StarTrack

Rebecca Baturin, EE, Christopher Boyle, CSE, Charles Urbanowski, EE, and Daniel Willmott, EE

***Abstract* — Even despite the banality of everyday life, the splendor of starlight and the space beyond continues to dazzle and inspire people of all kinds of origins. In order to aid the sense of discovery amongst astronomy enthusiasts and photography hobbyists alike, the StarTrack guided mount will allow users to track astronomical objects while maintaining the high standards of quality for a photograph. The system is composed of two accessories: a user-interfacing application and a mount for the user's DSLR camera. The mobile application provides the user access to a database of celestial objects to track and will also be able to wirelessly send tracking directions to the corresponding mount. The mount itself incorporates four powered motors to adjust the exposure angle of the camera in order to ensure the celestial object remains in clear focus during the length of several extended exposures. At the conclusion of each session, the user will be presented with several images of their specified object. While the individual images may not be notable in their own right, they form a distinctly focused and noise-free photograph when the images are stacked together.**

I. Introduction

ASTROPHOTOGRAPHY is the term for pictures of space. The night sky contains a multitude of celestial objects unseen to the naked eye even in rural settings. With long exposures of the night sky, it is possible to capture images of stars, constellations, and galaxies. Taking long exposure pictures of moving objects presents an inherent problem: after a 5 minute exposure any light captured will have moved, creating streaks of light instead of sharp images. In order to cancel out the movement of the earth, the camera must rotate at the same rate. This approximation of the Earth's angular rotation proves difficult without a mechanical system to compensate.

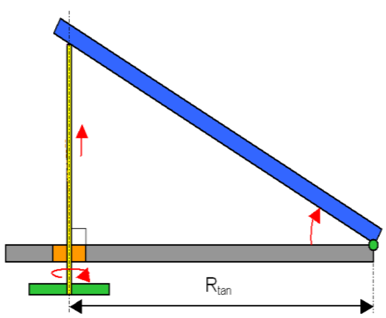
The biggest influence in low cost astrophotography, and the most popular tool for newcomers to the field is the barn door mount shown in Figure 1. First introduced by George Haig in the April 1975 edition of *Sky & Telescope* magazine [1], this mount replaces the mechanical motion of an equatorial mechanical mount with a manual or hand crank system for rotating at the same rate of rotation as the earth. The results, while good, require constant attendance and are frequently much less accurate than expensive solutions due to human error.

Our goal is that StarTrack will be cheap and effective way to allow people to discover astronomy. A beginner can take a camera they already own and use our mount to take beautiful images of the sky with little prior knowledge or expense. It is not our intent to replace a telescope that performs the same function but to provide and even lower entry point by using equipment someone will already have access to.

The inspiration for automating a barn door mount came from our team member Rebecca Baturin's coworkers during her co-op with NASA at the Kennedy Space Center. Unsurprisingly, many of the engineers there are both hobbyists and amateur astrophotography enthusiasts. Many had built barn door trackers themselves, but were dissatisfied with the quality of the images being produced. Another issue they found with this manual process was the need to be continuously outside with the mosquitos and Florida heat for 45 minutes to take a succession of exposures. They envisioned an automated barn door tracker as portable, easy to use, and above all accurate, and from there StarTrack was born.

Our next step in the research and design phase was to investigate the capabilities of currently available mounts. Astrophotography mounts and trackers come in all shapes and sizes: from Celestron's Nexstar 8SE Computerized Telescope [2], to Orion's StarBlast AutoTracker Altazimuth Mount [3]. These mounts allow users to take pictures of celestial objects while automatically tracking objects in the night sky. Additionally with optional components such as the Orion Atlas/Sirius Computerized GoTo Hand Controller [4], these devices have the potential to locate celestial objects with minimal input from the user. While the capabilities of these mounts are impressive, these features ultimately come at a price. Celestron's computerized telescopes regularly range from $449-$1199, while Orion's StarBlast AutoTracker with GoTo Hand Controller cost $599.98 together (the respective devices cost $199.99 and $399.99 separately). While these costs might seem trivial to astrophotography enthusiasts and professionals, they may seem daunting to hobbyists and newcomers alike.

Figure 1: Barndoor Tracker Mount



(http://commons.wikimedia.org/wiki/File:Scotch_mount.png)

R. Baturin from Norwood, MA (email: rbaturin@umass.edu)
C. Boyle from Springfield, MA (email: coboyle@umass.edu)
C. Urbanowski from Pepperell, MA (email: curbanow@umass.edu)
D. Willmott from Weymouth, MA (email: dwillmot@umass.edu)

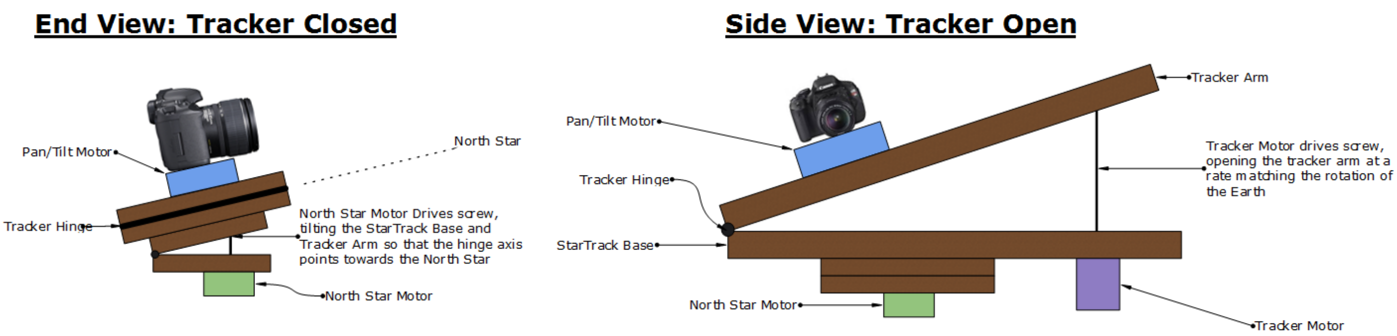


Figure 2: Conceptual Diagram of StarTrack Mount

Having assessed the options, we came up with a set of goals for the project. The most important factor was clear: automation of as many aspects of the mount as possible is imperative. This accomplishes two of our goals; automation reduces the need for the user to be present for the entire exposure, and reduces the amount of error dramatically.

Additionally, we want a low cost final product. Expenses for cameras and high quality photography can become expensive quickly, and we want to provide comparable results for a fraction of the price of a professional mount.

We also want the final object to be approachable for newcomers. The system should be usable by individuals without much knowledge of the stars, as well as customizable and adaptable for those with prior experience.

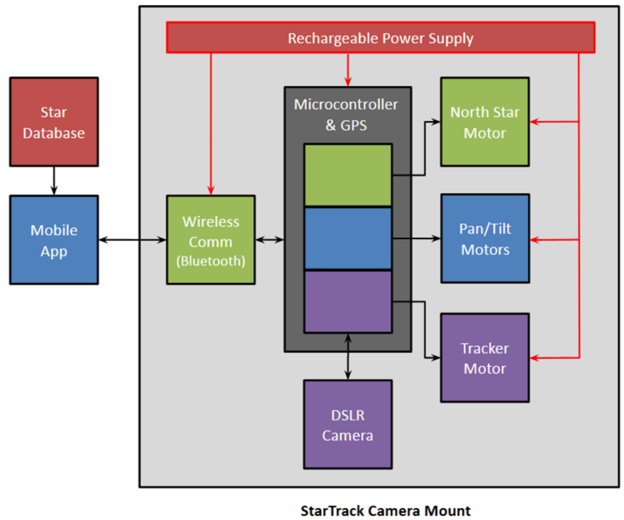


Figure 3: Block Diagram

II. Design

A. Overview

Our desire to create a simple but versatile electronic mount gave birth to the StarTrack mount concept that is displayed in Figure 2, and the Subsystem Block Diagram shown in Figure 3. Our solution to the problem of an economically viable and intuitive long exposure system for astrophotography is to develop a microcontroller based system. With this chip we will control 4 separate subsystems to create a motorized mount. The microcontroller will interface with a Bluetooth module in order to be wirelessly controlled via a mobile application. The mobile application will in turn interface with a database of sky coordinates of noteworthy objects.

We selected an ATMega328 for a low cost design option to control four separate subsystems on a mount [5]. We have experience using this microcontroller from previous coursework, and the controller will have enough processing power without consuming higher levels of power.

In total, the microcontroller will control four automated motors to find and follow the desired celestial object while taking long exposures. One stepper motor will align with the North Star, two servo motors in a pan/tilt enclosure will move the camera to the desired position, and a second stepper motor will slowly move the mount at the same rate as that of the earth.

Additionally, the mount will control the camera shutter for a camera weighing at least 2 lbs, and a power supply will be designed to supply power to all the mounted motors and components for an 8 hour session.

The wireless control will be implemented with Bluetooth to interact with a mobile application for an iPad. This app will allow the user to select the settings for all the pictures to be taken in a sitting, and will interface with a star database of constellations in view that night.

TABLE I
SPECIFICATIONS

Specification	Value
Weight Support	> 2 lbs
Height	< 4 ft
Length	< 2 ft
Width	< 6 in
Wireless Range	100 m
Battery Life	8 hours
Tracking Accuracy	Within .75 arc min.
Star Shape	Circular

The specifications for the mount are displayed in the table above. The most significant specification is the rotation of our mount with the apparent rotation of the stars. The apparent rotation of the stars over a 10 minute exposure is 2.5 degrees [6]. To aim for 99% accuracy we want to see our mount within .75 arc minutes of the destination position.

We felt this specification was too narrow, and have begun development on another specification: the shape of the star. If we track a star correctly, we will have a perfectly round shape regardless of size. We are developing an algorithm which will superimpose a perfect circle over the image of the star. The percentage of the star's area contained in each pixel as compared to the circle can be measured. We can sum these measurements and come up with a target for our mount.

B. Block 1: Star Database

Even with a well-constructed mount and an inviting mobile application, the user's desired image cannot be created without a sense of direction. By building a star database for the adjoining mobile application, the StarTrack mount will be able to properly track and maintain focus on a number of celestial objects visible by the operator.

The database is composed of multiple text files, with each file corresponding to a different astronomical constellation. Each text file contains multiple strings corresponding to each star in the constellation. Each string contains seven values, including the name of the star (along with any popular nicknames), the Right Ascension coordinates (composed of Hour, Minute, and Second values), and the Declination coordinates (composed of the Degree, Minutes, and Second values). In order to establish a standard for the database, all the coordinates are based on the International Celestial Reference System given by the Set of Identifications, Measurements, and Bibliography for Astronomical Data (SIMBAD) [7] [8]. An example of an object string is shown in Figure 4 below.

```
PS C:\Users\LH-12\StarTracks> TYPE Lyra.txt

Object Name (Nickname):        RA(h)   RA(m)   RA(s)          D(deg)  D(')    D(")

Alpha Lyr (Vega)               18      36      56.33635       +38     47      01.2802

Beta Lyr (Sheliak)             18      50      4.79525        +33     21      45.6100

Gamma Lyr (Sulafat)            18      58      56.62241       +32     41      22.4003

Delta Lyr                      18      54      30.29          +36     53      55

Zeta Lyr                       18      44      46.4           +37     36      16
```

Figure 4: Object Coordinate Example

The simplicity and versatility of the database's string structure allows for a modular architecture when it comes to building a database. Adding a constellation to the database is as straightforward as adding a text file to the system's directory. More objects may be added to a file to supplement the main stars of each constellation simply by adding a string. Furthermore, if a user desires to expand the breadth of knowledge of the database and add additional values such as the star's apparent magnitude or age, additional values can be manually added to each string. The modular design of the database and string structure enables it to be more easily integrated with a variety of programs, and it is platform agnostic since each constellation is a universal text file.

C. Block 2: Mobile Application

The mobile application will allow the user to operate and receive feedback from the StarTrack mount. It must be able to present an interface to the user to choose a star or constellation from our star database or manually input the sky coordinates if a star is not listed. It must then communicate over Bluetooth with the StarTrack mount to send the parameters indicated. The microcontroller on the mount will also send feedback with its progress or any errors. The application must be ready to receive and display this data to the user.

The application is designed for an Apple iPad and written in Objective-C. The application has only a single view which contains a list of celestial targets for the user to choose from as well as the option to input one manually. The interface will continue to be changed as we integrate for CDR. The hardware address for the Bluetooth block is currently defined in the code, and there is no way to choose between multiple StarTrack mounts. The mount may still need to receive commands even if the application is closed, so background operation needs to be added. Because the mount is designed to be used overnight and the number of consecutive exposures may be high, it is not reasonable to require the application to be open continuously while the mount is operating. It should instead be ready to receive communication in the background and notify the user when tracking is complete or if any errors occur.

Translation between coordinate systems will be performed by the application. Positions of celestial objects provided by the star database block will be given in equatorial coordinates which uses the center of the earth as the frame of reference. To move the camera, the pan tilt block will use horizon coordinates which will use the mount as its frame of reference. Conversion between the two is dependent on current time and latitude. The hour angle is calculated from right ascension and that, along with declination, is used to find altitude and azimuth for current time and position [9]. At this time the latitude is received from the GPS API available in iOS and not from the GPS block. It is planned to use the GPS data available on the mount in lieu of the iPad's GPS for accuracy concerns and because the mount needs to be in an outdoor location to function.

D. Block 3: Wireless Communication System

The implemented wireless communication system consists of a BlueSMiRF Bluetooth Module interfaced with the ATMega microcontroller. This module will send and receive serial data to and from the microcontroller and the iPad application. We intend to use this connection to send all the data about what the mount must do in an overnight photo taking session. This data includes what objects the mount will take pictures of qualitatively and quantitatively, including tables of positions for the motors to be in at specified times to keep processing and power consumption down. It will also provide the camera information about when to open and close the shutter. Conversely the microcontroller can send back data about the mount's real time position and what tasks it has completed. Future improvements could include more practical implementations about what data to send and receive as the mount's complete design takes shape.

The RN-41 Bluetooth chip on the BlueSMiRF boasts 100 meters of coverage [10]. We intend to experiment with the veracity of these specifications by testing the maximum range of the Bluetooth module to an iPad in typical settings a user might find themselves in, including reception from inside a car, with forest blocking reception, and without obstacles.

E. Block 4: North Star Motor and Control System

The North Star Motor and Control System is responsible for aligning the mount with the North Star. Stars in the sky rotate very closely around the North Star, therefore alignment with the North Star will allow us an axis to rotate around in the sky to cancel out the earth's rotation. The mount receives GPS data from a GPS module, calculates how far the North Star will be above the horizon, and moves the mount to face the star.

First, the Ultimate GPS Module by Adafruit [11] was selected for its relatively low cost and accuracy to 3 meters. We can find the position of the North Star above the horizon by extracting the latitude from the received GPS data; the North Star is simply the same number of degrees above the horizon as one's vantage point is in latitude above the equator.

We can then implement the shift the in mount's positioning by rotating a threaded rod to move the mount up. We calculate the number of rotations and distance required to align the mount correctly by using a sine function table.

Future considerations include implementing functionality to assess the amount of error in the placement of the mount facing north,

F. Block 5: Pan/Tilt Motor and Control System

The pan/tilt motor and control system is responsible for aiming the camera at the target celestial object that will be tracked. We are using two independent servo motors, one for panning the camera horizontally and one for tilting vertically. It must be designed to move a camera weighing up to two pounds to any location in the visible sky to meet reasonable requirements for DSLR cameras.

The position it will need to move to will be received in two values, altitude and azimuth. Azimuth is the angle that will need to be panned, with 0 referencing north. Because the servo is only able to rotate 180°, an azimuth value between 90 and 270 must have 180 subtracted and the opposite altitude used. The altitude must also be corrected from the North Star motor by the product of the sine of the azimuth and latitude.

The two servos being used are HiTec HS-5685MH digital servos which accept an angle input. The panning servo is configured for 0° pointing north and can accept the azimuth directly to move to the correct position. For the tilting servo 0° is pointing directly vertical which is a 90°azimuth. The control adds 90° to all inputs to correct for this.

G. Block 6: Tracker Motor and Control System

The Tracker Motor and Control System is responsible for moving the camera at a rate matching the Earth’s rotation. In astrophotography, this is done so that star trails are not apparent in images. To do this, we are controlling a bi-polar stepper motor with the microcontroller on the mount. This motor drives a threaded rod that opens the tracker arm with constant angular motion. The rate of rotation of the stepper motor depends on the length of the base board, the threads/cm of the threaded rod, and the step size of the motor. A conceptual view of the tracker arm is displayed in Figure 5 below.

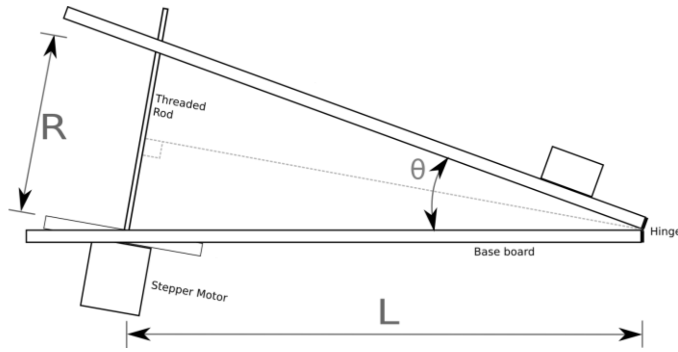


Figure 5: Side View of Tracker Arm

Using trigonometry, we were able to determine this rate of rotation of the threaded rod. Since the Arduino controls the length of the rod by adjusting the rotation rate of the stepper motor, the distance R that the tracker arm must move is:

$$R = \frac{rotations}{threads/cm} = 2L * \sin\left(\frac{\theta}{2}\right)$$

By combining these two equations and solving for rotations we are able to calculate the number of rotations needed to achieve a given angle between the boards:

$$rotations = threads/cm * 2L * \sin\left(\frac{\theta}{2}\right)$$

To find the desired angle we need at any time, we must use the sidereal rate (Earth’s exact rotation rate) which is 86,164.091 seconds [12]. From this, we find:

$$\theta = \frac{360 * t}{sidereal\ rate}$$

Combining this with our previous formula for the number of rotations and converting to radians, we find:

$$rotations = threads/cm * 2L * \sin\left(\frac{\pi t}{sidereal\ rate}\right)$$

Since the microcontroller actually controls the number of steps that the stepper motor turns, this equation becomes:

$$steps = \frac{360}{stepsize} * threads/cm * 2L * \sin\left(\frac{\pi t}{sidereal\ rate}\right)$$

In addition to its precise tracking mode, the Tracker Motor and Control System will also have a quick reset mode, allowing the tracker arm to quickly return to a closed position after the desired exposures have been taken.

To test this subsystem, we will analyze the accuracy of our images. Based on a focal length of 50mm and a pixel size of 4.3μm, the angular size of one pixel on the camera we are using for this prototype is 70.96 arc seconds [13]. This means that the stars we are imaging should take up only one pixel in our final images. For example, Polaris (the North Star) has an angular diameter when viewed from Earth of 0.00328 arc seconds, and will be represented as one pixel by our camera. We will also compare known angular distances between stars in constellations with the distances shown in our final images.

H. Block 7: DSLR Camera Control System

The DSLR Camera Control System provides control of the camera shutter during operation at a user specified interval. Control of other camera settings is not necessary, since they are static, and will be initialized by the user when setting up the mount.

The camera we are using with our prototype is a Canon EOS Rebel T3 which uses a 2.5mm TRS (tip, ring, sleeve) connector for its remote shutter jack. The sleeve is grounded. To focus the camera, ground the ring, and to press the shutter, ground the tip. The 2.5mm TRS schematic is shown in Figure 6 below.

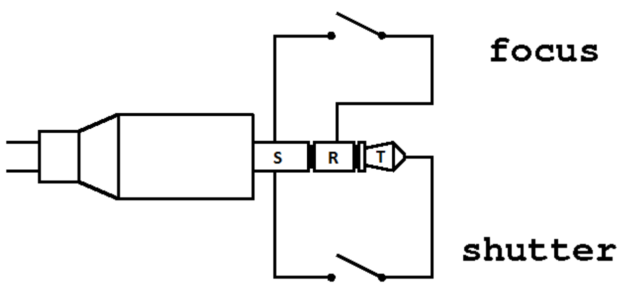


Figure 6: TRS Schematic

To have the microcontroller control the shutter, we initialize the corresponding output pin high, and then at the specified exposure interval, pull the pin to ground to take a picture. Since astrophotography requires the camera to be set to manual focus, we have connected both the focus and shutter wires to the same output pin on the ATMega microcontroller.

I. Block 8: Power Supply

In order to meet the desired goal of having the StarTrack mount be a portable system, a dedicated power supply is needed to ensure the mount's movement. The power supply is meant to provide power to five of the eight total subsystems: the wireless communication system, the North Star motor, the Pan/Tilt motor, the Tracker motor, and to the microcontroller governing each motor and the DSLR camera controller.

Amongst the powered subsystems the microcontroller, Pan/Tilt motor, and wireless communications system necessitate a nominal 5 V DC supply, and the necessary drivers for the North Star and Tracker motors use a 12 V DC supply (in-between a 7 V to 20 V supply range required by the driver). Having two different voltage requirements, an LM7805C voltage regulator and an LM7812C voltage regulator are used to achieve the 5 V and 12 V supply respectively [14]. Additionally, each voltage regulator is coupled with two 10 mF and a 0.1 mF in order to ensure stability within the output voltage regardless of the input voltage [15].

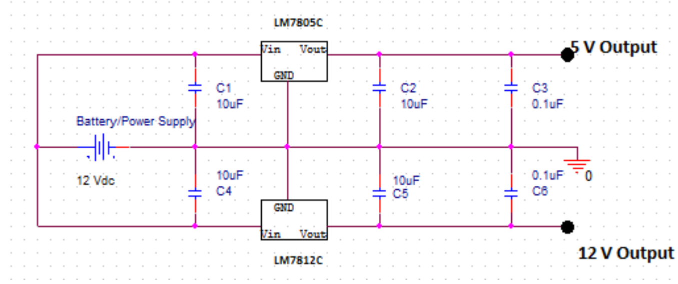


Figure 7: Power Supply Circuit Schematic

Providing the foundation to this power supply shown in Figure 7 will be a 12 V DC input. In order to achieve the portability that would benefit the mount, a 12 V lead-acid battery is going to act as the input to the voltage regulators. A lead-acid battery will be able to supply the voltage needed by the system and can also be dependably recharged with the implementation of a recharging circuit.

In order to test this subsystem, the power supply must be able to provide a dual 5 V and 12 V output voltages to the mount and it must be able to supply these voltages over the course of an 8 hour session. If the battery within the power supply can be successfully recharged, then it can provide continued functionality of the mount.

III. Project Management

TABLE II
MDR Goals

Specification	Value
Star Database	100
Mobile Application	100
Wireless communication	100
North Star Motor	100
Pan/Tilt Motor	100
Tracker Motor	100
DSLR Camera Control	100
Power Supply	100

Our MDR goals are shown in Table II. We set out to have subsystem fully working independently without integration. All motors are able to be controlled from the microcontroller in the ways we desire; the pan/tilt motors can point to a specified direction, and the Tracker and North Star motors are able to turn a specified number of turns at different speeds. The mobile application and Bluetooth module are both able to send and receive serial data. We have an initial collection of 15 popular visible constellations and their coordinates. The cameras shutter can be open and closed by the microcontroller. The power supply is able to deliver the correct voltages for the many components which will be on the mount.

The team has a great dynamic and everyone has fit into their role well. Having three EE majors and one CSE fits with the requirements of the project. Every member of the team has been responsible and can feel that each other will accomplish the tasks they are responsible for on time. We have a weekly meeting between team members where responsibilities are

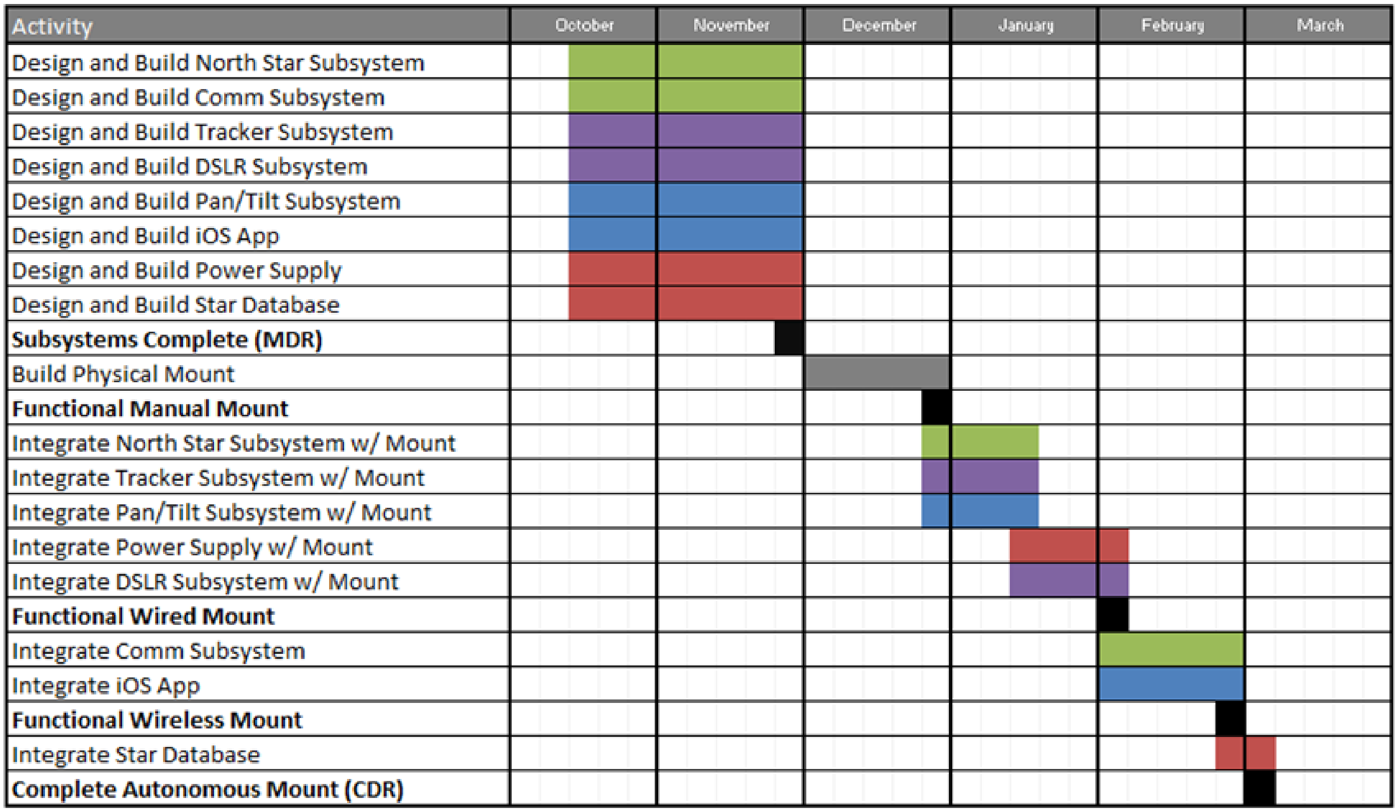


Figure 8: Gantt Chart

decided as well as a weekly meeting with our faculty advisor Professor Leonard. We divided our project into eight subsystems and each member of the team is responsible for two. Rebecca Baturin is responsible for the tracking motor and controlling the DSLR camera and is also the team manager. Christopher Boyle is the only CSE on the team and responsible for the iOS application and pan/tilt motors. Charles Urbanowski is responsible for the star database and the power supply. Daniel Willmott is responsible for wireless communication on the StarTrack mount as well as the North Star motor.

The majority of this project could be completed utilizing knowledge gained from our engineering coursework, though there was certainly additional research necessary and outside tools that were used. One example of this was learning about the imaging specifications and accuracy required for astrophotography. No one on the team had any prior experience in this field, so we leaned heavily on the expertise of faculty reviewers. Professor Looze lent us a book that has been immensely helpful in making accuracy calculations for our final pictures. We also worked with NASA engineers with prior experience in astrophotography to define our imaging specifications: how long each exposure should be and how many exposures should be taken for each target.

IV. Conclusion

As discussed above, we were successful in the completion of our MDR deliverables, demonstrating the feasibility of our eight subsystems. For CDR, our goal will be to integrate all of the subsystems that we demonstrated into a complete working prototype. Up until now we have each worked on two independent portions of the system. For the integration phase of this project we will each lead the task of integrating our subsystems, though the overall effort will be done as a team.

For StarTrack, we believe that integration will be most effective if we split the integration phase into four milestones as referenced in our Gantt chart. Our first milestone is to design and build the physical mount that will carry the camera, the motors, and the electronics. From there we will add in the three motor systems (North Star, Pan/Tilt, and Tracker) and their accompanying control systems. Once the motors can accurately work in tandem, we will integrate the Power Supply and the DSLR Camera Control System to create a fully functional wired camera mount. At our second milestone, StarTrack will be able to accurately align with the North Star and track while taking images, though the operation parameters and control signals will need to be programmed manually.

Next, we will integrate the Wireless Communication System and the Mobile Application with our wired mount. This will provide wireless control of the mount through an iPad. At this point, StarTrack will be able to manually align at any point in the night sky, but will not be able to find a specific star. Once we have completed our third milestone and demonstrated wireless tracking and control of the mount, we will integrate our remaining subsystem, the Star Database. At this point we will be able to demonstrate a complete working prototype.

For a complete demonstration of our system, we will demonstrate the following operation process at CDR. First the user will initialize the StarTrack iOS application. This sends a command from the mobile device to the microcontroller to align the mount with the North Star. To accomplish this, the microcontroller determines the mount's current positon and uses the North Star Motor to align the mount. Next, the user specifies the desired sky target through the iOS application. The star coordinates of the target are sent to the microcontroller, and the Pan/Tilt mount moves the camera to point at the desired coordinates in the sky. After the camera is in the correct position, the user specifies the desired number of exposures to be taken. The iOS application sends a command to the microcontroller to begin tracking and the DSLR camera receives shutter commands to take images. After the desired number of images have been taken, the tracker arm returns to a closed position and the iOS application notifies the user that the imaging is complete. At this point StarTrack can point at another target and repeat the process. Finally, once the desired targets have been imaged, the North Star Motor returns to a closed position.

ACKNOWLEDGMENT

First and foremost, all of us on Team StarTrack would like to thank Professor William Leonard, our Faculty Advisor. His insight and expertise has been invaluable to our endeavors. Additionally, we would also like to thank our Faculty Evaluators, Professor Mario Parente and Professor Douglas Looze, who have provided us with critical advice and avenues to combat the challenges of the project. Finally, we would like to thank NASA engineers Tim Van Ness and John Moss for the inspiration to create StarTrack and all of their support and feedback throughout the design process.

REFERENCES

[1] G. Haig, "Observer's Page: A Simple Camera Mounting for Short Exposures," *Sky & Telescope*, 4., pp.263-266, April, 1975.

[2] Celestron. (2006). "Nexstar 8SE Computerized Telescope." [Online]. Available: http://www.celestron.com/browse-shop/astronomy/telescopes/nexstar-8se-computerized-telescope [Accessed Web. 15 Dec. 2014].

[3] Orion. (2014). "Orion AutoTracker Mount." [Online]. Available: http://www.telescope.com/Orion-StarBlast-AutoTracker-Altazimuth-Mount/p/102781.uts [Accessed Web. 15 Dec. 2014]

[4] Orion. (2014). "SynScan V4 GoTo Hand Controller." [Online]. Available: http://www.telescope.com/Orion-AZEQ-Computerized-GoTo-Hand-Controller/p/7947.uts#tabs [Accessed Web. 15 Dec. 2014].

[5] Atmel. (2009). "8-bit Microcontroller with 4/8/16/32K Bytes In-System." [Online]. Available: http://www.atmel.com/images/doc8161.pdf [Accessed Web. 12 Oct. 2014].

[6] Weber State University. "Understanding Astronomy: Motion of the Stars". [Online]. http://physics.weber.edu/schroeder/ua/StarMotion.html [Accessed Web. 12 Dec. 2014]

[7] Richard Berry and James Burnell, *The Handbook of Astronomical Image Processing*. Richmond, VA: Willmann-Bell, 2000. pp 217-18.

[8] Wenger et al. "The SIMBAD Astronomical Database". [Online]. Available: http://simbad.u-strasbg.fr/simbad/#acklab [Accessed 23 Oct. 2014].

[9] P. Duffett-Smith, and J. Zwart, *Practical Astronomy with your Calculator or Spreadsheet*. 4th ed. New York: Cambridge University Press, 2011, pp. 22-66.

[10] Roving Networks. (2013, April). "RN41/RN41N Class 1 Bluetooth Module". [Online]. Available: http://ww1.microchip.com/downloads/en/DeviceDoc/rn-41-ds-v3.42r.pdf [Accessed Web. 21 Oct. 2014].

[11] GlobalTop Technology Inc. "FGPMMOPA6H GPS Standalone Module Data Sheet." [Online]. http://www.adafruit.com/datasheets/GlobalTop-FGPMMOPA6H-Datasheet-V0A.pdf [Accessed Web. 20 Oct. 2014].

[12] Swinburne University of Technology. "Sidereal Day". *COSMOS - The SAO Encyclopedia of Astronomy.* [Web]. Available: http://astronomy.swin.edu.au/cosmos/S/Sidereal+Day [Accessed Web. 24 Nov. 2014].

[13] "Pixel Scale". [Online]. Available: http://astro.uchicago.edu/yerkes/outreach/activities/Explorations/OpticalPowers/9a-pixelscale.html [Accessed Web. 30 Nov. 2014].

[14] Texas Instruments. (2013). "LM78XX Series Voltage Regulators." [Online]. Available: http://www.ti.com/lit/ds/symlink/lm7805c.pdf [Accessed Web. 23 Nov. 2014].

[15] Afrotechmods. (2010, Nov. 23). "*Voltage regulator tutorial & USB gadget charger circuit.*" [Video]. Retrieved from: https://www.youtube.com/watch?v=GSzVs7_aW-Y