 7 – Path 3)

Operators simply pick the star in the input interface and the system will load the quaternion of that star to the conversion manager and navigation manager before displaying directional clue, similar to path 2.

3.0 Statement of Functionality & Screenshots from Application

3.1 Current Quaternion

This functionality allows the operator to read the coordinate values for the point in space where the phone is currently pointing in real time. The user also has an option to view coordinate system in quaternion or RA/DEC.
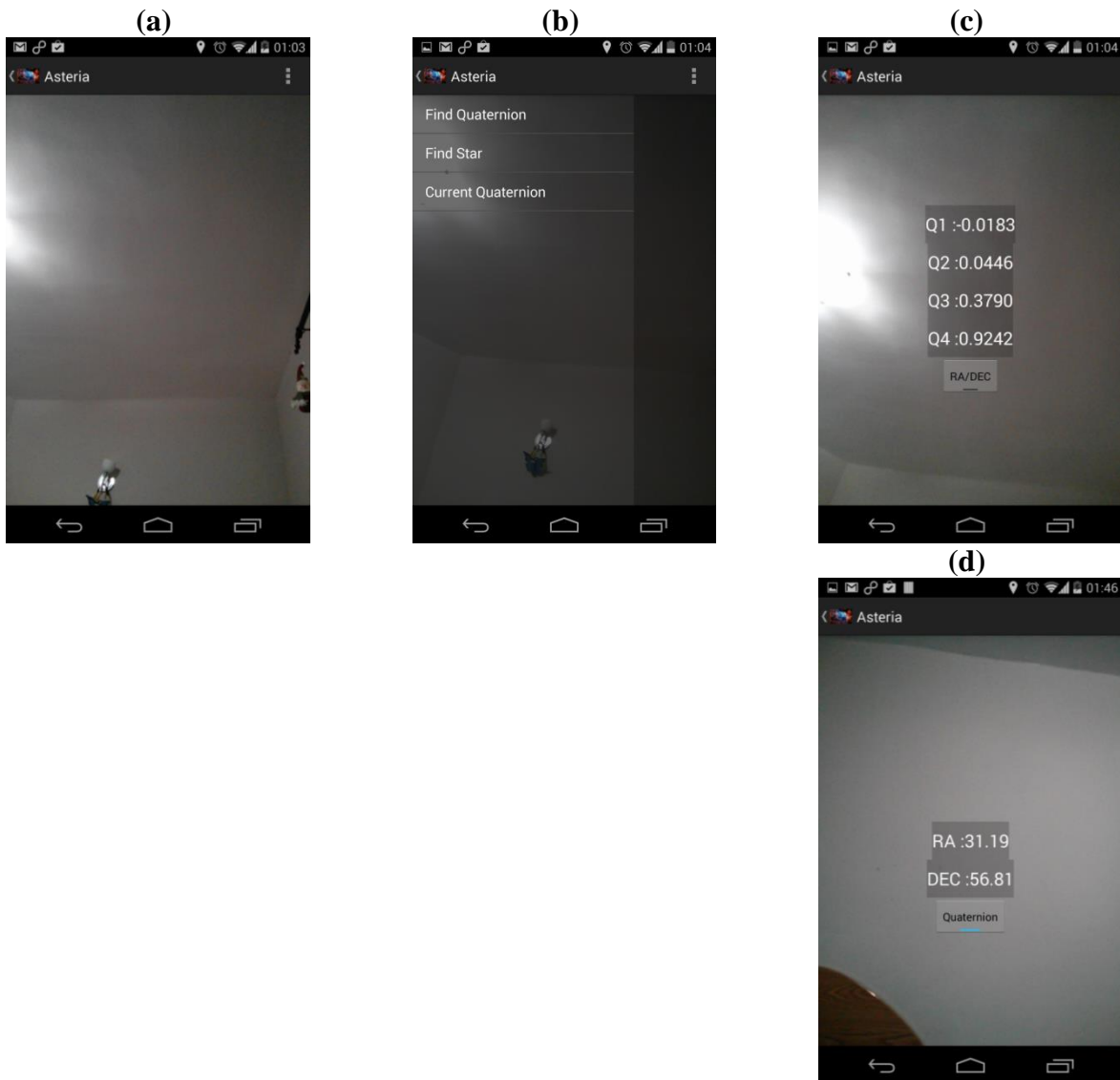
(a)

(b)

(c)

(d)

Figure 8: Screenshot of Current Quaternion function

- Figure 8a & 8b: The user selects the option to view the "Current Quaternion"
- Figure 8c: The screen displays coordinates values for the point where the phone is currently pointing at in Quaternion.
- Figure 8d: On Clicking the "RA/DEC" switch the user can view coordinates in RA/DEC

3.2 Find Quaternion

This functionality allows the user to input a valid quaternion coordinate values and navigate to the respective locations. A navigational clue (on-screen triangle) which would guide the user to the location corresponding to the input values, and once there it is replaced by a circle with vibrational feedback. As mentioned in section 2.1.2, when operator wants to find the transition path of the satellite they will first enter the current quaternion that the satellite is facing, navigate to that region, and then enter the target quaternion they wish to go for visualizing the transition path.
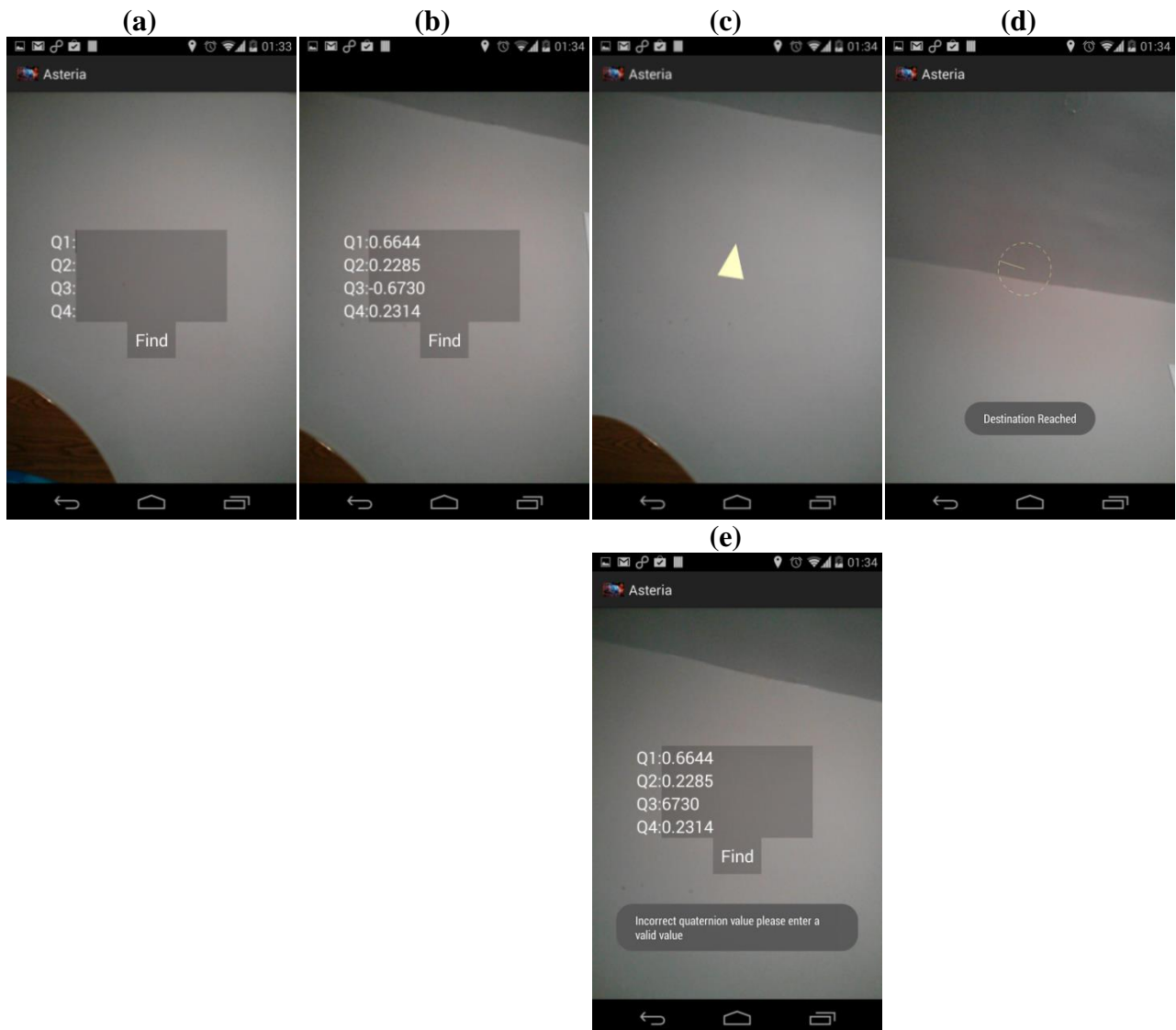

Figure 9: Screen shot of Find Quaternion function

- Figure 8b: User selects "Find Quaternion option"
- Figure 9a & 9b: Keys in the input values
- Figure 9c & 9d: On screen Navigational clue guides the user to the required location
- Figure 9e: The validity of the input value is check in the background. In case of invalid, user would be prompted to verify the input values.

3.3 Find Star

This functionality displays a list of commonly used stars. The user can select a star from this list and navigate to that star with the help of a navigational clue.
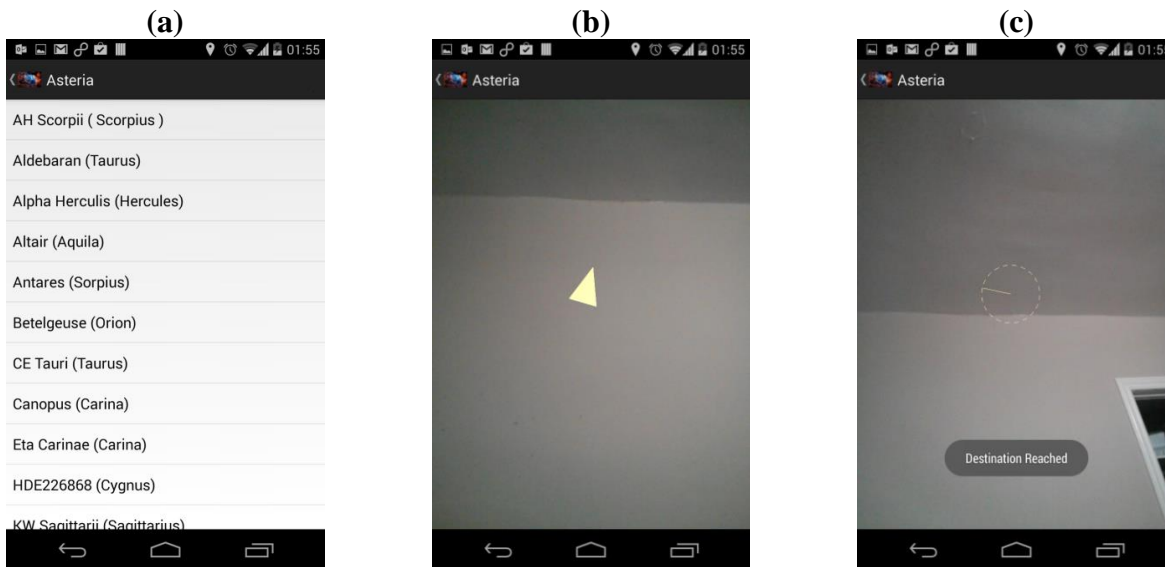

Figure 10: Screen shot of Find star function

- Figure 8b: User selects "Find Star" option
- Figure 10a: Select a star
- Figure 10b &10c: On screen Navigational clue guides the user to the required location

4.0 What did you learn - what would you do differently?

4.1 Celestial coordinate system

Other than teamwork, one of the most important things we learned is how the celestial coordinate system works for locating stars. The key learning includes the mathematics that account for coordinate conversion, the time zone which accounts for earth's rotation, and point of view of each of the viewing locations.

4.2 Android Compass

The major inaccuracy in this application is most likely to come from the error in compass reading. Google did not provide a reliable accuracy from these devices, or a method to determine

if the accuracy is reliable. Since our application relies heavily on the sensor, this is the largest limitation within our application. Nevertheless, there many third party developers, including Apple (figure 11) that implement some kind of calibration method which may be used.
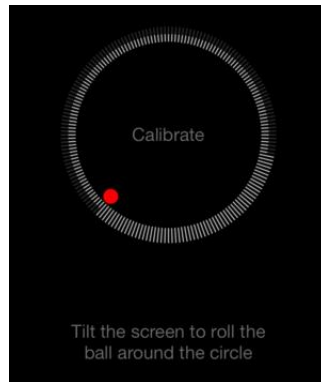

Figure 11: Apple's iPhone and iPad Calibrating Compass method

4.3 Graphics

As part of the functionality, the operator is guided to the input coordinates via a directional clue (figure 9c, 9d, 10b & 10c). This currently includes an arrow and circle that are being programmatically drawn overlaying the camera feed. Due to limitations of the Open Graphic Language (OPEN GL), the directional clue can sometimes be hard to follow which may require further research.

5.0 Contribution by Group Members

5.1 Choi – Apper

- Concept and Design
  - o Consult with the staff at the Space flight laboratory for mobile application idea
  - o Design functionality of the application, including setting scope of the project
  - o Design draft User Interface of the applications
- Celestial Coordinate System
  - o Learn how to locate the star from the ground
  - o Find star based on the given coordinates
- Mathematical formula for coordinates conversion
  - o MATLAB code for coordinates conversions (horizontal, equatorial and quaternion)

5.2 Subramanian – Programmer

- User Interface
  - o Implementing user interface design on Android application
  - o Implement graphics for the interactive screen of the application
- Integration of Application
  - o Camera feed

- o GPS sensor manager
- Graphical Interface
  - o Implement graphical engine interface for design and control of navigational clue and system

5.3 Likitlersuang – Programmer

- Orientation Manager
  - o Create an orientation class including yaw, pitch and row of the phone
- Mathematical java
  - o Implement all the mathematical functions from MATLAB to java
- Testing
  - o Using Stellarium Software to test the application
- Database
  - o Implementation of database

6.0 Apper Projects: Apper Context

As the Asteria has three functionalities, which shows the current quaternion of where the mobile phone is pointing at in space and the navigation of a given quaternion and the star name, it can benefit the satellite operators at Space Flight Laboratory at University of Toronto through the following:

6.1 Training new operator

As only a few people who are involved with space missions and astronomical research are familiar with the quaternion coordinate system, having a mobile application which reports the current quaternion of the phone will help them get familiar with the coordinate system and make it easier to visualize how the coordinates work. Since the quaternion displayed on the screen is the actual coordinates of the phone's orientation in space, and the ground location on the Earth has been taken into account through the GPS sensor, the new operator can be trained with consistent and critical thinking of where the star is relative to the Earth.

6.2 Seeing the transition path easily

By visualizing the transition path of the satellite through a physical mobile phone which is modelled after the satellite as explained earlier, it will be much easier to communicate with other satellite operators as well as being aware of the sunlight coming along in the view of telescope. As the Earth rotates around the Sun, the quaternion of the Sun will change, but it is pretty much consistent over a few weeks or so as the deviation of the Earth's position relative to the Sun is minor in a few weeks. Therefore, checking whether the Sun's quaternion comes into a view while the operator is navigating the second target from the first target through Asteria will be very helpful to keep the telescope away from the sunlight.

6.3 Easier to investigate the feasibility of the new target in selection process.

As mentioned above about how the observation of multiple targets would work in the previous introduction section, investigating the visibility window of possible target stars is included in the selection process. For example, if the second target is not too far from the first target, then their visibility windows overlap significantly to each other so that both of the targets are in eclipse at the same time. This can waste the rest of orbit period (figure 12). By using the mobile application which shows the transition path that the satellite has to take to move on to the second target, the operator can estimate the distance between the two targets so that it will be a good sanity check if their visibility window overlaps significantly or not.
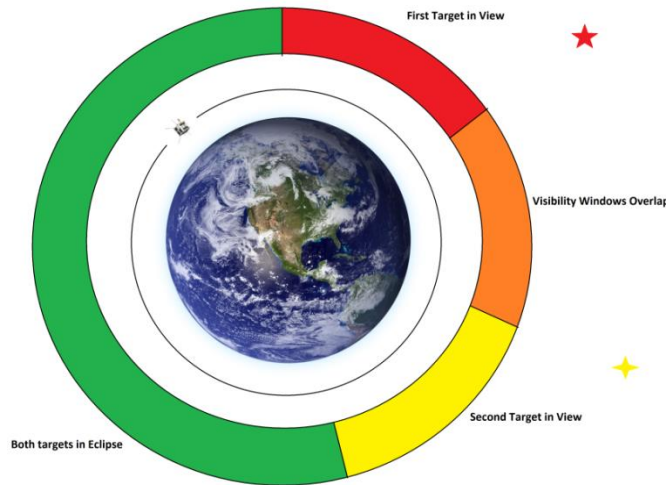

Figure 12: Overlapped visibility windows for two near targets

7.0 Future Work

7.1 Augmented Reality

Implement a star map alongside of the camera feed of the surrounding star in the area. This will help operator to see the overall constellation, as sometimes the operator will require the satellite to face the overall constellation (figure 13).
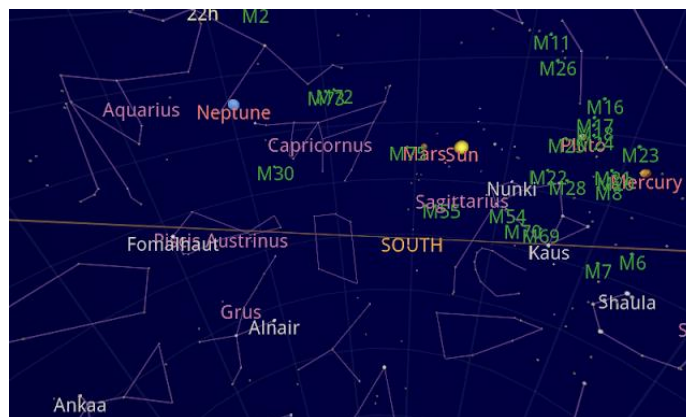

Figure 13: Example of star map in Google sky map application [3]

7.2 Cloud database to allow admin to update the star database from the cloud

Currently the database list of stars is based on the internal database of the phone. Given more time we would implement a cloud system database that allows the administrator of the application to update the star database with more coordinates.

7.3 Implement more coordinate systems

There are other coordinate systems that describe the position of the star based on the fixed origin system. Coordinate systems, such as RA/DEC, are often used by astronomers and hobbyists used to describe the location of the star in the sky.

7.4 Search field for star database

Allow user to keyword search in the database of stars, constellations, and other celestial bodies, instead of having to select from the list.

8.0 References

[1] B. L. Adams, F. George and M. Kagle, Star navigation: explorations into angles and measurement, Edmonton: Brush Education, 2006.

[2] J. R. Wertz, D. F. Everett and J. J. Puschell, Space Mission Engineering: The New SMAD, New York: Microcosm Press, 2011.

[3] "Stardroid: Sky Map open source project.," Google, 2014. [Online]. Available: https://code.google.com/p/stardroid/. [Accessed 10 April 2014].