PDR Presentation
StarTrack

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Team Introductions

Rebecca Baturin, EE

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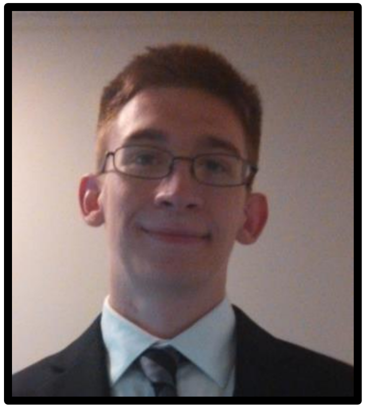
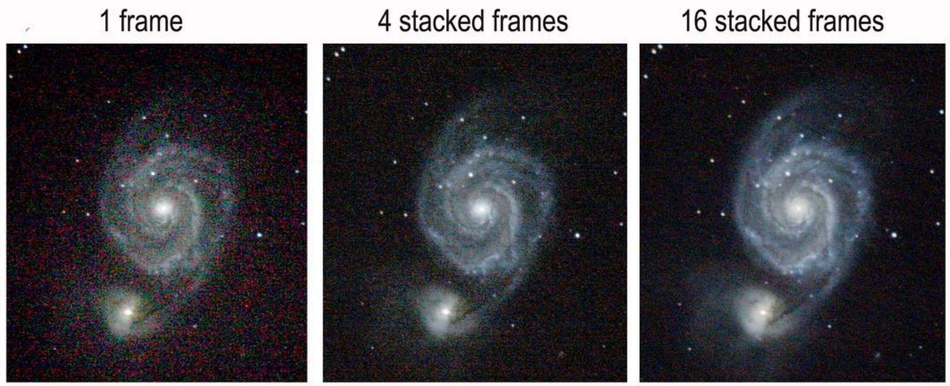


Daniel Willmott, EE

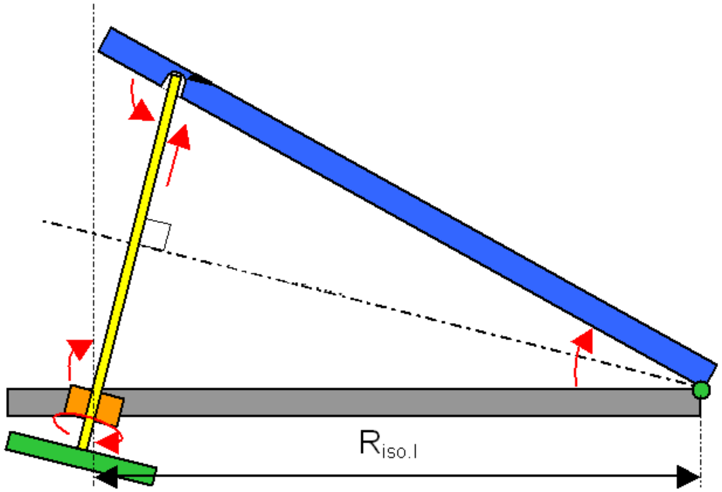
What is astrophotography?

- Astrophotography is a specialized type of photography for recording images of astronomical objects and large areas of the night sky, typically accomplished through long exposures.
- Long exposures allow more light to enter the camera's sensor, providing better images at night
  - Longer exposure = more noise
  - By combining multiple exposures, you can remove random noise while retaining the data in the image.



The Barn Door Tracker

- Because the earth is rotating, objects in the sky do not appear to be in a fixed position.
- During a long exposure the stars will have moved, creating streaks of light in your image.
- The common solution to this problem is the barn door tracker
- Opening the tracker at the same rate that the Earth is rotating cancels out the apparent motion of the stars in your images
  - Must approximate the angular rotation of the earth with linear motion of the screw (not constant)
- The hinge of the barn door tracker needs to be aligned with the north star, which does not change position as the earth rotates



What is the Problem?

- Without the correct equipment, astrophotography is difficult
  - Unintuitive: requires prior knowledge to take a successful picture
  - Requires many evening hours spent outdoors in the elements
  - Without proper tracking, images have star trails

- Ideal equipment is expensive and unavailable to the average hobbyist

Context: Effect on individuals and groups

- It is human nature to want to preserve beautiful sights with photography
- For most landscapes and scenery, this is easy, but to create a lasting image of the Milky Way, for example, it is not

- **StarTrack** provides an intuitive and economical way for the average hobbyist to delve into astrophotography

Design Alternatives

Manual Tracking Device

- Low cost to build (~$30)
- Not accurate, hard to execute
- Requires user to manually open hinge through entire exposure

Electronic Tracker

- Accurate, cost effective
- Replaces manual operation with a stepper motor
- No automation of finding a target

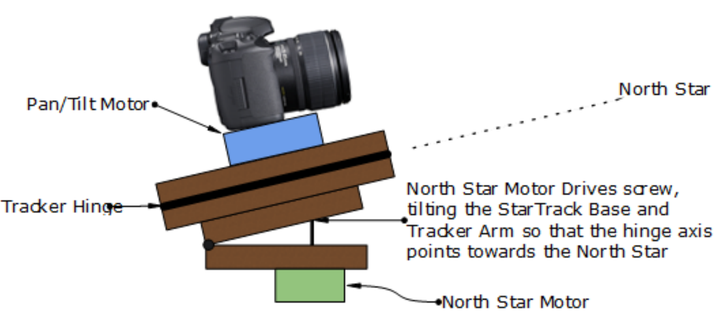
Computerized Telescope

- Expensive, entry level starting at $1,500
- Extremely precise
- Full automation of finding a target

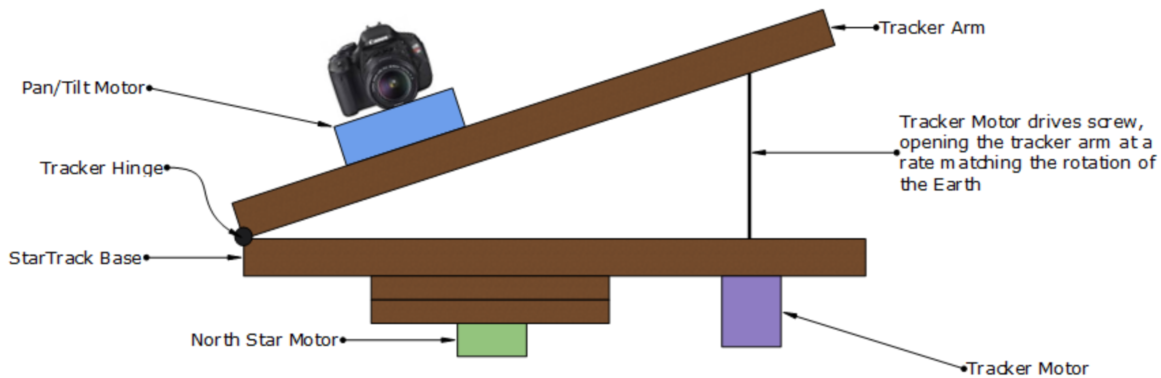
Our Solution: **StarTrack**

- Provides accuracy while keeping cost low
- Interfaces with entry level DSLR cameras
- Provides wireless control of camera and mount
- Automates the process of finding interesting targets
- Movement of tracker cancels out the Earth's rotation to eliminate star trails

End View: Tracker Closed



Side View: Tracker Open



General Requirements

Wireless Control

- The mount and camera must be wirelessly controlled through a mobile application from up to 100 meters away

Mount Control

- The mount must be programmable to take a succession of at least 5 exposures of 5 minutes each at each target
- The mount must continuously operate for at least 8 hours and must also be rechargeable
- The mount must support a camera and lens of up to 2 pounds

Motor Automation

- Once placed facing North, the North Star motor must be able to align the mount with the North Star within 1°
- Using inputs from the Star Database, the Pan/Tilt motors must be able to position the camera so that the specified object is in its FOV
- The Tracker motor must move in a way so that the Earth's rotation is cancelled out within 0.5°

Basic Inputs and Outputs

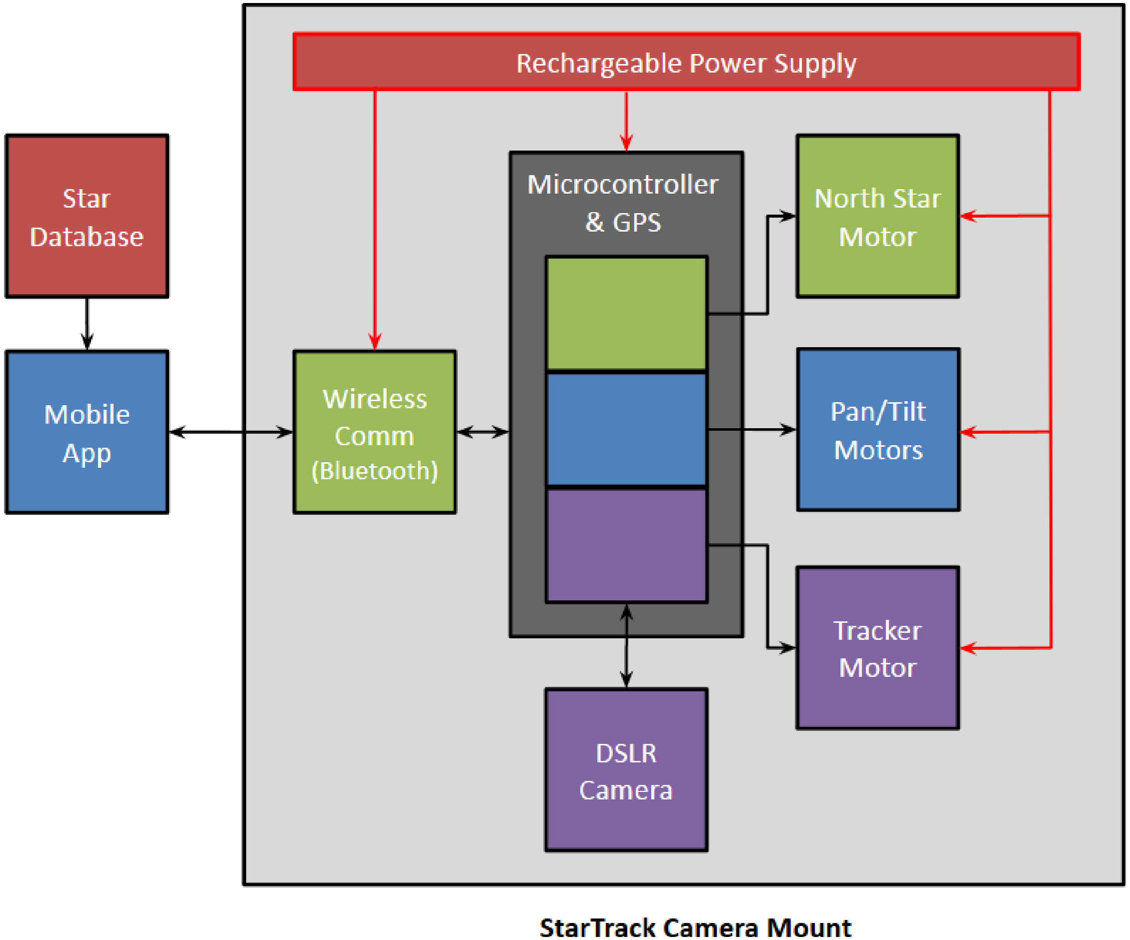
Inputs

- Desired camera settings
  - ISO, exposure, shutter length, etc.
- Operation parameters
  - Which target(s) to image, and in what order
  - How many exposures at each target

Outputs

- Multiple images at each target
- Metadata for each image

Detailed Block Diagram



Subsystem Owners:

- Red- Charles
- Blue- Chris
- Green- Daniel
- Purple- Rebecca

Rechargeable Power Supply (Charlie)

Requirements:

- Must successfully provide power to five subsystems for a period of at least 8 hours
  - Microcontroller & GPS
  - Three separate motors [North Star Motor, Pan/Tilt Motor, and Tracker Motor]
  - Wireless Communication Module
- Must be rechargeable to provide continued use

Implementation:

- Considering the different components, the power supply should operate between 4.8-5.5 V
- An NCP1402 Step-Up DC-DC breakout converter rated at 5 V is being considered

Star Database (Charlie)

Requirements:

- Must provide coordinates for desired target locations
- Must be accessible via mobile application in order to adjust motors

Implementation:

- Using the SIMBAD collection, create a database of meaningful information for StarTrack

Mobile Application (Chris)

Requirements:

- Must send and receive data over Bluetooth to communicate with the microcontroller
- Must send operation parameters to the microcontroller
- Must have an interface to select a target and set camera settings

Implementation:

- Design an iOS application that allows for complete control of StarTrack and the DSLR camera

Pan/Tilt Motor and Control System (Chris)

Requirements:

- Must receive coordinates of desired target from mobile application, taking into account the current mount position
- Must have pan and tilt capabilities to find any target in the entire sky

Implementation:

- Interface data using a ATMega328P-PU microcontroller with two HS-5685MH servo motors in a pan/tilt enclosure

Wireless Communication System (Dan)

Requirements:

- Must wirelessly send and receive data between the microcontroller and the mobile application
- Must have an operation range up to 100 meters

Implementation:

- Configure a BlueSMiRF Bluetooth Module to be a discoverable, low power transmitter of data
- Build an interface between the BlueSMiRF and the ATMega328P-PU microcontroller

North Star Motor and Control System (Dan)

Requirements:

- Must receive GPS data to align the axis of the mount with the North Star
- Must be able to reset to a closed position

Implementation:

- Configure a MTK3339 GPS Chip to receive latitude, longitude, and direction information
- Interface data using a ATMega328P-PU microcontroller with a NEMA-17 stepper motor to align the mount

Tracker Motor and Control System (Rebecca)

Requirements:

- Must open at a rate matching the rotation of the Earth
- Must reset to a closed position after the desired of exposures have been taken

Implementation:

- Calculate a table of values for the number of required rotations in each minute for up to 3 hours
- Program an ATMega328P-PU microcontroller to look up values from this table to determine the rotation rate for a NEMO-17 stepper motor

DSLR Camera Interface and Control (Rebecca)

Requirements:

- Must provide control of necessary camera functions and settings
- Must provide access to images stored on the camera

Implementation:

- Build an interface between the ATMega328P-PU microcontroller and the DSLR camera

MDR Deliverables

Rebecca Baturin:

- Determine accurate tracking algorithm and program microcontroller
- Build camera interface and demonstrate control of camera settings

Chris Boyle:

- Build iOS application that can send coordinates and camera settings over Bluetooth
- Program Pan/Tilt mount to point at a specific coordinate in the sky.

Charles Urbanowski:

- Build power supply to appropriately operate all components of StarTrack
- Build a compiled database of 15 noteworthy constellations

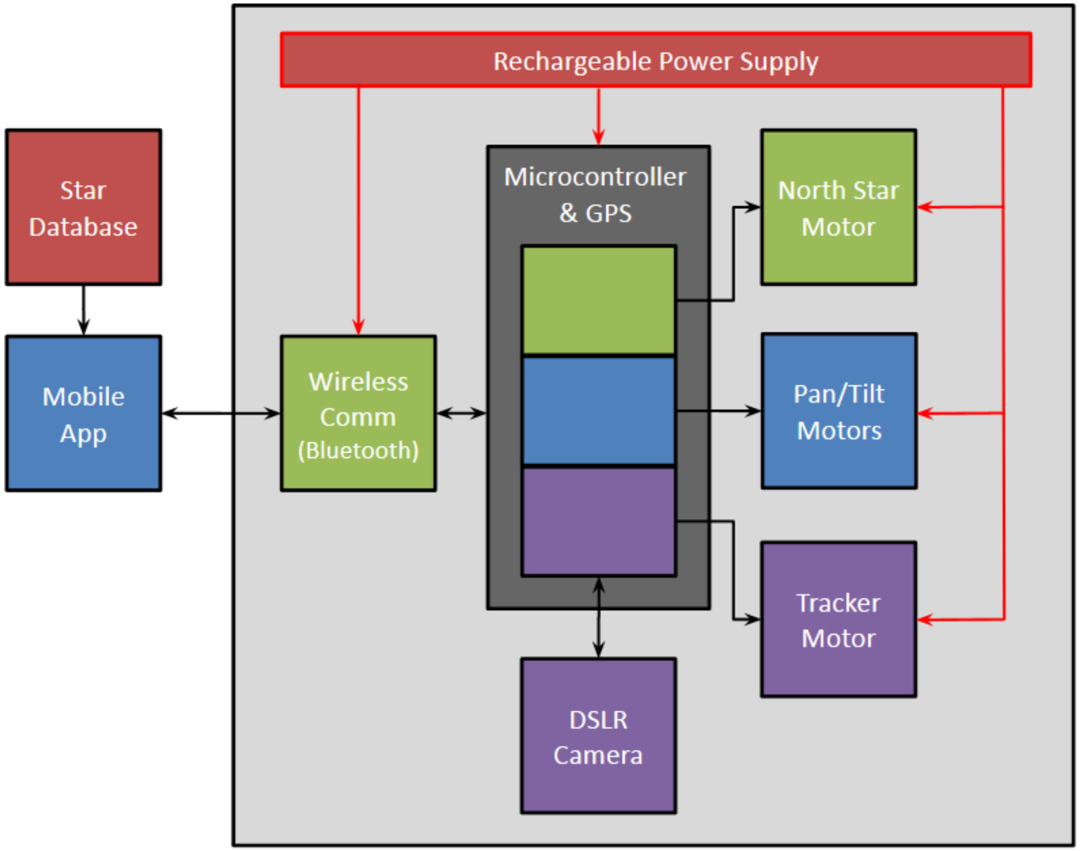
Daniel Willmott:

- Send and receive data from the microcontroller via Bluetooth
- Receive GPS data on the microcontroller
- Be able to move North Star motor via microcontroller

Thank you

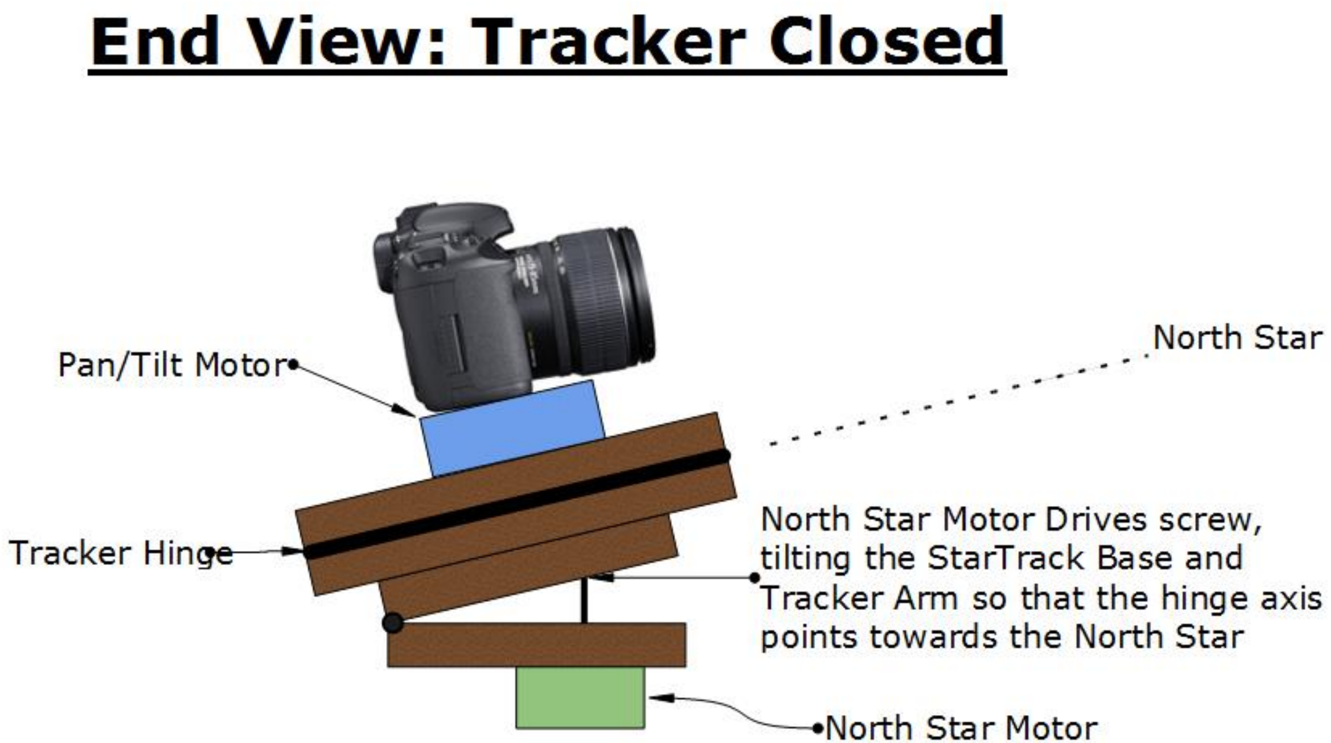
Questions

Detailed Block Diagram (for Reference)

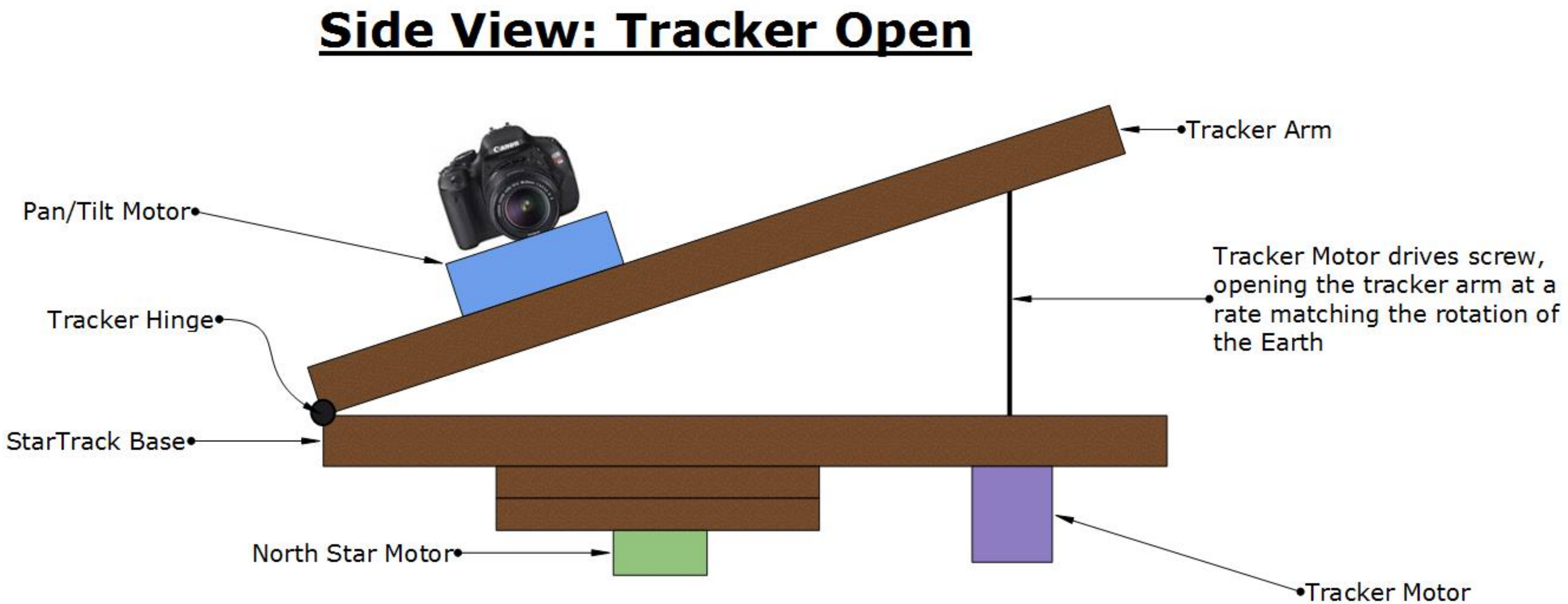


StarTrack Camera Mount

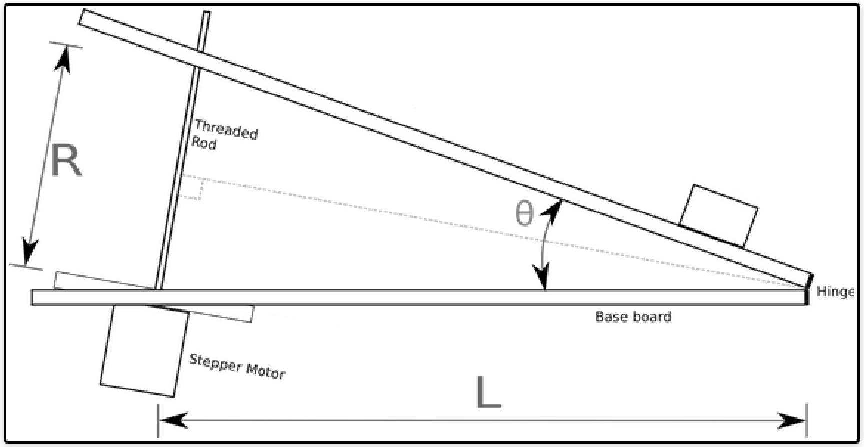
StarTrack Mount (for Reference)



StarTrack Mount (for Reference)



Tracking Algorithm (For Reference)



- Trig tells us: $R = 2L * \sin(\frac{\theta}{2})$
- But $R = \frac{rotations}{threads/cm}$ of the threaded rod
- Substituting for R, we get:
  $rotations = threads/cm * 2L * \sin(\frac{\theta}{2})$
- The above formula tells us how many rotations we need to achieve a given angle between the boards.
- The Earth doesn't take exactly 24 hours to rotate a full 360 degrees. The exact time is called the sidereal rate. The sidereal rate is 23 hours, 56 minutes, 4.0916 seconds.
- Thus, the number of rotations necessary to achieve a certain angle (in radians) is
  $rotations = threads/cm * 2L * \sin(\frac{\pi * t}{sidereal\_rate})$
- Since the microcontroller is controlling steps of the motor, and not rotations, the final equation becomes:

$$\boldsymbol{steps = \frac{360}{step\_size} * threads/cm * 2L * \sin(\frac{\pi * t}{sidereal\_rate})}$$

High Level Operation Procedure

1. Place the mount outdoors with the axis of the tracker facing due north
2. Align tracker with the North Star
3. Move camera to point at the desired sky coordinate
4. Start tracking and begin first exposure. Continue until reaching the desired number of exposures
5. Return tracker to a closed position, repeat steps 3 & 4 as necessary