Das Pan

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Contents

1 Executive Summary

1.1 The Problem

The state of today's roads is dire. The failure of the UBER automated vehicle program has left passengers stranded, abandoned and worse, run over.

1.2 Our Solution

Our objective is to solve this problem, by efficiently picking up all stranded passengers. The 'Das Pan' will feature a sweeping arm that pushes passengers into our 'pans', a holding area, where they will stay for the duration of their ride.

1.2.1 Design Specifications

The Das Pan, at a weight $\approx$ 8lb consists of three main modules all brought together by software.

Arms The arms, supported by a beam of height 30cm, have a length of 25cm, and sweep in a unidirectional fashion. They are powered by a geared colamn motor, in such a way that they are able to push the passenger into the pans, which have dimensions 20cm x 12cm.

Body The body, which consists of a base for the arms, wheel wells for the 6cm diameter wheels and a housing for the circuits, is the central portion of our design. On both the left and right side of the body, we have two large 20cm x 12cm pans for holding passengers.

Electronics The electronics, which consists of a series of sensors including four IR QDR1114 sensors for navigation, four OP805 phototransistors for sensing of passengers, and a series of switches for colission detection. The output of allof these sensors are controlled by a central TINAH boards, which contains a microprocessor.

Software Our microprocessor will run code to analyze the data from sensors and make smart decisions.Furthermore, the software will include a unique graph-based navigation algorithm to help us achieve target performance.

1.2.2 Target Performance

Our final Prototype will be able to navigate the roads in an intelligent Fashion, seeking out passengers by using the information it has at hand. In our final mechanism, Das Pan should be able to complete a passenger retrieval action in less than 10 seconds.

2 Preface

Work for this proposal was divided among our team using an excel spreadsheet. We began outlining the subsections of our report, using the outline provided in lectures. Subsections were defined from all pertinent information.

Once we defined subsections, as a team, we determined which member would be most knowledgeable about specific subject, and assigned them to the task.

All sections began by creating a set of figures and tables. We shared these tables and figures with one another, and provided feedback, continually making modifications until all members were satisfied with the result.

Throughout this process, we sought out the help of our mentors and instructors, namely Pam Roglaski, Jon Nakane, and Bernhard Zender, who guided us in the formatting and the technical writing of this document.

3 Overview of Basic Strategy

Our objective is to create a simple yet effective robot. We believe that a plain and straightforward design is a successful design.

3.1 Mechanical Overview

Precision plays a vital role in traditional passenger retrieval. We sought to engineering out precision. We came up with a broom and dust-pan design. Our arm will sweep passengers off their podium and drag them into our dust-pans. This does not require the precision of other candidate mechanism such as forklifts, since the broom can span a wide range. This also avoids destroying houses since the bristles of the broom will be elastic and will deform around rigid structures.

3.2 Electrical Overview

We plan on modularizing our electrical circuits such that each circuit that performs an atomic function (ex. H-Bridge, IR detect) is on its own board. We think that an encapsulated and modularized circuit design will allow us to individually test components. Such components are also easily replaceable.

3.3 Software Overview

We will store a graph representation of the playing surface in memory for decision making during navigation. Each node signifies an intersection on the surface, and each edge represents a path. We will use dynamic weights to decide which path to take. The weights depend on the likelihood of a passenger being in an edge, the presence of a passenger at an edge, and the path to the drop off area. We will adjust weights as we pick up a passenger so the weight of the edge from which we picked up the passenger is decreased, and the weights of the edges toward the drop off are increased. This means that once we are at capacity, the weights will make it more favourable for the robot to navigate to the drop off area rather than pick up another passenger.

Storing the surface in memory allows for smarter decision making and will reduce our dependency on detecting IR signals to find the drop off area.

4 Chassis

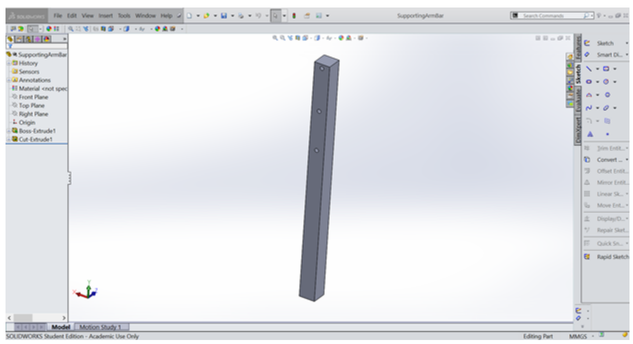


Figure 1: Model of the robot in its entirety

- The TINAH and other electrical components will be housed at the back of the robot for easy access.
- Before the final assembly, parts will be held together by screws to facilitate disassembly.
- The estimated mass of the robot is 8 lbs broken down as follows:
  - Arm: 2 lbs
  - Dust pans and dragging parts: ¡1 lb
  - Main body and circuitry: 5 lbs

4.1 Components

Refer to Appendix A for images of all parts

4.1.1 Arm

Name	Purpose	Machining	Assembly

Supporting Beam	Bear the weight of the arm and anchor it stably to the base	A square beam of material (or an I-beam) where holes are drilled through.	Will be anchored to the ground using 4 square brackets and hold up the arm using 2 connectors
Connector	To provide bearings and pivots for each of the arm1's parts	Laser cutting	Attached to the supporting beam by 3 screws
Top Rod	A rod used to provide the up and down motion in the sweep as controlled by a big gear	Laser cutting	To be fixed to a pivot joint on the connector and have a screw that is free to slide along the slot in the rod
Bottom Rod	A rod used to provide the out and in motion in the sweep as controlled by a big gear	Laser cutting	To be fixed to a pivot joint on the lower big gear.
Sweeper	Both rods will be attached by pivot joints to the sweeper. It will trace out a circular sweeping motion	"Laser cutting broom made from fingers of a rubbery material yet to be determined."	To be attached to the top and bottom rods by a pivot joint.

4.1.2 Dust Pan

Name	**Purpose**	**Machining**	**Assembly**
Pan	To carry and hold passengers from the pickup zone to the drop-off. Designed in a way that passengers can be swept into it like a dust pan.	A piece of sheet-metal to be cut on the waterjet cutter and then bent into shape using hand tools and machines.	Will be attached to the base of the robot by a pan-connector.

Pan connector	To attach the pan to the base of the robot in a way that the pan always stays as flat and close to the ground as possible.	A rubbery material yet to be determined that is cut into a narrow strip.	Glued to the edges of the pan and base of the robot.
Pushoff	A strip of material used to push the passengers off the dust pan and into the drop-off zone.	Waterjet cutting/laser cutting	Held to the back of the pan by an elastic band and winched forward by 2 pieces of string around either end.
Winch	A rod spun by a motor to pull the pushoff in the correct direction	2 laser cut pieces with a hole in them and a rod cut to size	Fastened to the base of the robot and spun by a motor at the back end.
Base	The base of the robot where all of the circuitry and components are housed.	"A waterjet cut piece of metal that is bent using hand tools and machines reinforced by several cross-bars along the underside."	"A solid base where many different parts are fastened using bolts glue and spot welding."

4.2 Redesign Potential and Flexibility

Where is this?

4.3 Estimated Final Specifications

Where is this also?

5 Drive and Actuator System

There are 8 actuators total in our design: a pair of geared Coleman motors to power the wheels (bidirectional), a pair of geared Coleman motors to move the arms (unidirectional), a pair of un-geared Coleman motors to power the pusher winches (bidirectional) and a pair of servo motors to lock the pushers in place.

5.1 Drive Mechanism and Transmission

There are two powered wheels, which are controlled independently to allow for tape following, turning and driving in reverse. In addition, there is an unpowered ball-and-socket roller to provide a third point of contact. To maximize control in tape following, the wheels were placed on the very back end of the chassis. To maximize torque while turning, the wheels were placed with the largest possible distance between them (12"). The roller was placed at the very front of the robot, along the centerline, to maximize its distance from the driving wheels and improve stability.

The placement of the wheels, drive motors and transmission is illustrated below:
//TODO: INSERT DIAGRAM + CALULATION

Therefore, in order to accelerate the robot at a maximum acceleration of $0.5\frac{m}{s^2}$, the drive motors must exert a torque of ___. This will consume ___ W of power. To maintain constant velocity, the motors must exert a torque of ___. This will consume ___ W of power.

5.2 Steering

The robot's pair or arms and passenger-collection pans allows it pickup and drop off passengers to either side without turning away from the tape line in the path's center. In addition, the robot will be able to drive in reverse, allowing it to enter and exit dead-end streets without needing to turn. Because of this, the robot will never need to turn under any circumstances other than at intersections in the path.

Therefore, in order to make a turn, the robot must be able to detect an intersection, right itself onto the correct tape line once the turn is complete, and be mechanically capable of turning itself. To detect the intersection, the robot will read the output of branch-detection QRDs placed near the front right and front left corners of the chassis. To right itself, it will rely on the normal tape-following QRDs.

The turning mechanism is illustrated below:
//TODO: INSERT DIAGRAM + CALCULATIONS

Therefore, in order to begin turning and maintain a constant angular speed, the motors must exert a torque of ___. This will consume ___ W of power.

Considering this and the previous constraints on torque calculated for driving and accelerating, the gear ratio should be approximately ___.

5.3 Arm Mechanism

The left and right sides of the robot both have an identical arm, so that passengers can be retrieved from either direction without changing the yaw of the arm. The arm is jointed and ends in a brush (made of rubber tines or fibres strong enough to push a passenger but flexible enough to give way when brought against a building or curb). The joint of the arm are designed so that, with a single rotation of the large, arm-supporting gears, the brush will trace out a horizontal path (allowing it to âœsweepâ passengers into the pans).

This mechanism is illustrated below:
//TODO: INSERT DIAGRAM + CALCULATIONS

Therefore, in order to move the arm through 1 complete cycle in 5 seconds (unobstructed by objects in path of brush), the motor must exert a maximum torque of ___.

5.4 Pan Mechanism

The left and right sides of the robot both have identical pans, which consist of a lightweight surface of sheet metal attached to the chassis by a narrow rubber strip. The pan also has a winch-powered pusher and pulley mechanism to expel passengers at the drop-off zone by pushing them out of the pans. In addition, if the pusher strip is held in place by a locking servo, the winches will instead pull the pans up slightly, pulling them off the ground to reduce friction and ensure that passengers don't fall out during transport.

This mechanism is illustrated below: (the pans are simple and required few calculation beyond basic size)
//TODO: INSERT DIAGRAM + CALCULATIONS

5.5 Motor Table

(All required values are estimated for 1 round of competition)

Motor type	Function	Required voltage	Required power	Required current
Geared Barber Coleman motor (FYQF 63310-9) x2 Drive individual wheel both forward and reverse	12V	(supplied by LIPO)	Driving: Accelerating: Turning: Stationary: 0 W Time spent in each state: D:A:T:S = 4:2:3:5,	TODO
Geared Barber Coleman motor (FYQF 63310-9) x2	Drive individual arm through its path cycle, forward only	12V (supplied by LIPO)	1 cycle: Approx. 20 cycles performed during 1 round	TODO
Un-geared Barber Coleman motor (FYQM 63100-51) x2	Turn winch to extend individual pusher (or lift pan, if pusher is locked)	12V (supplied by LIPO)	Lower pan: (approx. 10x / round) Raise pan: (approx. 10x / round) Expel passengers: (approx. 4x / round)	TODO
TowerPro 9g micro servo (SG90)	Lock pusher in place so that it can't be extended	5V (supplied by TINAH)	Lock/unlock: (approx. 10x / round)	TODO

6 Electrical Design

6.1 TINAH I/O Allocation

Type	Name	Use (Connected to)
Analog input	A0	Front left passenger-locating IR sensor PCB signal
Analog input	A1	Back left passenger locating IR sensor PCB signal
Analog input	A2	Front right passenger locating IR sensor signal
Analog input	A3	Back right passenger locating IR sensor signal
Analog input	A4	Left arm feedback potentiometer signal
Analog input	A5	Right arm feedback potentiometer signal
Analog input	A6	Unassigned (defaults to knob 6)
Analog input	A7	Bumper contact detection PCB signal (if unused, defaults to knob 7)
Digital output	0	Input of Left arm motor control PCB

Digital output	1	Input of Right arm motor control PCB
Digital output	2	Unassigned (defaults to Serial 1 - RX)
Digital output	3	Unassigned (defaults to Serial 1 - TX)
Digital output	4	Left front bumper contact switch
Digital output	5	Right front bumper contact switch
Digital output	6	Left rear bumper contact switch
Digital output	7	Right rear bumper contact switch
Digital output	8	Left arm brush contact switch (possibly redundant)
Digital output	9	Right arm brush contact switch (possibly redundant)
Digital output	10	Unassigned
Digital output	11	Left driving QRD PCB signal
Digital output	12	Right driving QRD PCB signal
Digital output	13	Rear rotation QRD PCB signal (possibly redundant)
Digital output	14	Left branch detection QRD PCB signal
Digital output	15	Right branch detection QRD PCB signal
Motor enable	PWM0	Unassigned
Motor enable	PWM1	Unassigned
Servo output	PWM2	Unassigned
Servo output	PWM3	Unassigned (also controls buzzer)
Motor enable	PWM4	Unassigned
Motor enable	PWM5	Unassigned
Direct motor outputs and indicators	Motor 0 to Motor 3	Unassigned (Barber Coleman motors used required more voltage than the 9V maximum the TINAH can provide)
Motor control output	Motor 0	Motor DIR, Motor !DIR, and Motor Enable pins to input of Left drive motor H-bridge PCB inputs
Motor control output	Motor 1	Motor DIR, Motor !DIR, and Motor Enable pins to input or Right drive motor H-bridge PCB inputs
Motor control output	Motor 2	Motor DIR, Motor !DIR, and Motor Enable pins to input of Left pan winch control PCB inputs
Motor control output	Motor 3	Motor DIR, Motor !DIR, and Motor Enable pins to input of Right pan winch control PCB inputs
Servo motor output	Servo 0	Signal to left pan locking servo
Servo motor output	Servo 1	Signal to right pan locking servo

Servo motor output	Servo 2	Unassigned

For the Electrical Design and the Wiring Table, please refer to Appendix B and C

7 Strategy, Algorithms and Software

7.1 Tape Following and Navigation

7.1.1 Machine State

There are two main states that our robot will inhabit for most of the duration of the competition - roam search empty, and roam search full - with the main difference between the two being the absence and presence of a passenger respectively.

When in roam search empty, which is the starting state of the robot, the robot will wander the playing field in search of a passenger using pre assigned weights for each path. Once a passenger is detected, the robot will attempt to pick up the passenger. If the attempt is successful the robot will go to roam search full state.

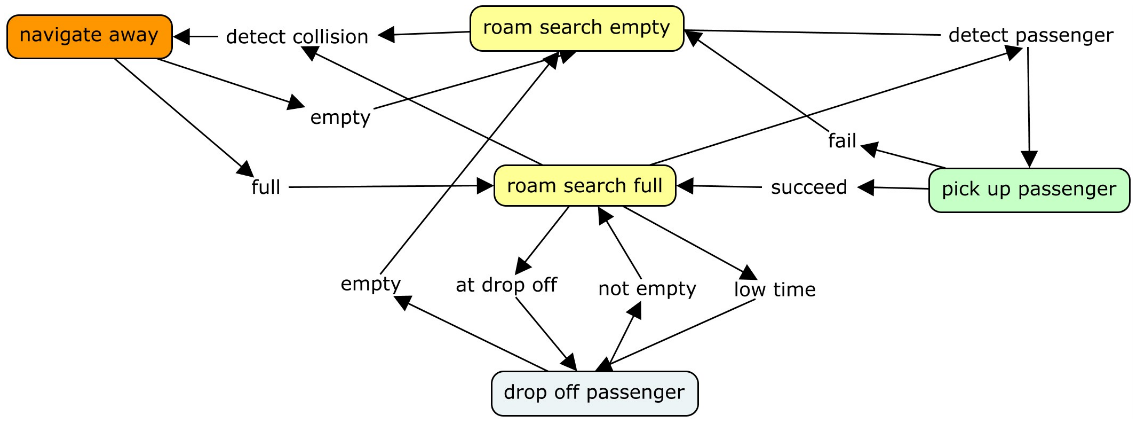
Every time a passenger is picked up, the weight of the path from which the passenger was picked will be reduced and weights leading to the drop off area will be increased. In roam search full, the robot will still be able to detect passengers and pick them up.

Eventually, with enough passengers, it will be more favourable for the robot to go to the drop off area. The weights of the path will reflect this since the weights of the paths on the playing fields are adjusted each time a passenger is picked. Since our robot will have passengers on both sides, it is possible that the robot is still full after the drop off operation. At this state, the robot will return to roam search full. If the robot is empty it will return to roam search empty.

In the last 30 seconds of the competition, if the robot is in roam search full state, weights will also be adjusted to favour the drop off area. While in roam search empty the weights of the paths reflect the probability of a passenger, in roam search full they also represent the urgency of a drop off - whether due to capacity or due to time.

At any time, if the robot senses that a collision is eminent, it will stop its operation and attempt to navigate away from the collision.

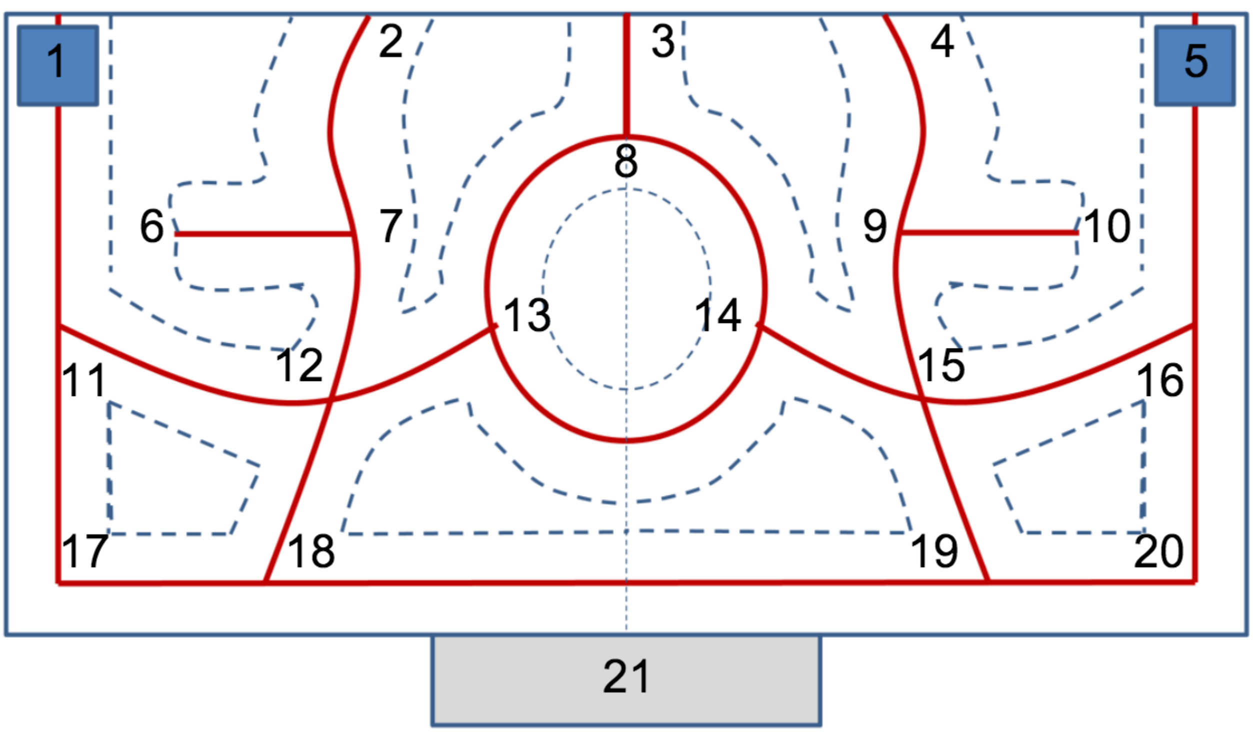
Please refer to the state diagram below for a summary.



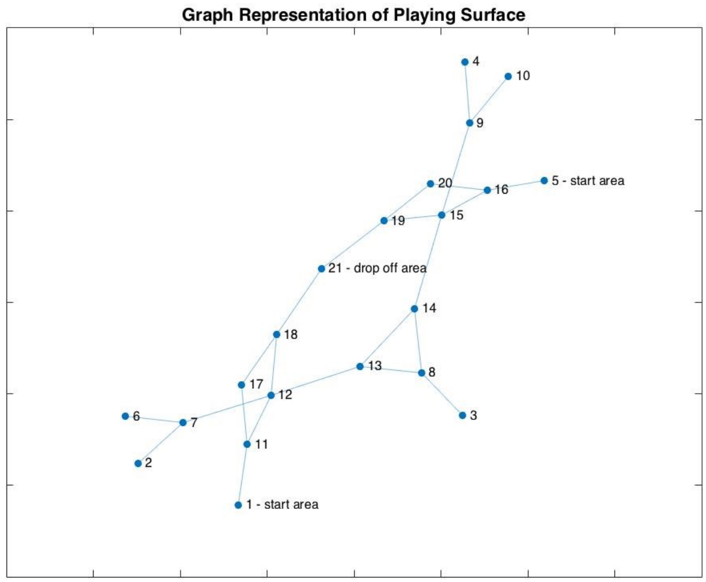
We will use PID control to follow the tape on the playing surface. We will finely tune the proportional, integral, and differential error gains with much data and experimentation.

7.1.2 Graph Based Navigation

We plan on storing a discrete graph representation of the playing surface in memory on the TINAH. Each intersection on the playing surface will be a node, and each path between the intersections will be an edge. The graph will be weighted, but not directional. The weights of the graph will characterize the likelihood of a passenger being on a certain edge.



The weights of the graph will also be dynamic, changing based on the state of the robot. The initial weights will be based on the number of possible locations for a passenger. Once we pick up a passenger from a certain edge, the weight for the edge will decrease. If we the robot has a passenger, the weights for the edges in the shortest path to the destination will be increased. The weights will also be ignored if the robot senses a passenger's beacon at some edge.



By storing the playing surface in memory, we hope to reduce the robot's dependency on IR signals for self-location and navigation. Storing the playing surface is also advantageous in making decisions based on history and location.

7.2 Passenger Detection

The robot will use IR signals to detect passengers. As mentioned before, if a passenger is detected at any time, the weights of the graph will be ignored and the robot will attempt to pick up the passenger.

7.3 Collision Detection

If the robot detects a collision, it will escape whatever state it is in and attempt to navigate away from the collision.

8 Risk Assessment and Contingency Planning

8.1 Risk Assessment

Risk Condition	Probability of Occurrence	Impact to Project	Change to Work Plan	Expected Date of Risk Decision
Robot get's lost in map due to failure to detect the presence of an intersection	(Based on Jon's expertise) Unlikely to occur so long as speed is kept within a reasonable range	Robot will be unable to return passengers to base during the competition	Create a structure that reaches the height of the destination beacon and	Week two of robot construction
During the competition a passenger falls out of its containment area during turning or otherwise	Dependant on the rigidity and geometry of container	Robot will loose the current passenger, but will be able to continue thereafter.	Minor Problem - increase side wall length Major Problem - further increase the walls of the containment area while redesigning the arm to ensure the passengers can land in this modified container	Week 2 of robot construction

During collision on competition day the extruding flaps in our design are more likely to be damaged than the chassis. If the flaps are damaged during a collision, the robot's passenger containment mechanism could be compromised	It is likely that during a collision, these low-hanging flaps will be impacted, however, by using stronger materials, and ensuring the flaps have reliable fixtures joining them to the main chassis we can mitigate this risk.	Minor damage will likely cause little impact on the robot's functionality, except for perhaps decreasing the integrity of the passenger containment area, and thus increasing the risk of passenger loss	Increase the number of collision sensors to prevent collisions in the first place	Final week of robot construction
Risk that the maximum reach of the arm will limit our capacity to pick up passengers when they are far away	Depending on the geometry of the track and placement of the passengers.	Inability to retrieve passengers located too far from the midline of the track	Changing the arm's length and range of motion. This will be made easy due to the arm's modular design	Decision will be made once track has been finalized
Risk of catching or stalling the arm on obstacles or buildings when operating	Very unlikely because the arm only operates when the robot is stationary, and the brush is designed to give way to obstacles.	Most likely temporary disruption of the arm's or robot's motion, possibly moderate damage to the arm.	Changes to the flexibility of the brush or design and range of motion to avoid future catching	Decision can be made once design is finalized while testing robot on track.

Risk that the arm's sweep knocks the passenger away from the arm's reach, fails to push it all the way to the pan, or fails to push it over the pan's edge	Probably unlikely given the arm's motion shouldn't allow this. It is difficult to say without testing	Failure to retrieve the passenger, possibly knocking it into the path or off the arena	Change the structure of the brush and motion of the arm. If necessary, add more degrees of freedom to the arm	During the testing and development of the arm over the next few weeks

8.2 Mitigation and Contingency Planning

In order to prevent our robot from getting lost, due to it's lack of a destination beacon detector, we will ensure that we have a large safety factor on our tape IR detection. We will engineer our navigation systems such that it can perfectly detect intersections while traveling at top speed. This will greatly mitigate the risk of getting lost due to a failure of the intersection detection mechanism.

Furthermore, if time permits, a beacon detector may be implemented in order to verify the state of our robot's navigation system.

We can mitigate the risk of losing passengers by ensuring that we use a material with a high coefficient of static friction for the surface of our passenger containment area.

By improving our collision detection systems we can reduce the risk of damage due to collision. Furthermore, by protruding the anterior and posterior portions of our robot, we can ensure that they take the brunt of most impacts.

To mitigate the risk of a limitation due to arm length, we will ensure that our design will be as modular as possible

9 Tasklist, Major Milestones, Team Responsibilities

9.1 Task List

9.1.1 Construction

1. Construct chassis (without arms) and mount drive and transmission systems
2. Assemble all QRD mechanisms and affirm they function properly
3. Attach QRD and motor electrical mechanisms to chassis, achieve tape-following

4. Attach functional collision-detection bumpers to chassis
5. Assemble arm, confirm it retrieves passengers properly by itself
6. Assemble and attach pan mechanism to chassis, confirm it lowers/raises and pushes properly
7. Combine all elements into fully functional robot, affirm that all components still work when operating simultaneously

9.1.2 Software Development

1. Develop and optimize tape-following software for speed, stability and corner-following
2. Develop an internal representation of the playing surface
3. Write the code to actuate the arm
4. Implement graph based navigation
5. Develop collision response software and confirm it functions in all circumstances

9.1.3 Interfacing, Testing and Refinement

1. Successfully detect passenger at a distance, navigate to passenger and retrieve passenger consistently for a variety of passenger locations
2. Successfully navigate to destination area and drop off all passengers consistently
3. Successfully respond to collisions during every phase of operation
4. Optimize competition routine for number of passengers retrieved per unit time

9.2 Miltestones

1. Each independent component is fully functional
2. Having a fully functional 'Das Pan', containing all complete modules

9.3 Team Responsibility

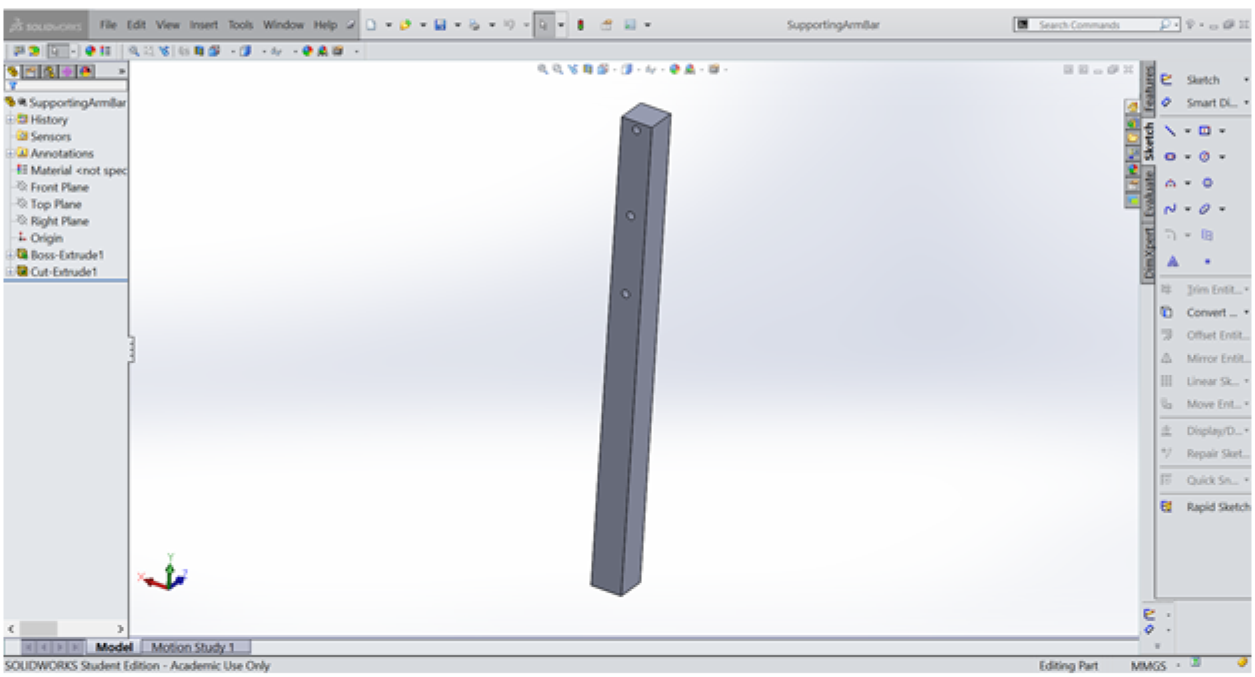
**gannt

10 Document Contribution Summary

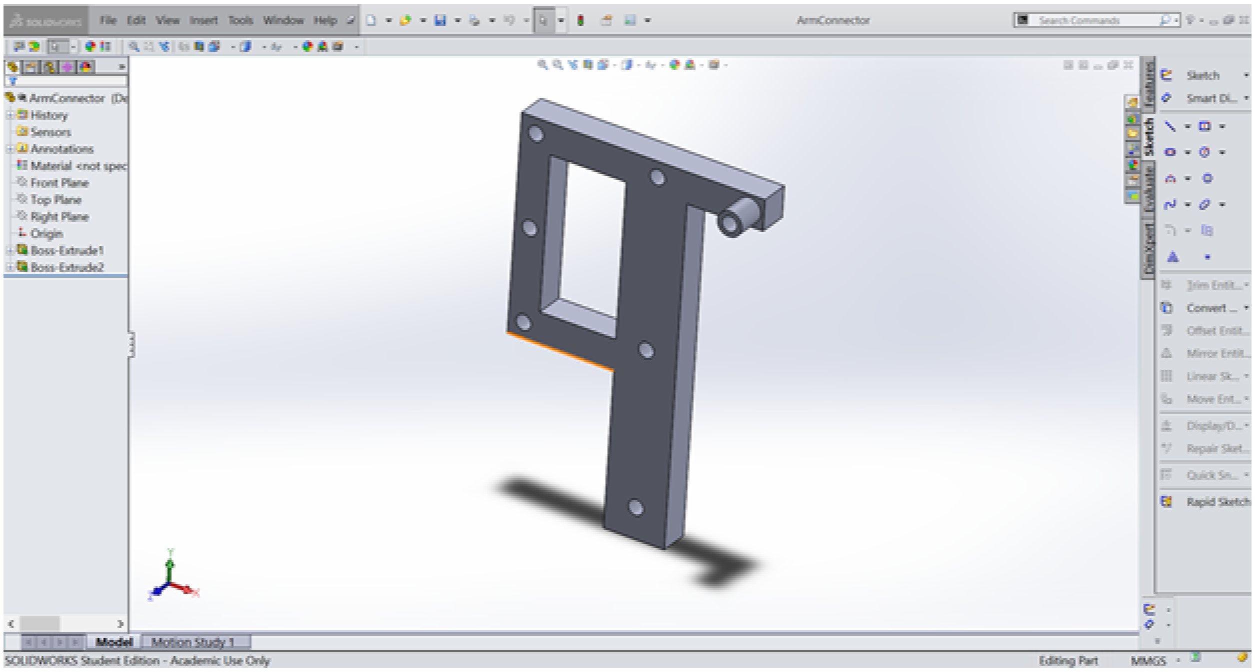
Document Section	Draft Writers	Editors
Executive Summary	Justin	Rahat
Preface	Justin	Justin, Rahat
Overview of Basic Strategy	Rahat	Justin
Chassis	Andrew	Justin, Rahat
Drive and Actuator Systems	Andrew, Alex	Justin
Electrical Design	Alex	Justin
Strategy Algorithms and Software	Rahat	Justin
Risk Assesment and Contingency Planning	Justin	Rahat
Tasklist	Justin	Alex , Rahat
Appendix A	Andrew	Justin

A Solidworks Models of Parts

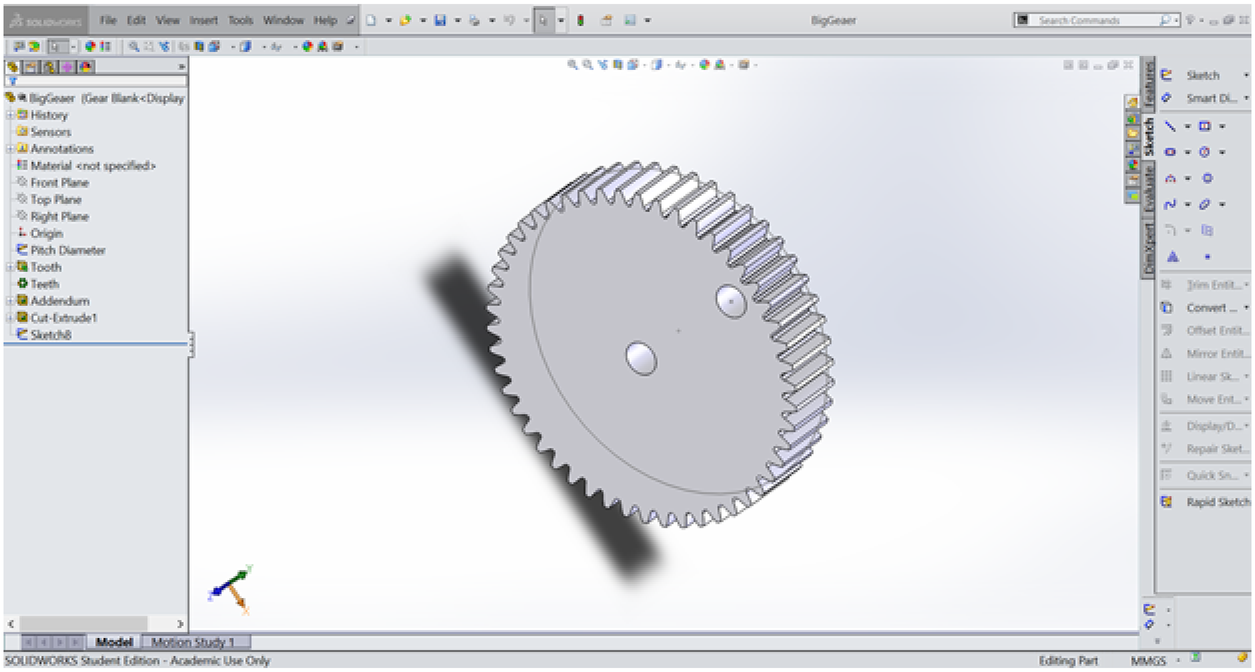
A.1 Arm



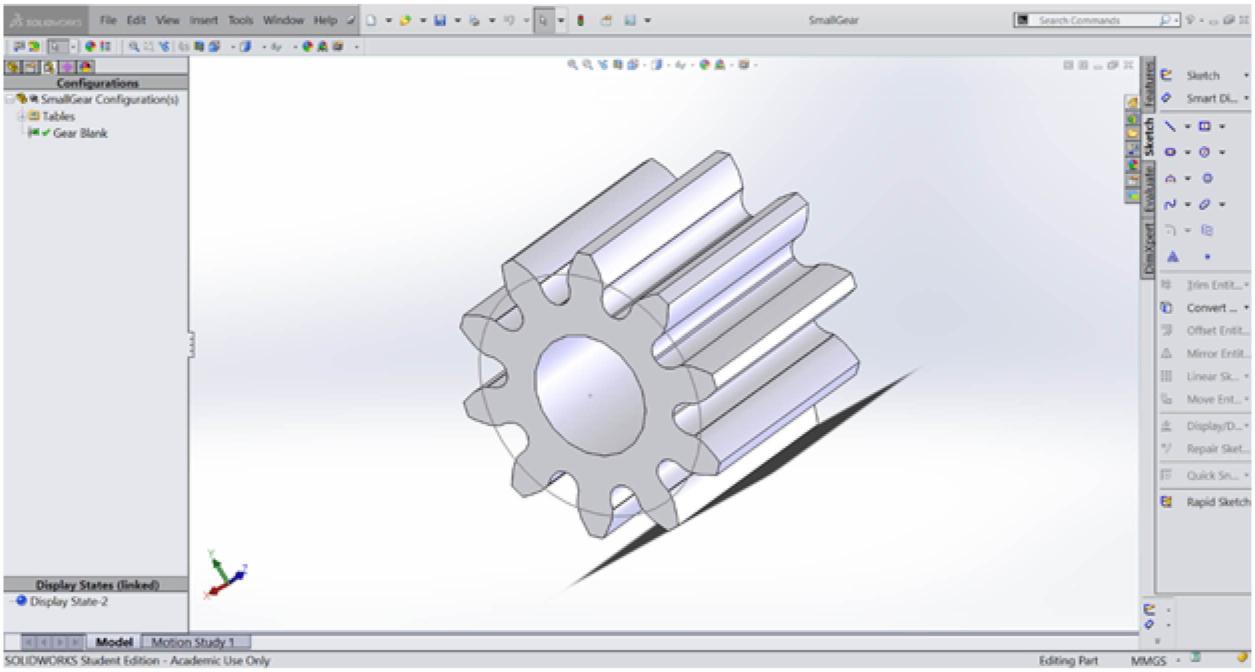
A.1.1 Connector



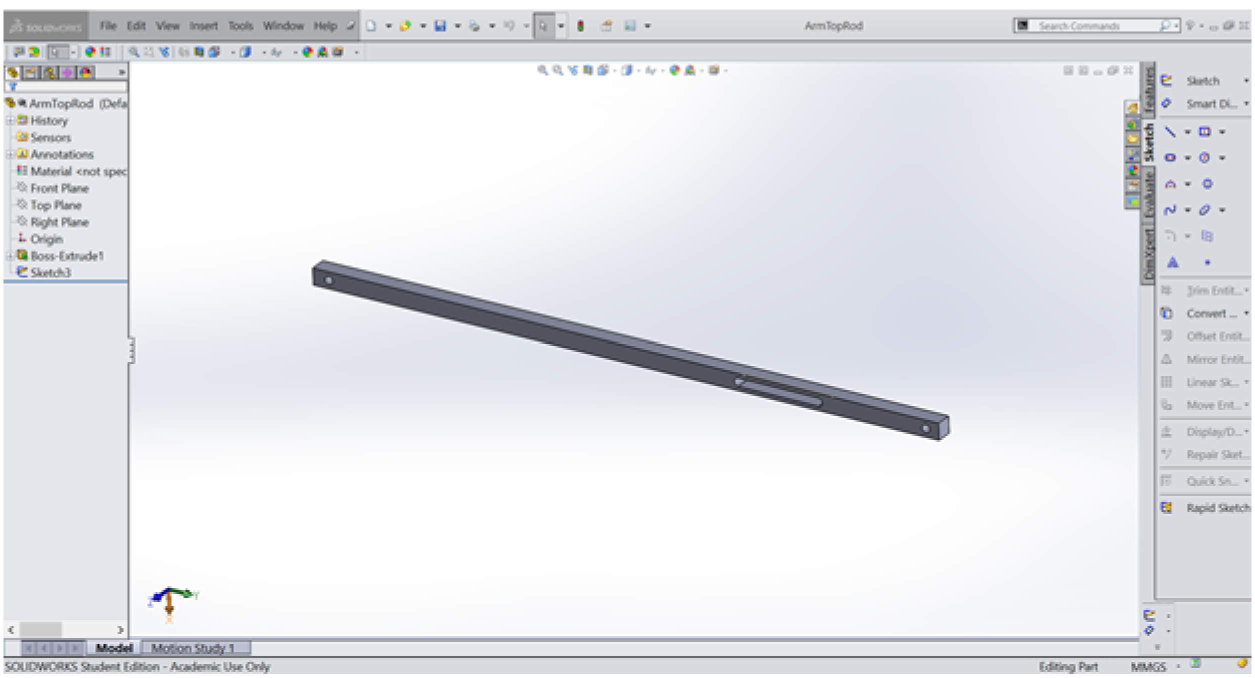
A.1.2 Big Gears



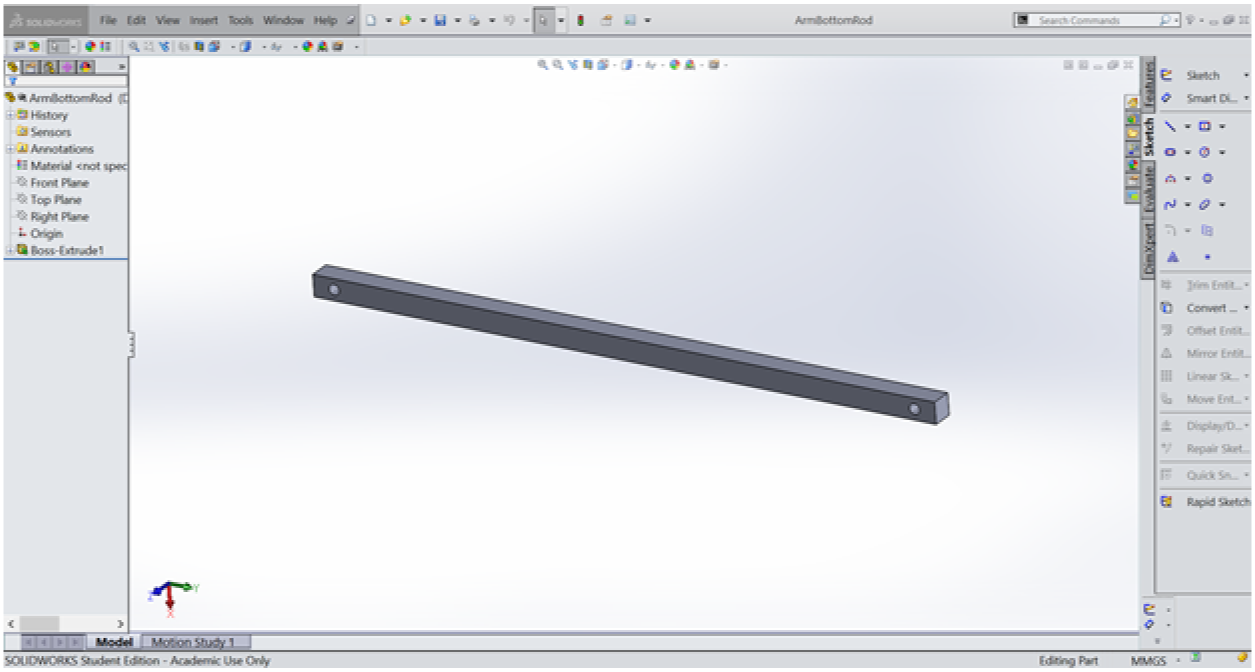
A.1.3 Small Gears



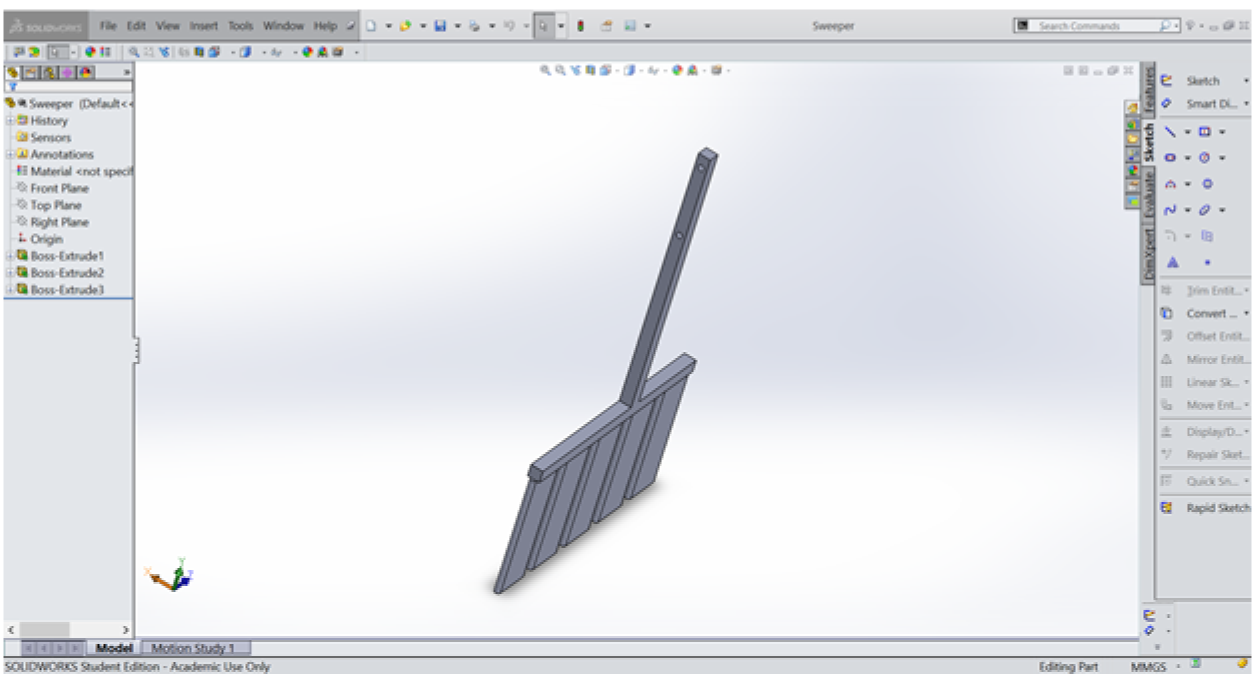
A.1.4 Top Rod



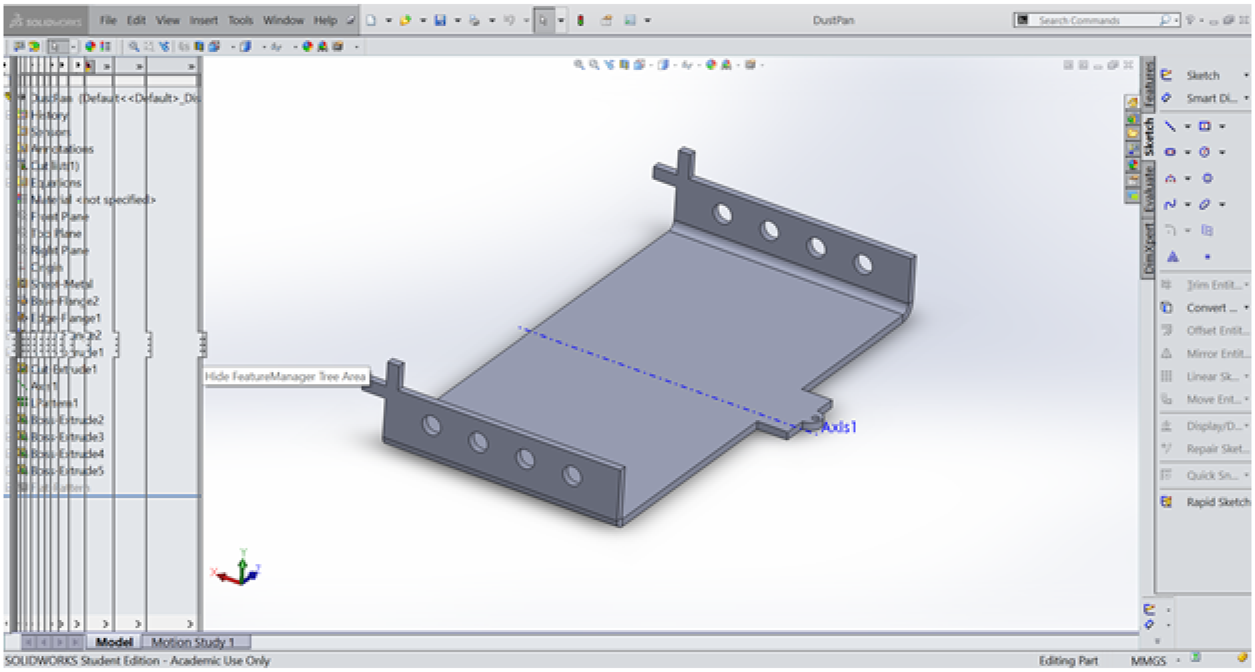
A.1.5 Bottom Rod



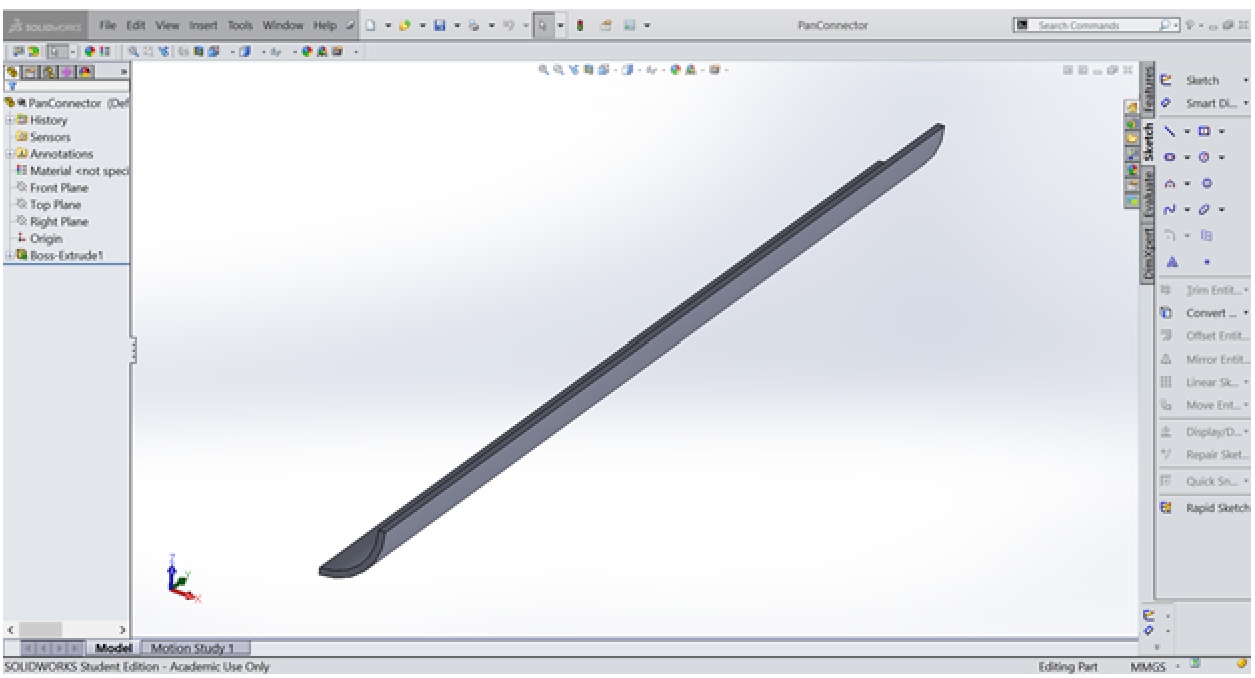
A.1.6 Sweeper



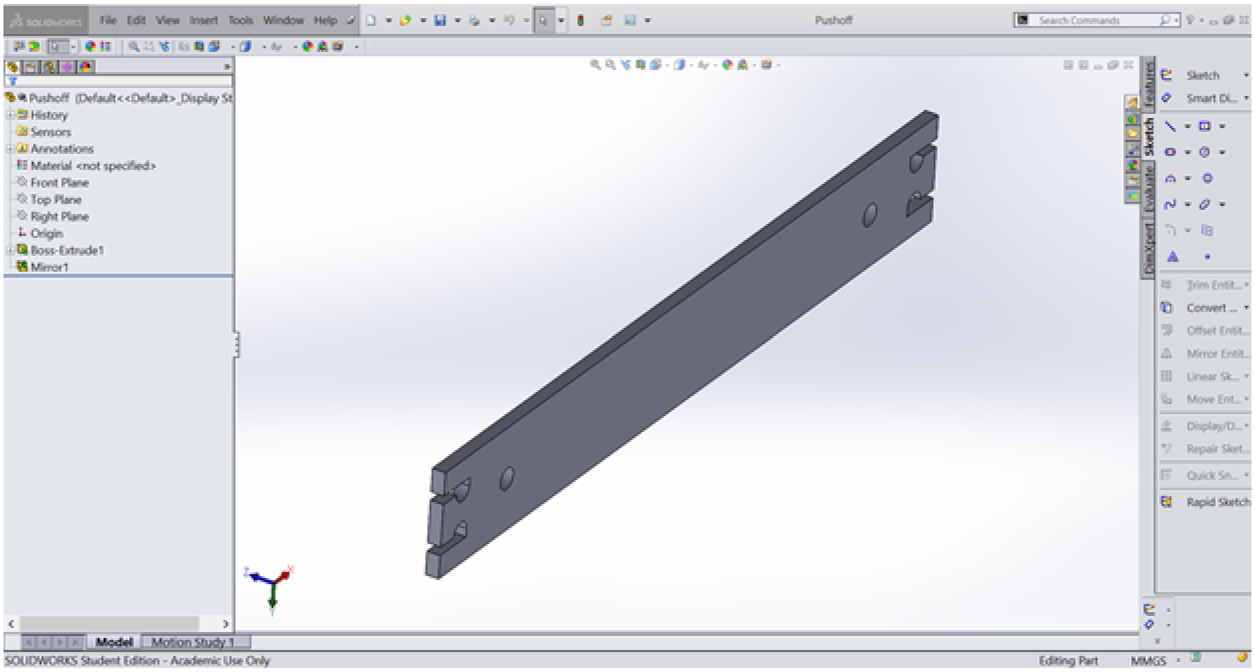
A.2 Dust Pan



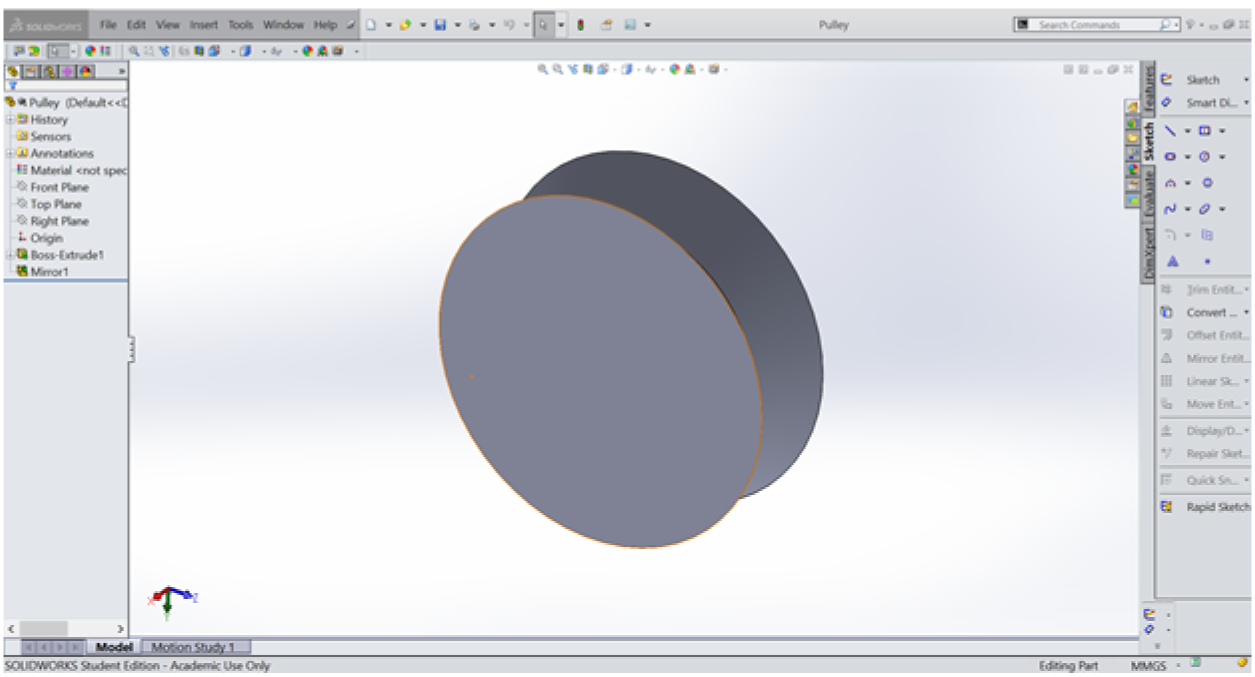
A.2.1 Pan Connector



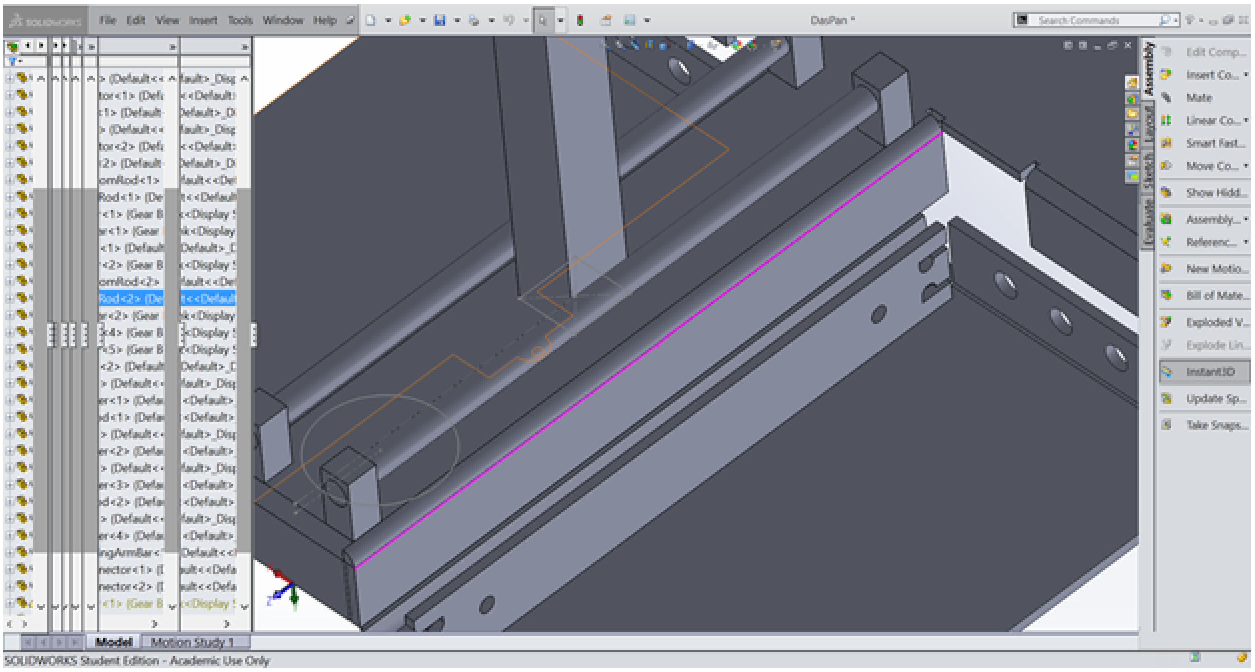
A.2.2 Push-off



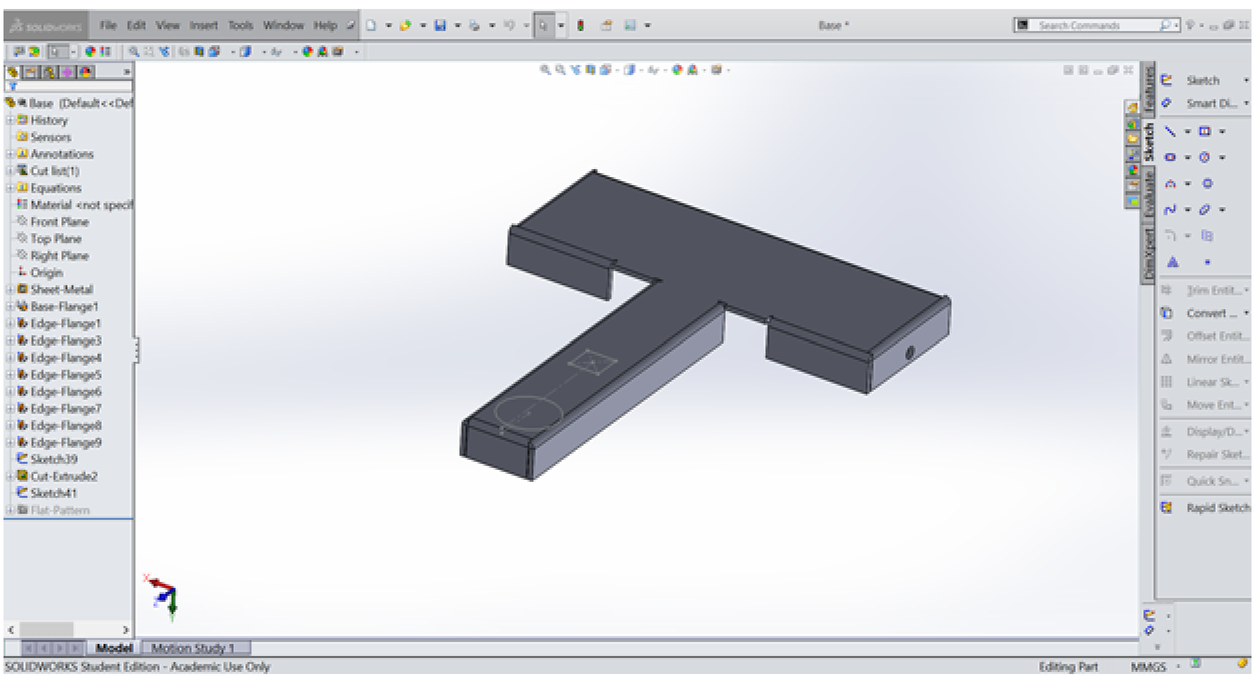
A.2.3 Pulleys



A.2.4 Winch



A.2.5 Base



B Electrical Design Tables and Schematics

PCB name and number	Function	Material and Size	Connections
Passenger-locating IR sensor PCB X4 identical copies: • Front left • Back left • Front right • Back right	Read directional IR levels at sensor, filter out noise and DC components of signal, amplify 1 kHz component of signal, convert to DC. Output: DC analog signal proportional to sensor distance from IR emitter	- standard PCB backing - front copy and back will be wired onto the same 3’’ x 2’’ board (making for 2 boards total)	For each board (x2): GND (MTA-100 connector) +5V (MTA-100) +15V (MTA-100) -15V (MTA-100) IR sensor signal (x2) (from IR sensor) Output signal (x2)(MTA-100)
QRD PCB X4 identical copies: • Left driving • Right driving • Rear rotation • Left branch detection • Right branch detection	Read reflectivity of ground beneath QRD sensor, compare to fixed to produce digital signal. Output: DC digital signal - +5V if sensor is above tape, Ground otherwise.	- standard PCB backing - all PCBs will be wired onto the same 4’’ x 2’’ board	For board (x1): GND (MTA-100) +5V (MTA-100) QRD signal (x4)(from QRD) Output signal (x4)(MTA-100)
Bumper contact detection PCB: X1 copy	Reads the state of 4 switches representing the positions of bumpers (open: uncontacted, closed: contacted), converts to single analog output Output: analog resistor ladder signal describing state of bumpers	- standard PCB backing - a single 1’’ x 1.5’’ board	For board (x1): GND (MTA-100) +5V (MTA-100) +15V (MTA-100) -15V (MTA-100)

Figure 2: Electrical Design Table

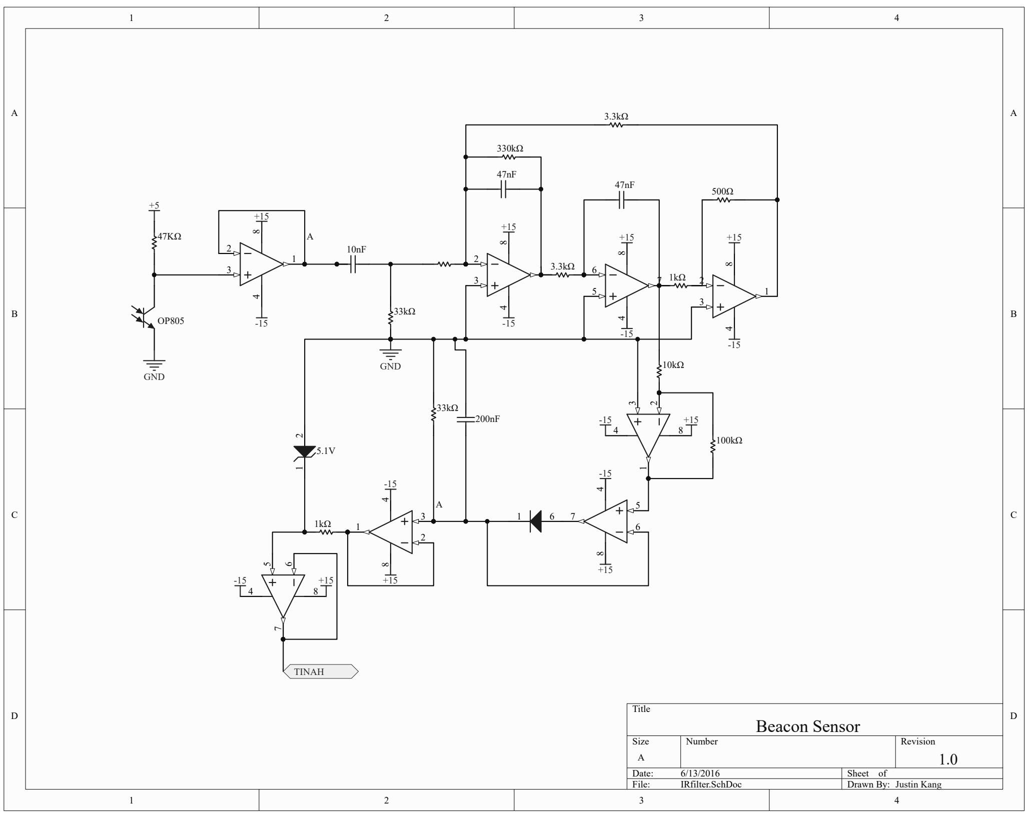


Figure 3: Beacon Sensor Schematic

Wiring harness	PCB connections	TINAH connections
Passenger-locating IR sensor bundle X2 bundles: • Left side • Right side (Use shielded wire)	Terminals will be soldered to male headers on the PCB. MTA-100 connectors attach the wire bundle to the headers (specific terminals listed in PCB table)	Output signal, +5V and GND will be soldered into three connected male header pins that can be plugged into the TINAH. +15V and -15V will be connected to the LIPO
QRD bundle X1 bundle (Use shielded wire)	Terminals will be soldered to male headers on the PCB. MTA-100 connectors attach the wire bundle to the headers (specific terminals listed in PCB table)	The output signal, +5V and GND for each QRD will be soldered into three connected male header pins (each) that can be plugged into the TINAH
Bumper contact detection bundle X1 bundle (Use shielded wire)	Terminals will be soldered to male headers on the PCB. MTA-100 connectors attach the wire bundle to the headers (specific terminals listed in PCB table)	Output signal, +5V and GND will be soldered into three connected male header pins that can be plugged into the TINAH. +15V and -15V will be connected to the LIPO
Pan winch Hi-bridge bundle: X2 identical copies: • Left side • Right side (Use shielded wire)	Terminals will be soldered to male headers on the PCB. MTA-100 connectors attach the wire bundle to the headers (specific terminals listed in PCB table)	Motor DIR, Motor !DIR, Motor enable and GND will be soldered into a group of connected male header pins that can be plugged directly into the TINAH. The +15V will be connected to the LIPO
Drive motor H-bridge bundle: X2 identical copies: • Left side • Right side (Use shielded wire)	Terminals will be soldered to male headers on the PCB. MTA-100 connectors attach the wire bundle to the headers (specific terminals listed in PCB table)	Motor DIR, Motor !DIR, Motor enable and GND will be soldered into a group of connected male header pins that can be plugged directly into the TINAH. The +15V will be connected to the LIPO

Figure 4: Wiring Table