AP Physics C

Mr. van Bemmel

Documentation

Rudimentary Spacecraft Guidance System

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Prospectus and Planning

- Guidance systems are an integral part of many complex vehicles, including aircraft & spacecraft
- They allow for a proper understanding of measurement
- of various important maneuvering data
  - this includes position & velocity
- This enables operators & computers to monitor the movement of the vehicle, and if needed, make correctional changes
  - for spacecraft in particular, it is common to employ an Inertial Navigation System (INS) which uses an inertial frame such that tracking the movement of the vehicle is not dependent on external objects or references
  - to accomplish this devices such as a computer and Inertial Measurement Units (IMUs) are combined
  - Typically, IMUs may include components such as gyroscopes & accelerometers which collect different data & send it to computers that store & process it
  - this processed data can then be used to create a navigation path or make necessary

corrections to ensure that the spacecraft is headed to its desired destination
- Traditionally in the past, IMUs have been an important tool for the Apollo missions
  - it utilizes a 6 degree of freedom system in three axes of rotation & linear movement
  - Since the system uses gyroscopes & gimbals, it avoids the wear & tear of a gear system which may have been used instead
- for this reason, the IMUs used by the Apollo missions were a reliable back-up navigation system for when the spacecraft is out of direct contact with the Earth-based team
  - The IMUs aboard the mission used three gyroscopes & three accelerometers & an optical measurement system
  - it was found to be an accurate source of orientation & location for the crew
- outside of spacecraft missions, IMUs are a common technology used in everyday devices such as pedometers, GPS, and drones.
- many are also in our smartphones

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- Scope of Project
  - while a fully fledged IMU would have many accelerometers & gyroscopes used for linear and angular measurements, our project only needs to measure angular measurements
  - the guidance system will focus on 3 identical single axis gyroscopes which informs the user of roll, pitch, and yaw in real time
  - Results will be displayed on the screen & can be manifested physically through the flaps of the system
  - the main components needed to be designed are the gyroscopes which detect changes.
  - the gyroscope will be constructed from PVC plastic & has a colour sensing mechanism
    - there is a budget constraint of $175 CDN
  - we also lack specialized equipment such as metal-working machinery
    - this also limited the amount of materials we could use
  - finally, time constraints also determined which ideas/plans were feasible
    - extremely complicated system could not be built with our limited expertise

- despite the budget & other constraints, the following proposed design of a spacecraft navigation system is well within the constraints & achieves the fundamental purpose of displaying 3D corrections that are needed to be made to the spacecraft when it is rotationally moved from its initial position

- Theory
  - Gyroscopes
    - the basic premise of the project is to find the position of the spacecraft in all rotational axes
    - through physical maneuvering & handling, lab technicians would orient the spacecraft in various directions
    - from this, the rotational information must be relayed back to the computer which would send the information for auto-corrections to be made by fins attached
    - the foundation of measuring this rotational motion is done by the 3 gyroscopes attached within
    - gyroscopes are devices that consist of discs mounted so that a rapidly spinning axis is free to alter its direction
    - as such, the orientation of the spin axis is not affected by the tilting or the mounting

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- this is extremely helpful as the spin axis can be referenced by an inertial frame
- wrt to the gyroscope, once a gyroscope spins, the spin axis will keep pointing in the same direction
- the gyroscope is mounted w 2 gimbals which supports & allows the rotation of the wheel in one axis
- the traditional gyroscope consists of a set of gimbals where they are mounted on one another in orthogonal axes & allows the inner gimbal to remain inert when the orientation is changed
  - the outer gimbal has one degree of rotational freedom & is used as the gyroscope's frame and is in its own plane
  - the middle gimbal has one more axis of rotational freedom & is perpendicular to the pivotal axis of the outer gimbal
- In our gyroscope, the outer gimbal will be locked as the stationary housing box
- this leaves the gyroscope w one degree of freedom

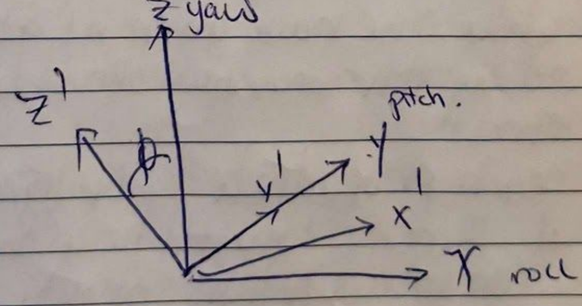
one will mount two gimbals w their axes at right angles to one another on a platform & place the platform inside a set of gimbals

- the platforms w remain rigid as the gimbals rotate in the desired axis
- a rotational motor is attached to the inner gimbal & is also the spin axis, which is placed perpendicular to the middle gimbal
- the motor will spin around this axis & remain inertial as the gyroscope moves in different axes
- it is free to turn in any direction around the fixed point
- additionally, the addition weight from the motor on one end of the spin axis must be balanced by a counterweight on the other end
- using the conservation of angular momentum, we see that the net angular movement at $t = 0s$ must $= t = 120s$.
  - from this, we know that if the net external torque acting on a system is 0, the angular moment of the system w remain constant no matter what changes take place within the system
- if we take the spin axis, we see that a rapidly spinning ~~gyroscope~~, changes in one rotation of the inertial frame result in other gimbals to move

- however, we will not see any rotational changes on the spinning axis
  - this is because one cannot put torque on the spinning axis, assuming no frictional losses.

- Inertial frame
  - In its original motion, the spacecraft can change its rotational orientation
  - however, due to the conservation of angular momentum, the spin axis of the gyroscope will always point in the same direction relative to the inertial frame of the Earth.
  - Due to the spacecraft existing in its own inertial frame relative to the Earth, a fiducial point must be set
    - the reference point will be set at point inside the box
      - its initial angular position (θ, Ψ, Φ) on the x, y & z axes will be calibrated to (0,0
  - any movements thereafter will be as a rotation relative to the initial orientation on the 3 principle axes: roll, pitch, & yaw
  - for this project, the spacecraft will be situated inside the classroom which can be counted as an inertial reference frame

- for an actual application of this gyroscopic inertial navigation system, the spacecraft would be in a moving frame relative to the center of the Earth or Sun
- to simulate the realism of the project, the fiducial is set to the end of the end effector.
  - Since this point is at the origin, any rotation of the spacecraft will not change the end effector's location in 3 space
- however angles for roll, pitch & yaw must be calculated
  - also, it must be noted that rotation on the y-axis, for example, is represented by the angle between the initial z axis to the new one
- pitch is characterized by ϕ
- similarly, roll is characterized by the angle ψ between the initial & final y-axes
- lastly, yaw is characterized by the angle θ between the initial & final x-axes



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- Arduino & Raspberry Pi
  - the spacecraft will have two microcontrollers which help in collecting, processing, & communication of data
  - an arduino Mega w connect each of the motors powering the gyroscope & will be attached to any additional sensors
  - the information collected by the Arduino will be processed & sent to the Raspberry Pi which is connected over a USB B cable to USB A
  - the Raspberry Pi will then communicate the data wirelessly over Bluetooth to the software on the controller's computer & display results accordingly

- Colour Sensor
  - the colour sensor on the guidance system comprises of a 8x8 grid of photodiodes which gives a current reading
  - a quarter of these have no filter on them while some have green, red, & blue on top
  - doing this separately allows for colour in RGB format
  - each photodiode reads light in front of it & current is converted to a frequency that corresponds to light intensity

- on the colour sensor there are X LEDs which are angled inwards & illuminate the surface so colours can be accurately taken in the dark & there is consistency in the lighting environment for each reading

- Fin Gimballing & corrections
  - the success of the final design is determined by the spacecraft ability to self correct its flight mid-course when large rotational movements are imparted on it
  - the info process is as follows: first, the three gyroscope's spin axis will remain in place as the spacecraft is shifted in all 3 axes of rotation
  - then, three separate colour sensors measure the $\theta°$ of rotation from the spinning gimbals.
  - the Arduino w/ process this info & send it to the fins
  - the angles w/ be flipped in their directional motion so corrections must be made to stay level
  - this info is sent to the servo motor controlling the fin's angle
    - then the fins are adjusted accordingly
  - the fin & their corrections will be set to the initial starting point.

4. Build Specifications and Diagrams

a. Exterior of Spacecraft

The spacecraft guidance system will be enclosed in a sample spacecraft, which in this case was chosen to be a space telescope. Not only does this represent the real-world significance and applications of similar navigation systems, but also communicates the importance of such devices in furthering our understanding of outer space. The body of the spacecraft was chosen to be a rectangular box, similar to other telescopes, and three flaps decorated as solar panels will be attached to either of the long sides.

The choice of painting horizontal lines on the flaps to symbolize solar panels as they rotate to show the corrections computed by the guidance system. This is consistent with how space telescopes orient their flaps to receive the most sunlight. Each flap corresponds with a certain axis, and the flaps are attached to a motor to enable them to adjust their position.

Lastly, the approximate dimensions for the rectangular cardboard box enclosure, after taking into account the dimensions of the interior parts, are 55 cm x 20 cm x 20 cm. In addition, the rough dimensions for each 'fin', or cardboard flap would be 50 cm x 15 cm, 10 x 15 cm, and 30 cm x 15 cm, for the x, y, and z-axis fins respectively.

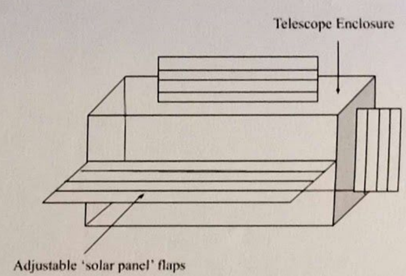

Fig 2. Side View of Exterior. Shows the telescope enclosure in relation to the adjustable flaps, decorated to represent solar panels. The cardboard box houses the other design elements outlined later. This diagram has slightly modified dimensions in order to give a full view of parts.

c. **Gyroscope System**

For the interior of the gyroscope enclosure, a gyroscope-like device would be created in order to mechanically show the change in orientation within each axis. This gyroscope would feature a rotating gimbal. A plastic rectangular frame, which would be constructed especially for the guidance system, and would have the dimensions of 10cm x 10cm x 1 cm. The gimbal should be attached to a central strut made from a wooden dowel that would connect the top of the plastic frame to the bottom. An electric motor, which was chosen to be a full rotation servo motor, would power the system. The two wires from the motor would be attached along the gimbal to prevent interference and would exit through a small incision made in the back wall.

In order to counter the effects on rotation the addition of the mass of the motor has, a counterweight constructed from a wooden block with a hole drilled in the middle would be attached on the other side of the rotor. The servo motors will be weighed during the building and testing procedure; the counterweight must also be uniformly distributed in mass and have a similar size to the servo motor to maintain a stable centre of mass. The counterweight would be made of wood or plastic and made to be the same mass as the motor. The dimensions and specifications of the counterweight would be determined during the testing phase. A wooden disk, of approximately 9 cm in diameter, would be cut with a saw from a wooden block. A hole would be drilled in the middle with a diameter of 3.1 mm (1/8") to ensure that the rotor functions properly. The motor, counterweight, and wooden rotor would be attached to the central wooden dowel with strong, adhesive glue.

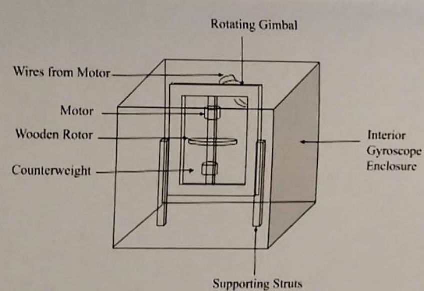

Fig 5. Front View of Gyroscope System in Interior Gyroscope Enclosure. This diagram only displays the parts related to the gyroscope, or mechanical portion of the detection of change in orientation, and omits the sensing parts discussed in the following section. It includes the gimbal, motor, wooden rotor, counterweight, wires, and supporting struts.

d. Sensing System

In order to sense the changes in rotation produced by the gyroscope in response to the change in orientation of the spacecraft, a colour-sensing system was placed inside the enclosing cube. The principles of such a system were explained in the section (3.d). Essentially, a TCS 3200 Colour Sensor with dimensions of 28.4 mm x 28.4 mm (1.12" x 1.12") would be attached directly above the rotating shell. This would be exactly 7.25 cm from one edge of the cube, ensuring that the sensing can be calibrated correctly. In addition, a ring made of cardstock with dimensions of 4.5 cm in radius would be attached orthogonally to the gimbal along the central wooden dowel.

Pasted directly onto said ring would be a gradient-coloured paper, printed to size, that would cover the entire surface area of the object. The colour gradient would begin from black, with an RGB red value of 0, and gradually transition to a value of 255, which would be pure red. One edge of the paper, the red colour value of 0 would be placed directly below the colour sensor on the shell and the other edge would be secured around the shell.

Thus, when the gyroscope, and thus, cylindrical shell rotates, the sensor would sense the colour value of the portion of the paper directly beneath and relay the new colour value to the Arduino. Based on the change from the initial colour reading to the end colour reading, the angle of rotation and angular velocity can be determined. The sensor chosen is equipped with LED lights, as to ensure accuracy of detection. The wires from the colour sensor would connect to the Arduino controller from wires protruding through the back of the cube.

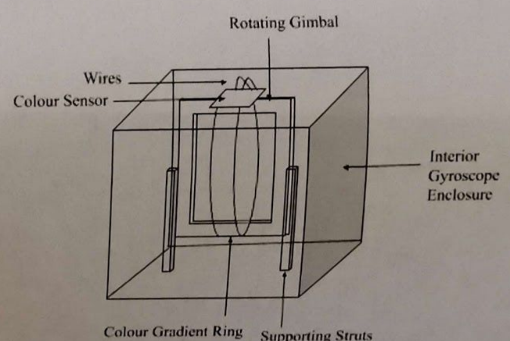

Fig 6. Front View of Colour Sensing System in Individual Gyroscope Enclosure. *Shows the colour-sensing, and gradient scale mechanism set up in order to accurately obtain the amount of rotation done on the wheel, and the change in angle. Set up includes a colour sensor, cardstock ring covered with gradient paper, and wires to the Arduino. The sensor is enlarged in the diagram for clarity.*

e. Overall Interior of Gyroscope System

Previously, only either the gyroscope or colour sensing systems were fully shown to avoid confusion. However, now that both have been explained, the following diagram shows how they would interact when merged. Both the wires from the colour sensor and the electric motor would exit the interior through a small incision made at the back to reduce potential light interference. In addition, the wires would be attached firmly to surfaces with duct tape in order to avoid damage and to improve the overall efficiency and elegant design.

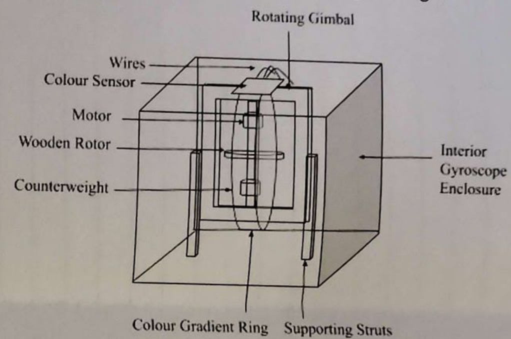

Fig 7. Front View of Entire Interior Gyroscope Enclosure. Displays both the mechanical gyroscope system as well as the unique colour-sensing mechanism devised. It obtains a measurement for the change in orientation on that particular axis and relays it to the external Arduino. The same design is repeated for all three axes.

f. Adjustable Flap System

In order to demonstrate the correction calculated by the gyroscope and colour sensing system, each of the three 'solar panel' flaps would replicate the rotation along each axis, but reversed, in order to 'correct' the orientation of the spacecraft. Thus, a 120-degree servo motor would be attached to the interior of each flap where it connected to the exterior cardboard enclosure which would allow for this to be possible. The dimensions of each flap is outlined in the beginning section, and the servo motor attached is 23 mm x 11 mm x 29 mm. The exact mechanism of a single flap is shown as each flap would be equipped with identical mechanisms.

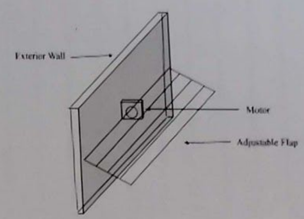

Fig 8. Close-up of Adjustable Flap System. Shows the motor, which would rotate to adjust the flap. Both the motor and flap would be attached to the exterior wall, which an incision made in the flap to allow the motor to pass through. This system would be replicated for all six flaps.

g. Wiring Diagram

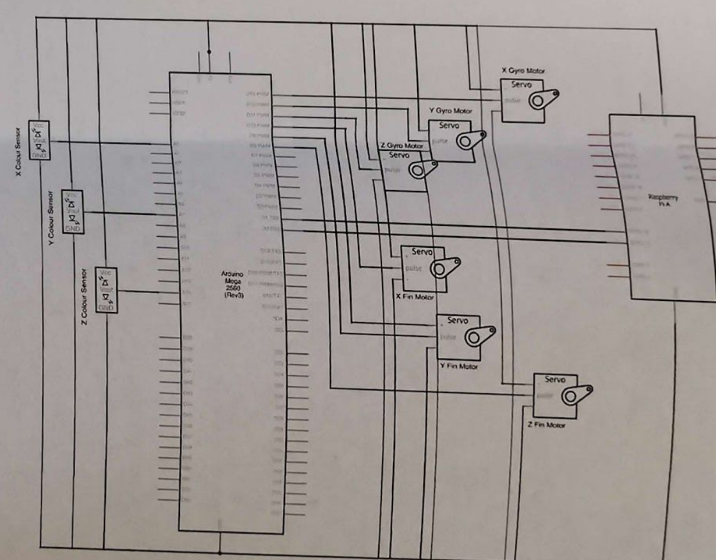

Fig 9. Wiring Diagram. Displays the wiring of each motor and colour sensor from the different gyroscope enclosures to the arduino microcontroller and the Raspberry Pi attached to the computing system. In addition, it also shows the necessary resistors.

5. Program Flowchart

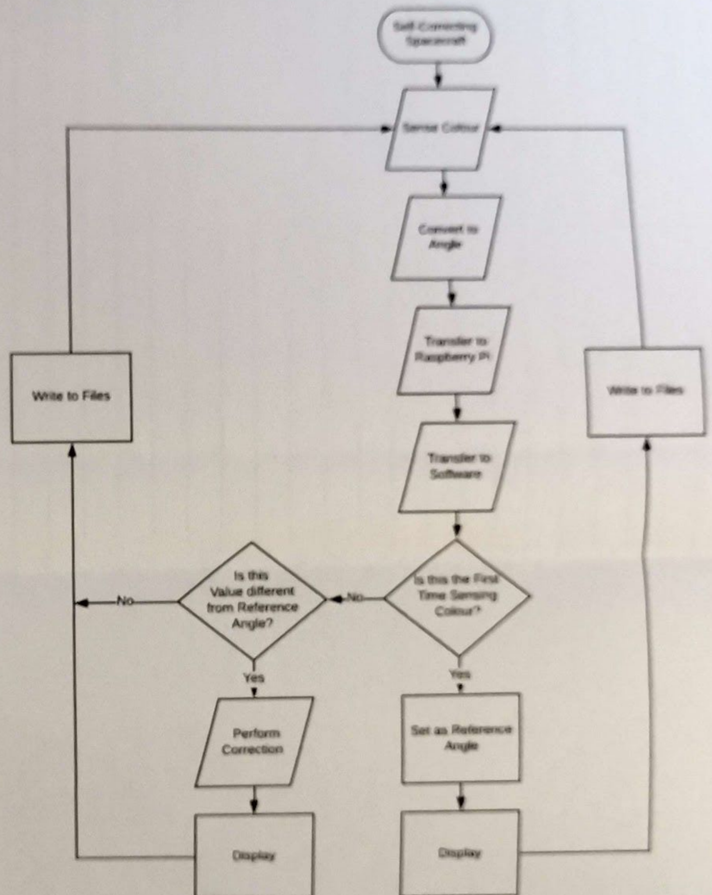

Fig 10. Program Flowchart. Displays the program to be run on the computing system in conjunction with the device described in the above section. Shows the computing process, as well as the output displayed to the user.

6. Testing Procedures

a. Colour Sensor

The three colour sensors will first be tested in well-lit settings, such as a room with normal lighting, to ensure that the differences in colour are sufficient to correspond to an angle that can be read. Next, the same experiment would be tested in a dark room that emulates the conditions of the container it would be in on the spacecraft to ensure that the sensor is still functional in the dark. Additionally, the color gradient should be in a range that is representative of the full 360° range of rotation. Since the colour sensor can only detect 256 different values and a range of 360° is needed, the gradient must be constructed in a certain fashion to account for all necessary angles. This will be tested by seeing if the sensor can accurately detect all the values. The size of the gradient must also be tested when attached to the gyroscope to find the optimal size that maximizes the number of accurate detections from the sensor.

b. Gimbal Ball Bearings

The gimbal ball bearings will be tested by tilting the gyroscope at a known angle and measuring the angle observed. If the residuals are small, then the ball bearing's ability to facilitate movement will be adequate for the project. However, if the ball bearings show under-turning, lubractive substances must be applied to ensure accurate movement and additional fixes must be employed.

c. Motors

The continuous servo motors should be tested for their power to keep the rotor spinning at a rapid rate to maintain gyroscopic properties. If the motor cannot reach high rotational speeds, gears should be used to enhance the rotations per minute to ensure the gyroscope can function. The servo motors used for flaps will first have the flap piece attached and tested in various directions before placed on the entire spacecraft.

d. Arduino and Raspberry Pi

Microcontrollers will be tested for functionality by running rudimentary code through them and observing if the functions of the code are properly executed. This tests the basic functionality of the motors, colour sensors, and wiring along with the microcontroller's ability to function. Another test must also be conducted to verify that the communication between the Arduino, Raspberry Pi, and software is in working order. During the process of writing the code for the spacecraft guidance system, functions of the code must be tested while using the spacecraft as guidance to verify that the calculations are correct.

7. Schedule

December						
Sun	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
	2 Prospectus	3	4	5 -Purchase all materials	6 -Assemble spin axis and test motors -Attach to mount and gimbal	7 -Assemble spin axis and test motors -Test gimbals for low friction
8 -Assemble spin axis and test motors -Test gimbals for low friction - Begin code for one axis	9	10	11	12	13 -Finish code for one axis -Test one-axis gyroscope system	14 -Debug code for one axis -Test one-axis gyroscope system
15 -Debug code for one axis -Test one-axis gyroscope system	16 -Debug code for one axis -Test one-axis gyroscope system	17	18	19 -Finish code for three axes	20	21 -Finish assembly of two more gyroscope units
22	23 -Test gyroscope units on one axis, then together on three axes	24 CHRISTMAS EVE -Test and debug code and gyroscope units	25 CHRISTMAS DAY	26 BOXING DAY -Test and debug code and gyroscope units	27	28

29	30 -Finish testing entire system -Document quasi-working runs	31 NEW YEAR'S EVE -Paint exterior housing				
			January			
			1 NEW YEAR'S DAY	2 -Paint exterior housing -Fine-tune any issues with system	3 - Fine-tune any issues with system	4 - Finish Marketing Brochure and Operating Manual -Finish and document fully working system
5 -Check system's working order	6 -Check system's working order	7 -Finish compiling testing data -Finish explanations of deviation from prospectus	8 -Check system's working order -Format report -Last-minute fixes	9 -Check system's working order -Last-minute fixes	10 Presentation Day	

8. Budget Cost

The following table describes the budget for this project. Any shipping costs are included in the cost for each item.

Item	**Quantity**	**Cost per item ($)**	**Costs w/ Shipping ($)**	Notes
Elegoo Mega	1	19.99	19.99	To be purchased
Raspberry Pi	1	15.00	28.25	To be purchased
PVC Pipe (1/2" by 10')	1	8.98	8.98	To be purchased
Ball bearing	10	1.10	11.00	To be purchased
Wood for rotor	1	1.00	1.00	Owned
Wooden dowel (1/8")	1	0.60	0.60	To be purchased
Wd-40	1	0.50	0.50	Owned
Full rotation servo motor	3	6.65	22.60	To be purchased
120 degree servo motor	3	4.75	16.90	To be purchased
TCS 3200 Colour Sensor	3	7.85	26.20	To be purchased
Colour strip (Paper)	*1*	*0.05*	0.05	Printed
Cardstock	1	0.50	0.50	Owned
9V Battery	2	1.50	3.00	To be purchased
Battery case	2	0.40	0.80	To be purchased
Resistor	2	0.10	0.20	To be purchased
Copper Wires	1	2.00	2.00	To be purchased
Construction paper	30	0.01	0.30	Owned
Soldering Materials	1	1.00	1.00	Owned
Superglue	1	4.50	4.50	To be purchased
Cardboard	1	0.50	0.50	Owned
Subtotal ($ CAD)			148.88	
Tax ($ CAD)			19.35	
Total ($ CAD)			**168.23**	

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- Rejected Designs
  - throughout the three-month planning process for this project, there were numerous versions & designs considered to ensure that there was an efficient way to sense angular rotation & velocity
  - the spacecraft, however, did not consist of only the measurements of angular rotation but also numerous electrical aspects to be taken into account
    - as such, different restrictions & objectives had to be taken into consideration
  - the first was how to sense real life angular rotation & velocity
    - from basic understanding of gyroscopes from lessons on rolling, torque, & angular momentum & the procession of a gyroscope, there was a strong sense that we were to use gyroscopes
      - sensors were prohibited from use

- Since we had to build a real life gyroscope, there was a significant discussion on the construction of such a gyroscope
  - two major designs were considered
  - we could construct a gyroscope w/ 3 axes of rotation or leave our gyroscope to 3 separate ones with pristine axes of rotation

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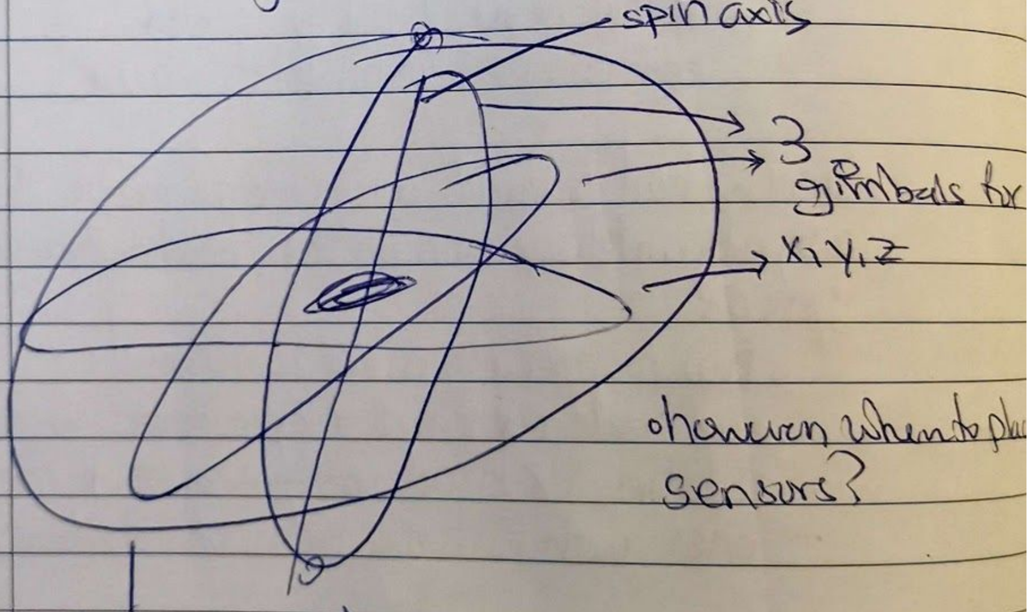
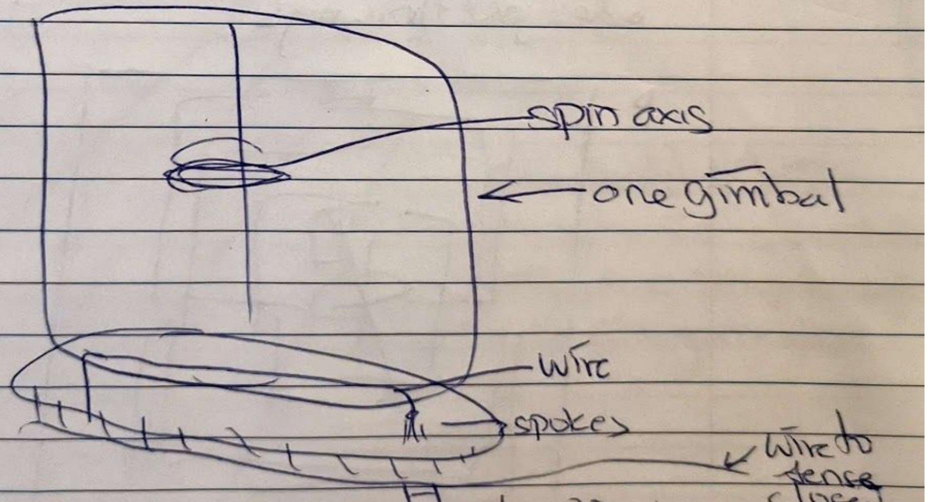
- benefits of the first one included having it act on all 3 axes so we could display the rotation w/ just one gyroscope
  - it could sense more w/ less space & volume taken up
  - however, it would be hard to mount it on a set frame w/o building another gimbal on the outside
  - ⇒ 4 gimbals!
  - as well, since we're using materials such as PVC, it would be very difficult to build such a gyroscope.
  - volume diff not too much.
  - difficult to measure velocity w/ 4 gimbals



- however, where to place sensors?

- We then looked at the different ways to measure the rotational movement & angular velocity
  - we analyzed 4 methods
- mechanical wire method
  - we hoped to have a bristled wire on the ~~free~~ axis gimbal poking ~~downwards~~ at 2° intervals facing upwards.
  - When the circuit closes, a signal is sent to the Arduino
  - then, the CPU analyzes the peaks of current
  - but due to significant spacing & how it is so mechanical, there is significant error from when we sense nothing in the in-between intervals



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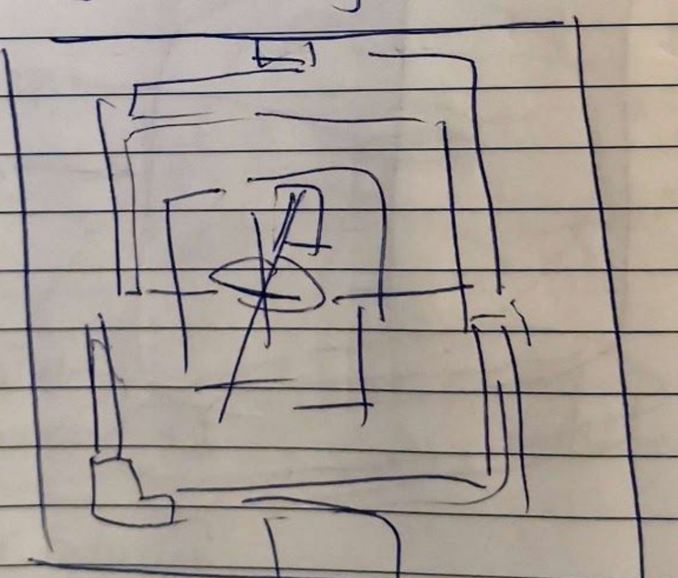
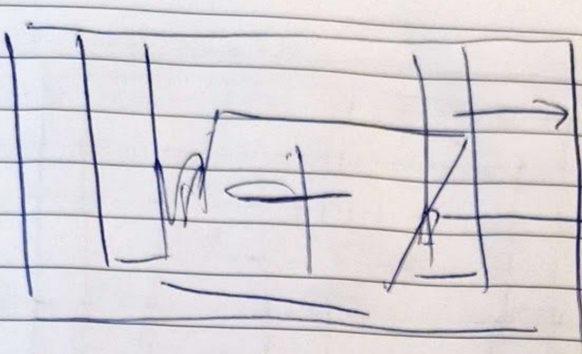
Construction Detailing & Testing

DEC 6. - PA Day

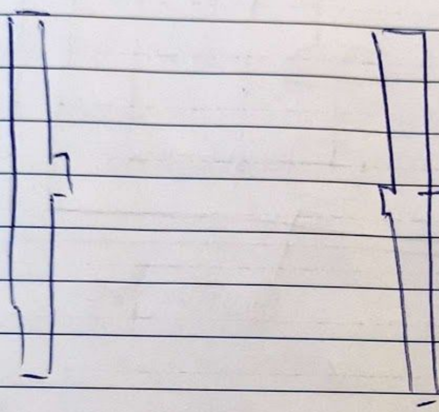
- Initial plans for the day
  - collect PVC pipes,
  - cut PVC pipes
  - figure out how to construct the gimbal casing from PVC
    - hot glue, other options.
  - analyze how grommet ball bearings &
- designs & drawings
-



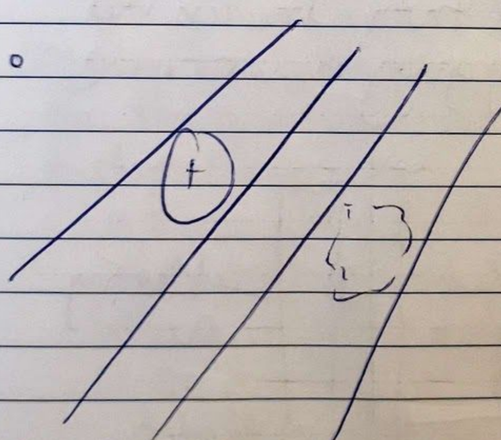


struts from PVC.

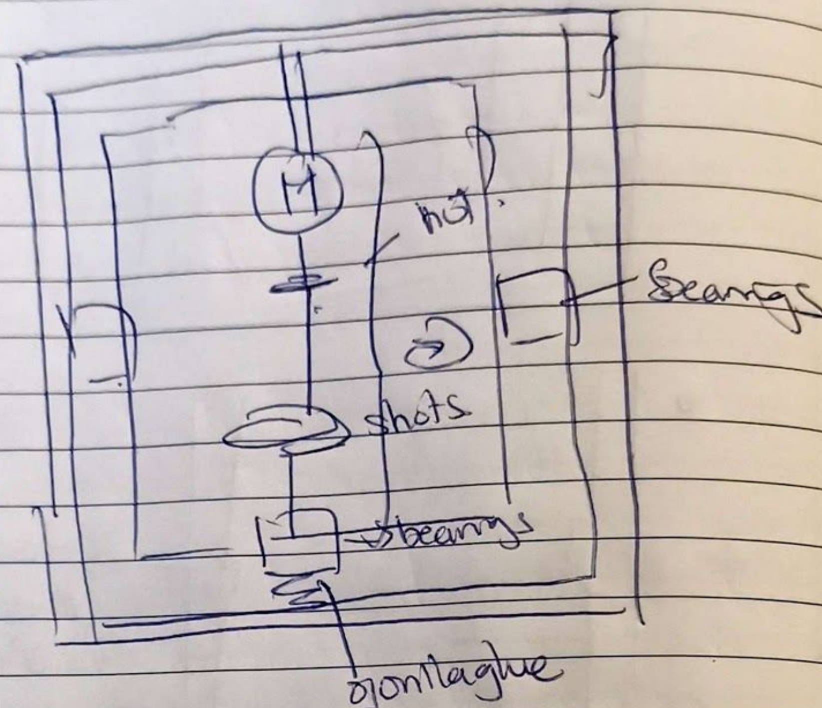
ball bearings



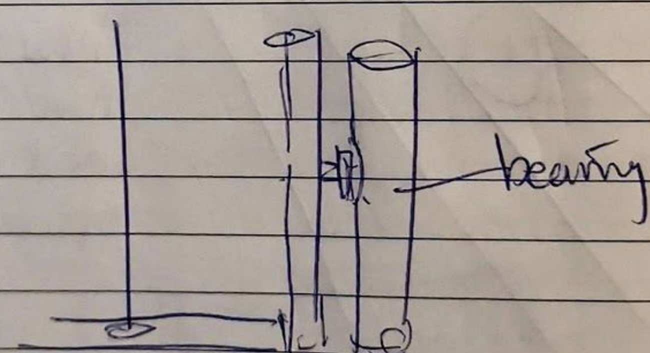
shouldwe use T-PVC pipes and place the ball bearings inside & the go from the to see the rotational axes



- how should we drill through using a one-time drill piece large enough or something smaller?



- the ball bearings were suppose to arrive by 8 from Amazon but the delivery guy never came



- we took apart some fidget spinners to analyze how we would do & use the spinners & ball bearings inside to analyze what worked / didn't work.
    - had to gorilla glue in a way to not cause stuck rotations

- also there was heavy debate on whether to hot glue the PVC at joints or use corner pieces
    - hot glue: is strong, but not strong enough because we see some movement when we tested it
    - ultimately, we went w/ corner pieces b/c its more sturdy & not big pressure point

- spent rest of time cutting 15cm PVC pipes for the gimbals
- future plans
    - depending on the Wed 11 Dec strike, we may build our entire gyroscope then w/ colour sensor
    - or do it on the friday & sleep over into the saturday
        - depends
        - play by ear.

DECID

Because our motors have not arrived which means that they are still in Montreal. Contacted the company but have not responded despite repeated attempts.

We will instead build the various aspects of the gyroscope without the motor installed.

The same issue described on paragraph 1 on page 32 with the arrival of our colour sensor. The parts still have not arrived for the various aspects of the colour sensor. This will slow down on our progress for the setting up of the colour system.

However all other material arrived.

- Ball bearings arrived
- PVC pipes purchased
- PVC pipe elbows purchased
- rowers were also purchased from Michael's
  - these were 1 1/2 inch diameter wooden circular disks with smoothed-out sides
- the prints are are friction that will substantially affect performance of the gyroscope.

- following the detailed plans from the last meeting, Jimel & Steven bought PVC elbows in the morning at Home Depot, for 1/2 inch
  - however, this did not fit the 1/2 inch PVC pipe or 3/4" we bought earlier in the week
  - so we went out again to buy parts
  - this time, we brought the PVC parts to compare at the stores

- When we went to RONA to buy the elbows, we used the PVC Pipes brought along to judge
  - everyone went to RONA
  - We bought another 12 PVC elbows for the various parts of the gimbal construction
    - we needed this to hold together the various parts of the gimbal structure together
    - without this, as debated earlier on Friday, our structure would not be sound enough to hold together under extreme circumstances

- Because of the way we set up everything, we decided to start drilling through the PVC tubes to have the place to put the ball bearings

34

- all group members were all using the drill
- Drill bits were chosen to make the hole within the pvc pipe
  - what drill bits were used were determined by how large the hole needed to be
  - drill bits from sizes ranging from small to big were used
    - we slowly increased the size until the ball bearing were able to fit properly within the inside of the drilled hole
  - for future references, the direction of the drill matters
    - backwards drill bits would not work
      - it only pushed rather drill through which is not ideal
- we would continue doing this throughout the day, inputting all the ball bearings into the PVC pipe
  - this would be repeated for the 6 PVC pipes that would have ball bearings

- the wooden dowel fit quite perfectly in the ball bearings we can later have the dowel super-glued in
  - however, we should probably do this after we get the motor in case further changes needed to occur
- we then started drilling the rotor which was a wooden disk-like material
  - we then drilled through
  - initially, we used our hands to stabilize
    - however, this resulted in some shaky cuts
  - then we discovered that we could cut & drill with a more stable outcome
    - we decided to use a tennis table stand grip to act as a vice
    - this was able to clamp down on the rotor
    - we were then able to properly drill through
  - as well the hole that Michaels indicated was inaccurate
    - we also indicated which hole was proper

DEC 16

The motor came from a store in Montreal &
took forever to ship

- Now that it has arrived, we could
test the motor

DEC 17

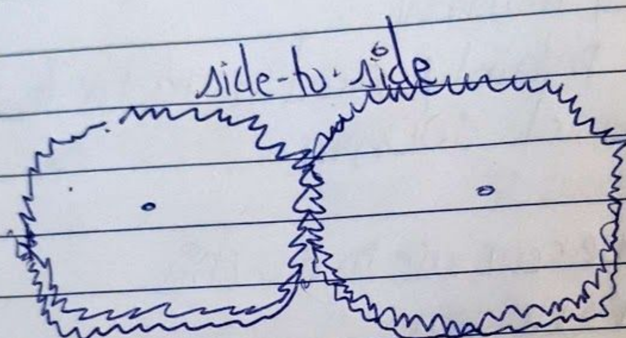
- Time to test motor!
- the colour sensor also arrived

- to test the motor, we had to insert

(put arduino motor code here)

- the motor from RobotShop (servomotor) turns rather slow
    - around 1.5 turns per rotation per second which is way too slow for our purposes
- 0.12 seconds per 60 degrees
    - 0.72 s per rotation
    - ⇒ so around 80 rpm
    - way too slow.
    - we probably need a motor that turns around 400 rpm
- Two methods we can use to do this
    - we can use gears
        - pros
            - they are reliable because with the number of teeth, we can do some basic calculations & get the rpm that we want.
            - they could be metal
                - ⇒ could be con because it could be heavy
            - gears could be relatively cheap if we take it from our Lego or Connect Sets.

- cons
  - they could be heavy if metal
  - there may not be enough space for our gym spacing as the gears either have to touch side to side or on top of one another



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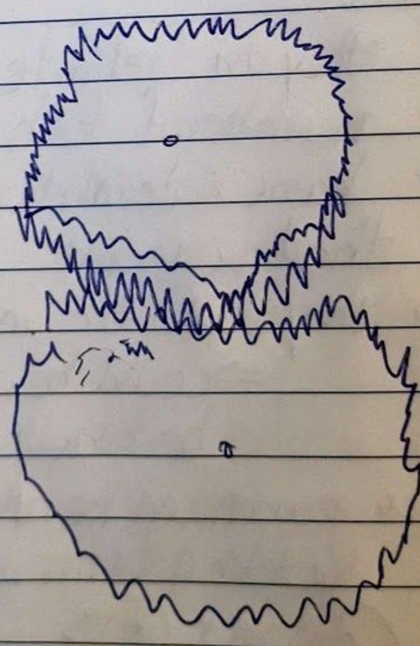
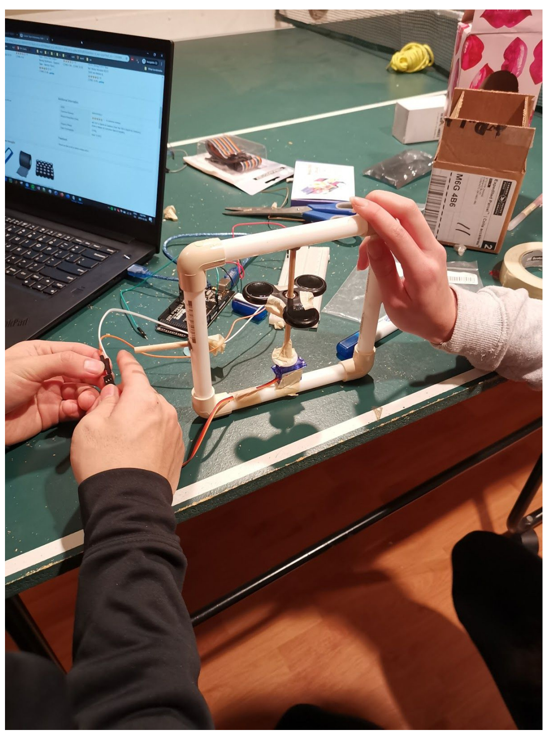
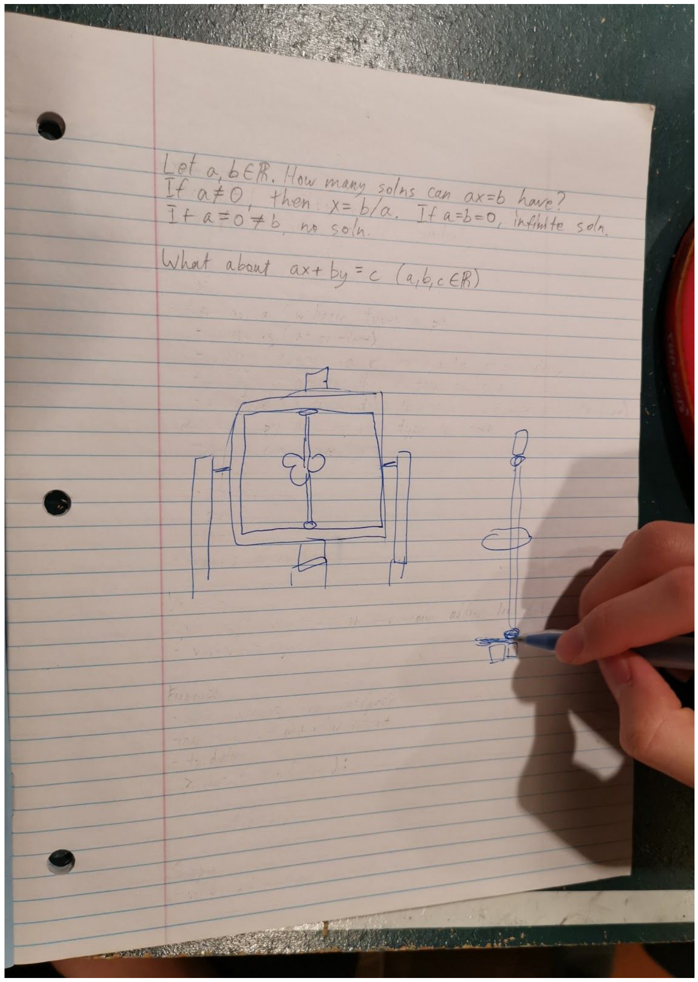


on top of another so it is faster & takes less space

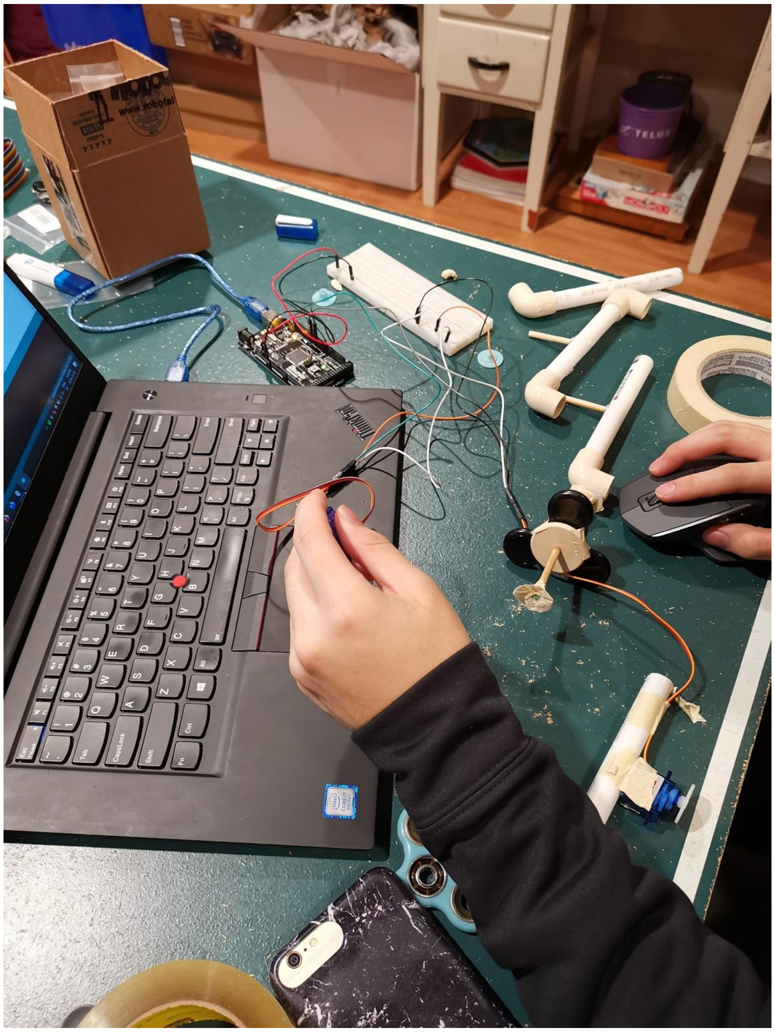
- Steppers
  - pros
    - they don't pause
    - it is fast to get it to the RPM that we want
    - the reliability for a step motor is very high
    - can impart high torque at low speeds
    - a simple, rugged construction that allows us to use it in the gyroscope & the motor.
    - error is non-cumulative
  - cons.
    - relatively low torque capacity compared to better motor but due to sizing is what we have.
    - may encounter pulse-missing problems due

- Due to concerns of the wooden rotor being not being able to rotate at a fast enough speed due to its relatively light weight, several alternatives were considered
    - The first of the alternatives was the repurpose of a fidget spinner—a children's toy—as the rotor
    - The advantages of the fidget spinner are that it is relatively heavy, and already designed to have an even weight distribution
    - This would decrease the drag and error on the motor as the spinner is professionally manufactured instead of being handmade
    - However, the disadvantages of using the fidget spinner is that it is difficult to find three identical fidget spinners
    - In addition, the size of bearings, even if the fidget spinners look identical, could differ causing imbalances amongst the three gyroscope systems.

- Other alternatives considered included adding more than one wooden disk on an axis, which would
    - We looked at some alternatives
        - Fidget Spinner, however it is heavy but we are unable to get the same fidget spinner that is reliably similar
        - It also has different size bearings
        - 
        - https://drive.google.com/open?id=1FRJW1-lB7KnnDUMBifzooDNEKbacVW90
- Eric and Steven also talked about different motors

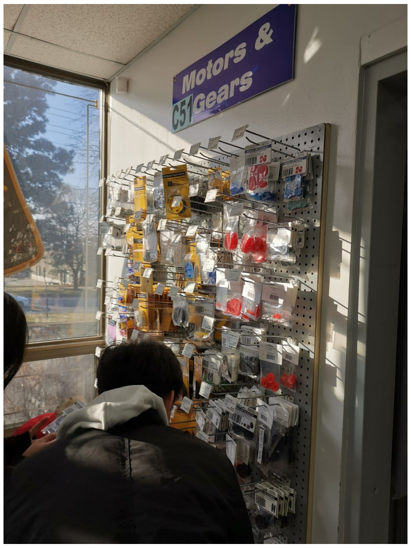
- 
- Draft 1 of motorization
- Use 2 motors on either side of the dowel

- They spin at more power which spins better



- Or we can stack the motor so they spin faster, but the overall power goes down because there is additional weight
- PWM
    - We don’t care about variations in speed for this motor, we just want maximum speed, variance in speed will only matter for fins
- https://drive.google.com/open?id=1FR2MmBCVYM74IzriT4bUFe5R7Xvlgkby
- https://drive.google.com/open?id=1F7FtSWjK7gjU-_rkpJhzofeSdNuarz0g
- We will use gears to make our motor fast

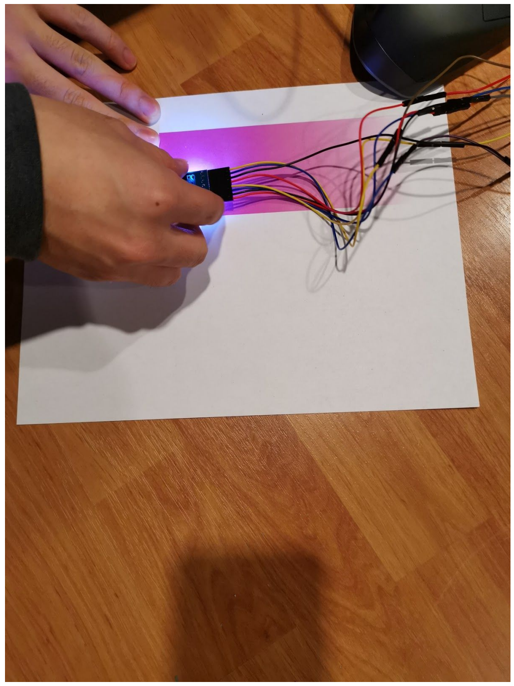
    - We will get a 870150 gear from Sayal, $6, relatively cheap

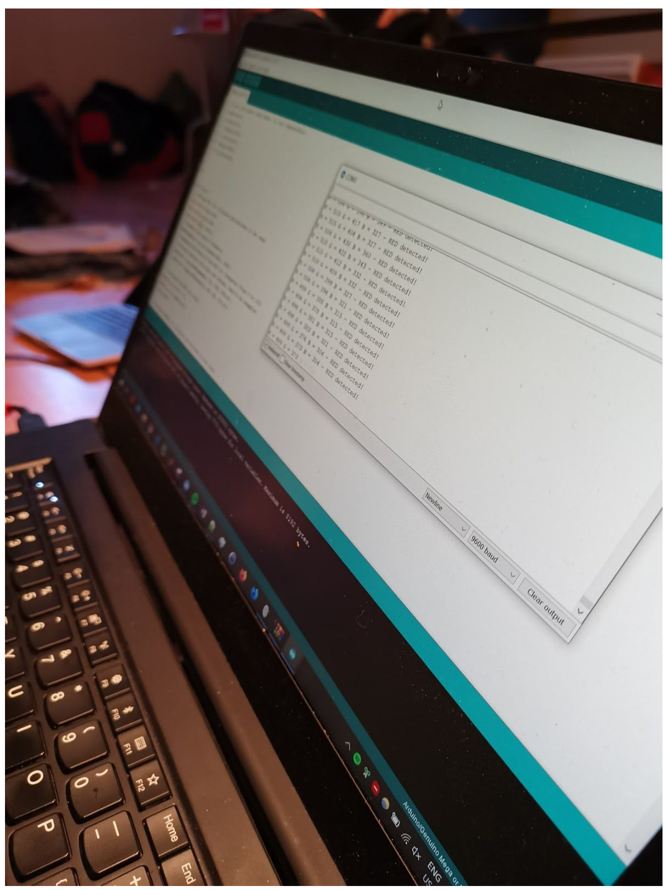


- We will get a shopping list
    - Gears
    - Dollarama, barbeque sticks and duct tape
    - 

- Colour sensor
    - Red to black gradient
    - Makes it easier to calculate
    - Used RGB colour gradient maker
        - CSS Colour gradient, red to black
        - Will need to run the CSS code to make this image
        - We used an online website to try and generate it and then see if we can screenshot, but we could also run it on a team member’s CSS code
        - Then the screenshot was taken from the generated picture
            - Saved as PDF afterwards

- Angela sent Picture DEC 28 3:29 pm
- Should we not do red to black because black could be confused with the blackness of the box on the side
- What if we did (0,255,255) to white
    - Ultimately, we found that this does not affect the colour sensed, so we chose 255,0,255 to white to measure and show within the colour changes
- Jim is also making and checking that the colour sensor works
  - Steven and Jim went to get a DC source to test
- So the colour sensor was placed within the breadboard and the arduino, plugging into ground
  - Colour sensor runs with this code: https://randomnerdtutorials.com/arduino-color-sensor-tcs230-tcs3200/
- Angela and Jim starts to put in the circuit
- It works!



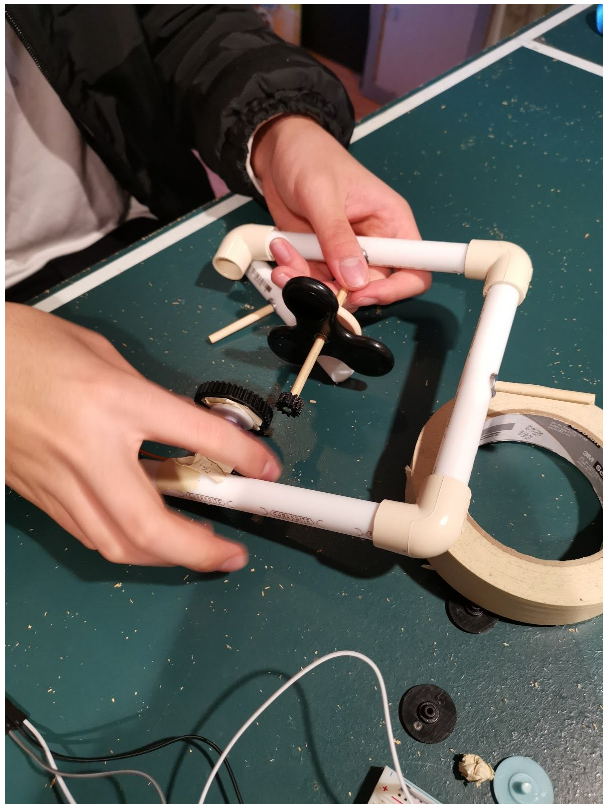
- 

- The only issue now is that there isn’t enough length for the paper gradient for it to form a circle around the gyroscope as it spins and rotates

    - As well, instead of using values from 0 to 255, we could do it from 0 to 180 so we measure at 2 interval angles and not get any ambiguity
  - We bought a bristol board and a metal circular can
    - Used duck tape to see if the circular shape can hold
    - Instead, we got a metal container to place the paper colour strip upon
    - 

- Gears
  - Need to figure out how the gears will be mounted
  - Product #870147 from Sayal
  - Putting drill bit on the drill to make the hole at the centre of the gear to be larger so the barbeque skewers from Dollarama to insert

- 
- Using a drill bit, all the gears were drilled through
- We also have a new vice method to drill
- 
- New set up

- 
- First try didn't work
    - https://drive.google.com/open?id=1F6m_7hAW24dJg5rH_szAvraNE134hT0a
    - Need a skewer that goes across to hold the gears in place while things rotate
    - To glue it in, we can try this method Eric suggested
        - Using hot glue or gorilla glue, we have to have at least 3 people regulating the placement so the rod is perfectly perpendicular
        - They do it at orthogonal angles
- Instead of using old set up, we used new set up with two ball bearings on the inside of the rod so there is more stability and accuracy to being orthogonal so when the gears rotate, they are done properly

- 
- https://drive.google.com/open?id=1F4wYvABoXAU9oH5EtE3T0mlIye4oQhhk
- https://drive.google.com/open?id=1F38pkcYONHnQkZI2vwijodFec8h3B_zG
- https://drive.google.com/open?id=1EyV_ihiblwTkpWmPs3oo4H8iqeDrRKf_

DEC 30

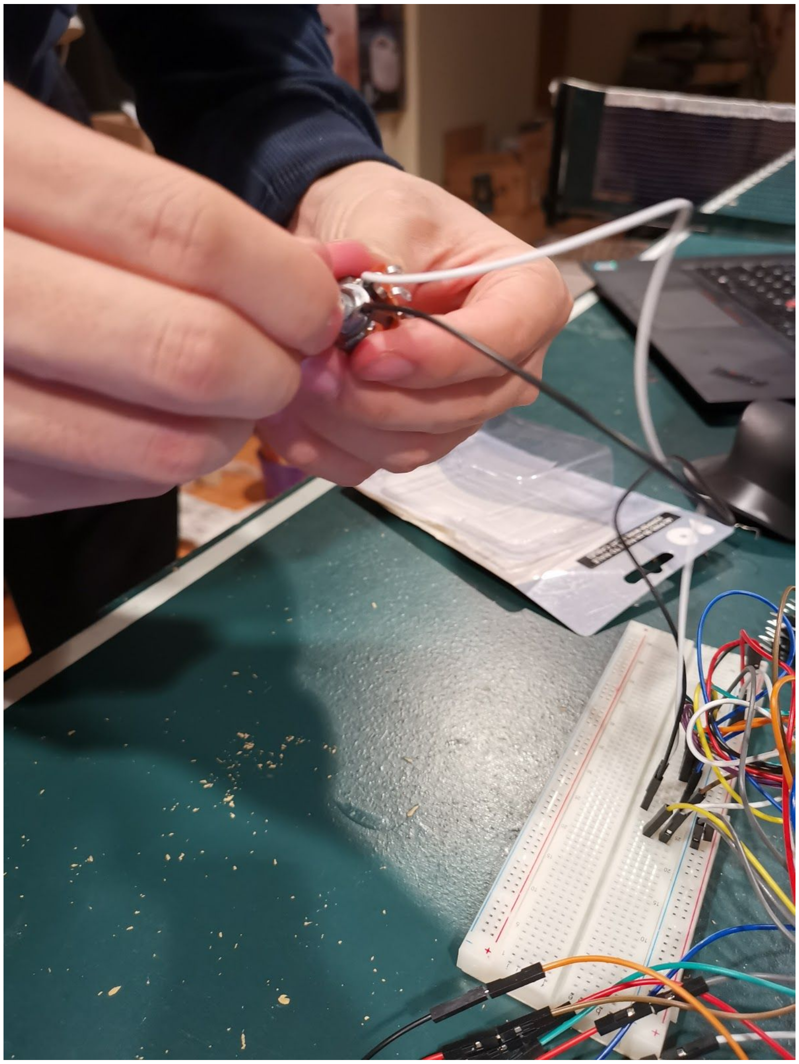
- Arrived at Nelson’s house to work on rigging up the colour sensor
- Connected all the components together
    - The values for the RGB sensor don’t line up as when we try and measure the white, the values are all around the 50s
    - The increase as we go around the colour sensor doesn’t change much in terms of the values it gets
    - We can place the colour sensor at the edges when the joints move so the area of measurement is much smaller

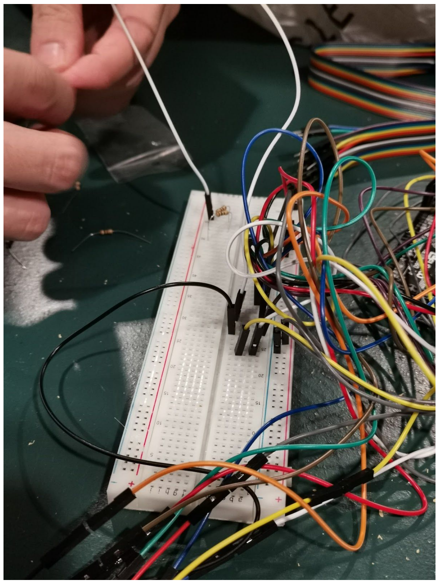
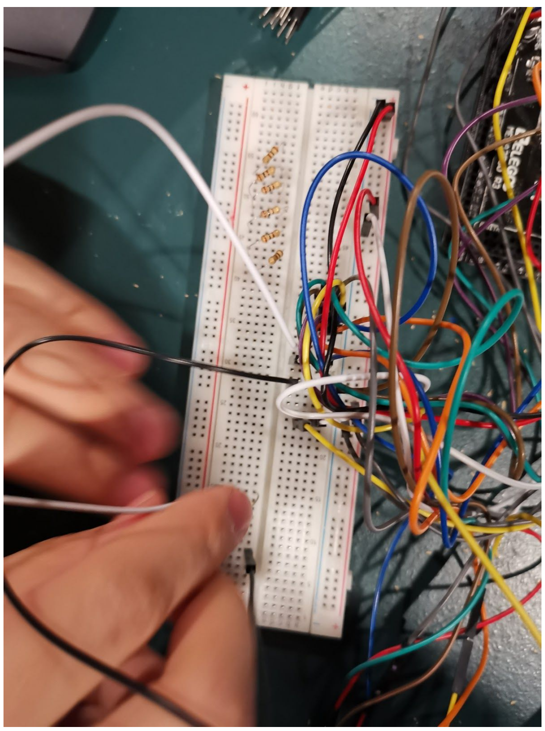
- 
- 
- We placed the colour strip into a box so we can test it without any light interference
    - We may need to calibrate the colour sensor using a pure white background

            - Add what Steven sent on DEC 30

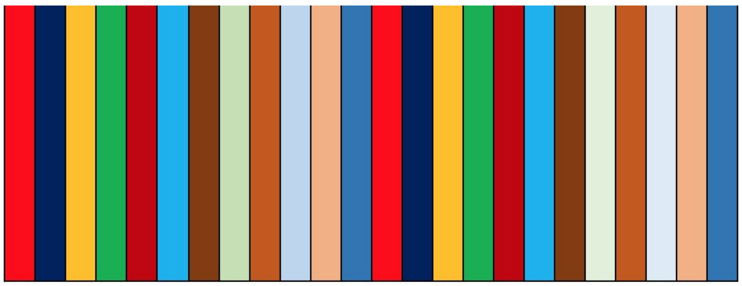
Dec 31st
- Add what Steven sent on DEC 31
- Motorized the colour strip
    - This will allow the strip to turn more smoothly
    - Then, if the strip is circular, this will result in more precise and accurate values
- Turning the colour strip manually resulted in shifting the strip up and down
    - The change in distance also changes the RGB frequencies received by the sensor
    - Further distance has less light washing out the colours
        - The white LED was too bright
        - On white paper, the values for RGB were about 17 20 17
        - The LEDs wash out the colours on the colour strip, they're all white

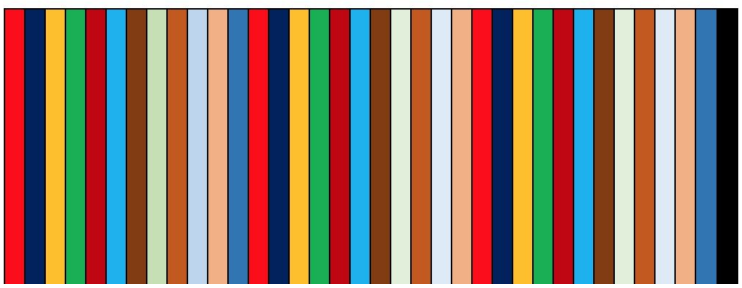
Jan 3rd
- Started day trying to get colour sensor to work
- First job is to debrighten the colour sensor LED lights
    - We feel that the current brightness of the colour sensor LED lights are 'bleaching out' the results obtained which is leading to a smaller spectrum of colours and RGB values detected
- We added a 10 ohm resistor, did not work, then connected a potentiometer

- 
- The 1k ohm potentiometer made no noticeable difference in the overall brightness, thus was scrapped for the use of larger resistors
- We then tested a 100 ohms resistor on the breadboard to see if we can get the colour bleaching and brightness to reduce
    - Once again, there is no noticeable difference between having the resistor and not having the resistor
        - Could there be something here that’s making it not work?
    - What if, we connect multiple resistors to increase overall resistance in the system
        - This has to reduce brightness

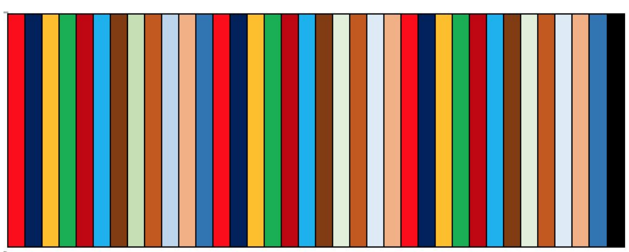
- 
- 
- It’s 3.3 volts, so why does putting in this many resistors not reduce brightness?
- At like 12k ohms, it doesn’t work
- Therefore, it’s somewhere in the middle
- What if the wiring is set up in a way where we aren’t plugging things in the correct position
- So nothing is working to reduce brightness, we could place more tape on the LED lights
- We could do an LED strip or just buy LEDs

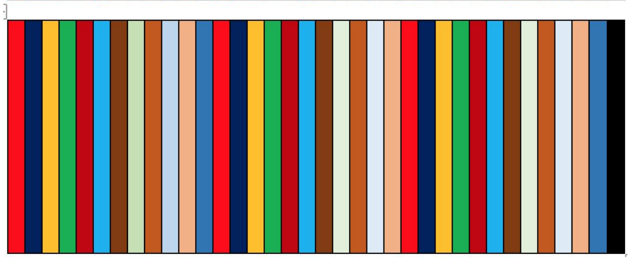
    - Instead of the sensor lighting up, we could have the LED strip light up the colour strip of colour
    -
- While we are tackling the light bleaching issue, we also tried using a discrete value strip for the measurements of the angle change
  - We think this may work better because the large difference will get us a relatively accurate estimation of angle within a certain range
  - Then, we use continuation of colour within each section to get a more accurate angle detection





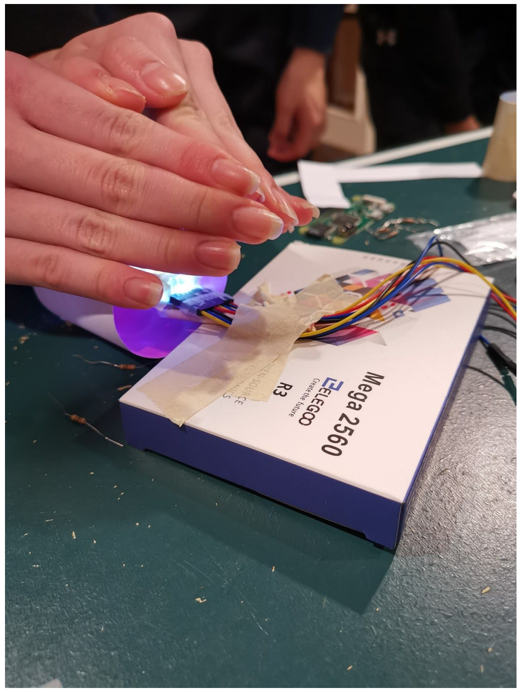
  -
  - This was used as a test for the discrete values
    - The top strip shows to an accuracy of 15 degrees at an actual real-life size interval of 0.66 cm
    - The bottom strip shows to an accuracy of 10 degrees at an actual real-life size interval of 0.44 cm



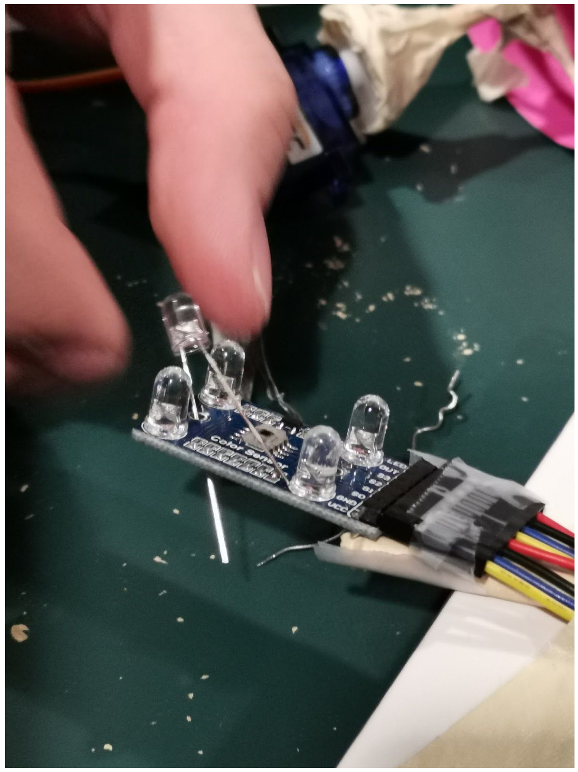


  -

- Both these strips were printed to be conjoined later
    - They are used for the 5 degree interval with real-life interval of 0.44cm, connected together would be 72 different joints, which correlates to 5 degree interval accuracy
    - We will set this up a bit differently, by having a larger circle, then the colour sensor needs to be placed more to the side
    - The coding aspect of this whole endeavour would be relatively harder, as we need to code to calibrate the beginning and for the code to know when we go forward and backward in rotational motion
    - 
- We can also have 2 strips of continuous at 180 degrees and place it together
- Or have 3 with 3 different colours, one for red, blue, and green, because currently, we're just using one colour and it senses around a range of 20 RGB
- So we tested the 15 degree interval strip, it doesn't sense any changes probably because the LED light is still bleaching out the colour, so we still need to find a way to reduce that LED light
    - One suggestion is to break 2 LED lights so the overall brightness is reduced

- Another other option is to not have LED lights from the sensor and to install our own LED light
- We can use the principle that “if everything is evenly uneven, then the thing is even”
- 

- We gave up on this, we will input 2 more LEDs of our own and not use the LED from the sensor

- 
- We tested in a dark room to simulate the dark box of the spacecraft
- The discrete values did not work well as the changes in the data received jumps, but is inconsistent so we cannot accurately say when values are in the appropriate places for the code to know the angle interval

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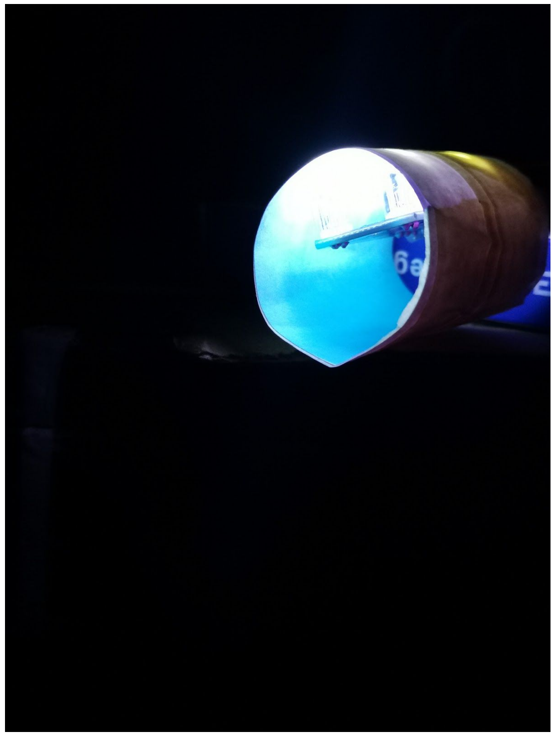
- 
- The continuous strip worked better as the ranges were around 25-30 for 180 degrees values, which means an accuracy of around 6 degrees with more accuracy through coding later
    - We will use this, but ultimately, we will use one colour symmetrical so there is no jump
    - However, we will do this then because it's hard for the code to understand which direction we are moving in

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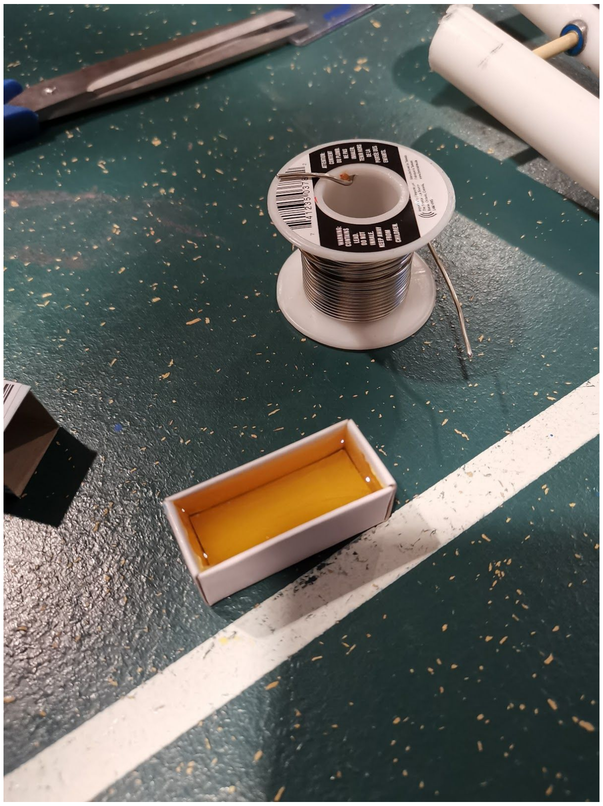
    - This chart is for the RGB testing data for our gradient strip in a dark on Jan 3
        - We tested using the two-colour gradient in a dark room with a shorter strip
            - Shorter strip has a smaller radius
            - Also used bristol board and clear tape on the colour strip to reduce transparency and isolate the colour detected by the sensor to the strip
            - On the jump between the cyan (R focused) and magenta (G focused) there is a significant difference in the G value
                - The value changed from about 50 to about 30
                - We can determine if it is on the R-focused strip to the G-focused strip

- We will also test the rosin flux
    - Makes it easier to work with
    - Test whether the rosin flux works

- 
- Need to wait to go to garage to test, unsafe to do this inside the house

- We then started building the gyroscope frame and gear set up for the other 2 gyroscopes
    - Continued to do this with the additional part to connect the colour sensor to the side of the gyroscope
    - Instead of placing the colour strip on top of the gyroscope, we had to move it to the side because the larger the colour strip, then we have much larger inaccuracies with the angle detected
    - Filing continues to even out lengths of the PVC pipes to make things square

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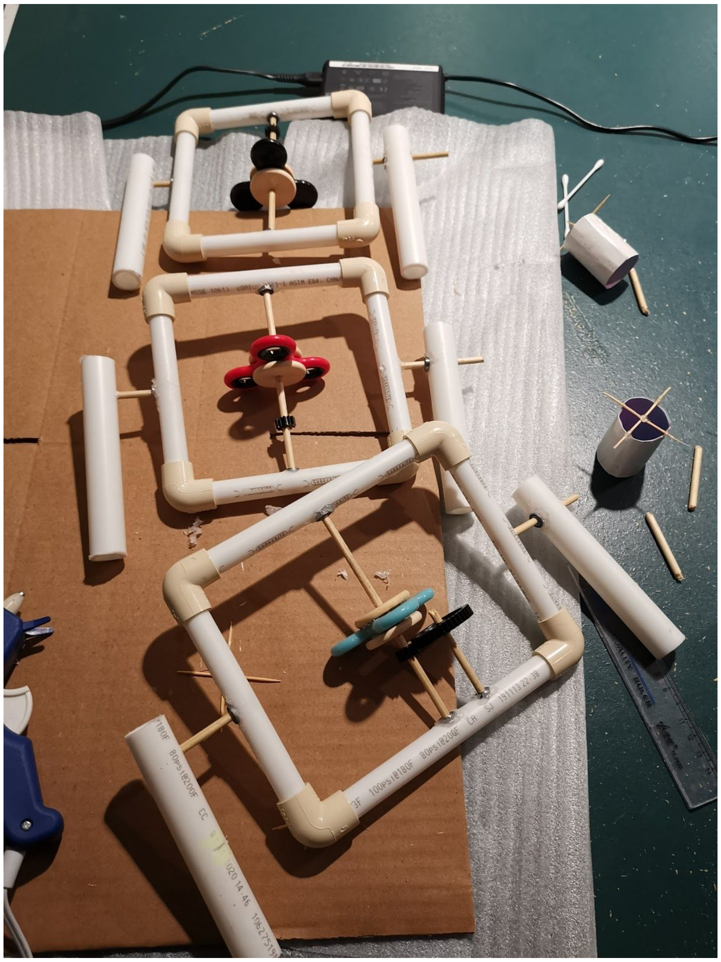
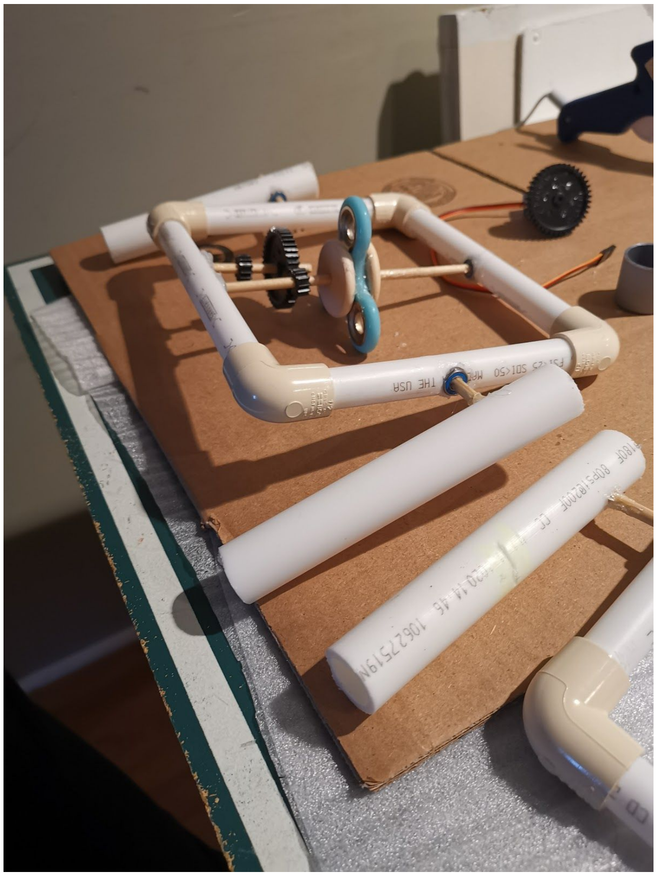


- 

- Jim’s Computer Diary
    - Goal right now is to connect Pi to computer to gain access to Pi’s files to connect to Arduino
    - To do that, first, we have to burn the image of the Raspberry Pi SD card and then put in a few files to put the wifi details into it because the Raspberry Pi is wifi enabled
    - Enabled the SSH (Secure Shell), used to connect computer to the Pi, it’s a protocol so we’re on the same network
    - Attach power to the Raspberry Pi and SD card to Pi
    - SSH from computer into Raspberry Pi
        - Now we have access to the files within the Raspberry Pi
        - Headless Installation through the computer
    - There were some bugs, mainly no connection to the network
        - We fixed this by using different ways to write the wifi file until it worked
    - Now, we are working on the Arduino to the Pi connection
    - We might need to attach an external battery to an Arduino

- We got a cardboard box and started cutting cardboard for the walls to block out light and interference from one light to another
  - The cardboard box was from an old lawnmower box, dimensions were 82 x 42 x 60 cm
  - So the dimensions for the walls we want to place on the inside is 4 pieces of cardboard is 42x26 cm, 60x26 cm, 41x26cm, and 26x26 cm
    - We did this at first, however, there was a mistake for the height of the pieces for one wall
    - We added an additional 10x60 cm piece on top of one of the boxes to add height to the box
    - We then placed duct tape on the edges of the lids and the cardboard to add additional protection from light entering the lid
    - We will then add velcro to the entire structure to prevent the lid to open
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PUSH
QUALITY RULER

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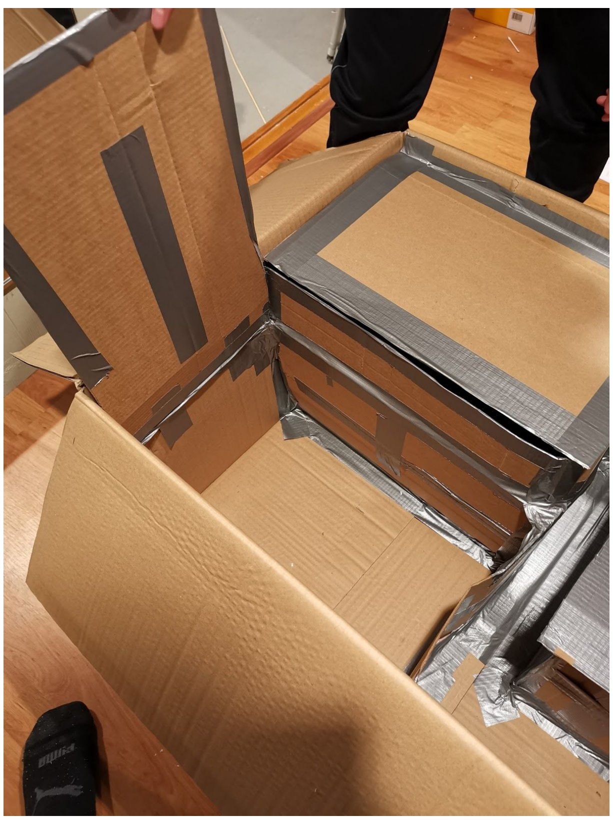
- 

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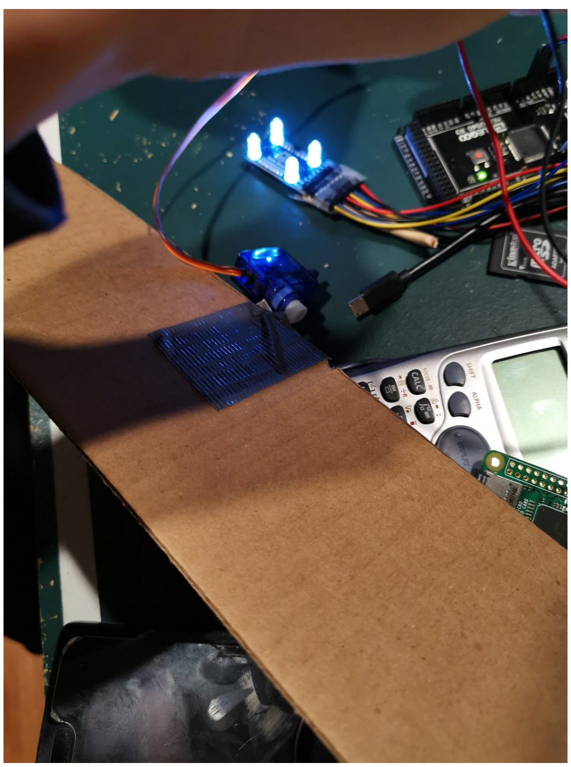
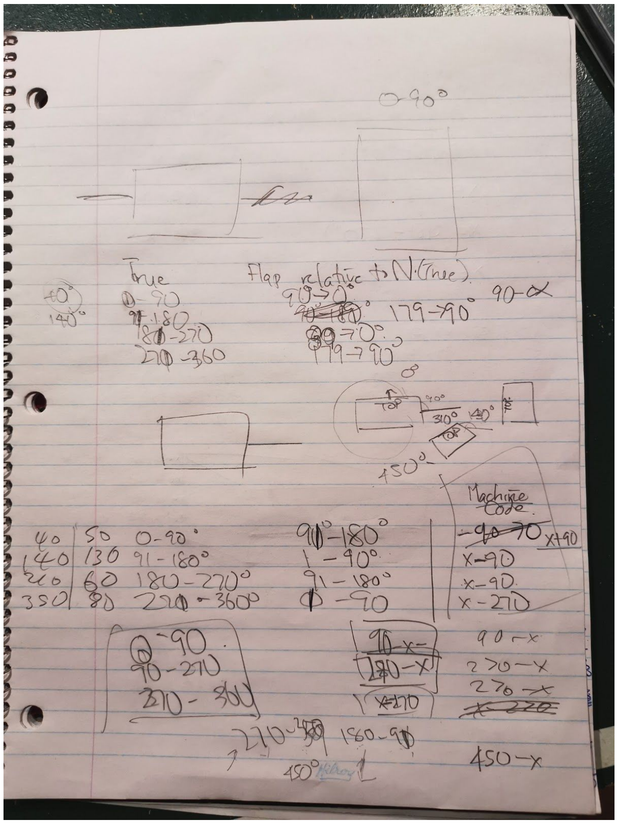
- Testing the servo fin motor and finding the appropriate angles to input
    - 

- 

- We first used the various aspects of our knowledge about relative angles
- To set things straight, we set 0 degrees to the direction perpendicular to the ground
    - Then rotation of the machine is always relative to Clockwise motion
- When we place the fin on the right side relative to the front, we calculated the following angles
    -

Angle of the Spacecraft (in degrees)	Angle of Fin to Spacecraft (in degrees)
1 => 90	91 => 180
91 => 180	1 => 90
181 => 270	91 => 180
271 => 360	1 => 90

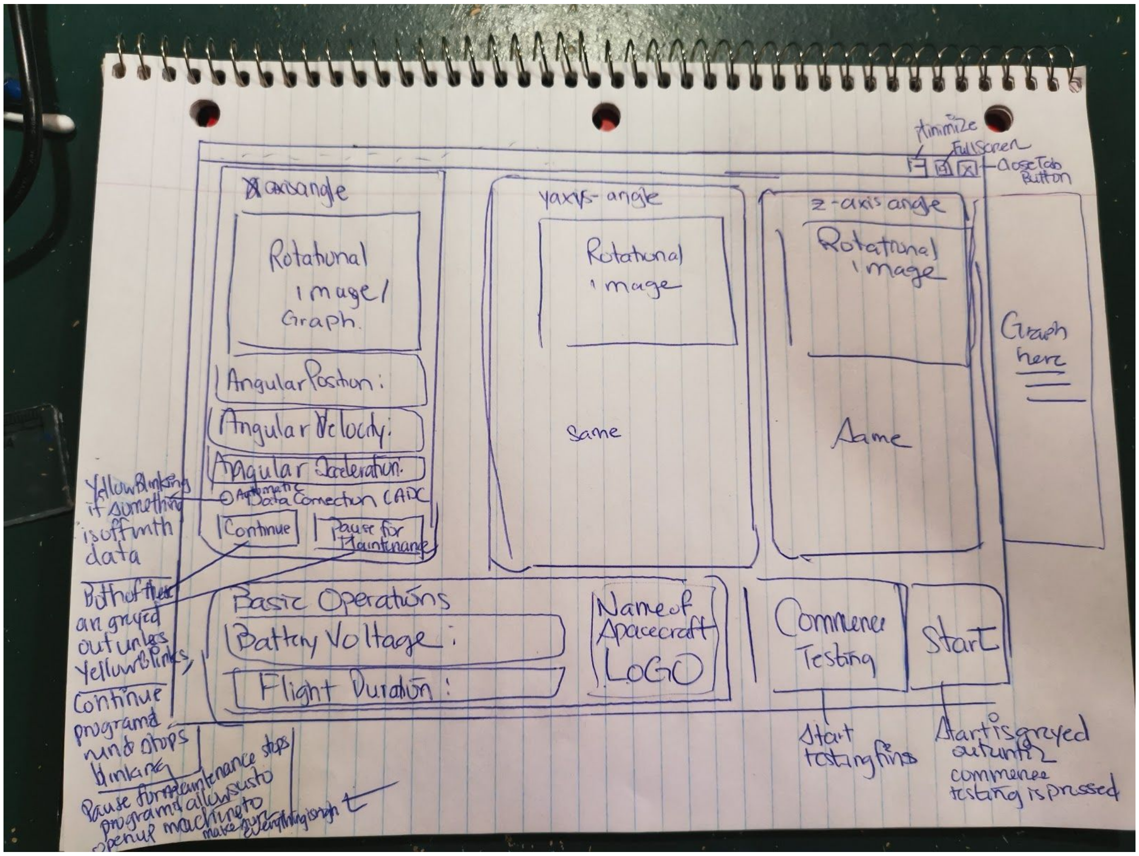
    - This is the correction that we will put into the Arduino code

Angle of the Spacecraft (in degrees) (x)	Angle Correction (in degrees)

1 => 90	90 - x
91 => 180	270 - x
181 => 270	270 - x
271 => 360	450 - x

Jan 4

- GUI
    - Stuff to input
        - We will need to display the following aspects for the gyroscope
            - Rotational Image
            - Angular Position
            - Angular Velocity
                - This will be obtained by subtracting the difference between the two positions, then divide by time
            - Angular Acceleration
                - This will be obtained by subtracting the difference between the two velocities, then divide by time
            - We will have a blinking warning sign on our GUI
                - We will input values where if some values hold constant or act in a very erratic manner
                    - There will be a continue button which stops the blinking which is something we would press if there is no issue
                    - Pause of maintenance button will stop the program and allow us to analyze the gyroscope or fin that has the issue
                - We also have basic operations where we will display the battery voltage and the overall flight duration of the run
                - We will also be displaying a 3D graph transferred from MATLAB to graphically display the angles of the box
                - We will also have a commence testing button, which will conduct some testing procedures on our fins
                    - The Start button will be greyed out unless we conduct the testing procedure

- 

- GUI Construction Documentation
    -

- Jan 4 Shopping List
    - Velcro for the gyro lids
    - Hot glue sticks for hot glue gun
    - Food for lunch
    - Paint for the Gyroscope outside
    - Breadboard from Creatron
    - Jumpers from Creatron

- Gluing sensor and motor to gyroscope
    - Some of the motors' gears didn't bite, so we had to readjust the positioning of the motor and glue it on that way using gorilla glue
    - Hot glue was placed over the gorilla to make it even sturdier

- 
- We also placed servo fin motor in their respective positions
    - Zero difficulties encountered
    - 
    - The tapes were put around to stablized the fins
    - We found out that one of the placements of the fins was improper as all three fins faced the same direction, meaning two fins displayed yaw

- 
    - The servo motor was taken out from its duct tape encasing using an exactoknife
    - Then was rotated 90 degrees to properly face the direction intended to obtain the pitch corrections
    - All motors were temporarily labelled using masking tape to avoid confusion

- 
- The lids of the individual boxes were made closed with velcro strips we purchased from Walmart
  - We also placed velcro strips on the general box lid to keep it shut when we tilt our spacecraft upside down
  - 

- We later then placed the length of wires needed to soldered down and connected with one part to another
    - The breadboards will be placed on two sides of the long crevice in our machine
    - We labelled each of the wires to reduce confusion and to make soldering and communication between group members easier
    - 

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- We also cut holes within the walls of the boxes using BBQ skewer sticks to reduce as much as possible the amount of light entering the boxes, interfering with the colour sensor
- 

- We then soldered the wires, but this had to be done in the garage to prevent the fumes from intoxicating group members
    - Due to the cold weather and the inexperience from all group members, we were only able to solder three wires with jumpers together
    - As a result of the slower speed, we identified places where we could solely use jumpers to connect parts of the spacecraft


I DREAM TO...
I WANT TO SPREAD KINDNESS BY:
I WANT TO LEARN TO...
SHAH

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TO-DO LIST

- Colour sensor
  - ↳ Calibration method
  - ↳ " code and conversion
- Battery and power
- Painting
- Pi connections
- Put wires into breadboard
- GUI
  - ↳ Table, graphs, box images

~~LOGO~~

- Test gyro w/ sensor
  - ↳ Once code is good, test fins

Miscellaneous: - Voltage divider circuit

- Soldering
- ~~motors &~~ bearings
- Put fins back
- LOGO AND NAME
- Glue gyros down