AUTOMATION OF RIGHT ASCENTION

BY TEAM THYCHO BRAHE

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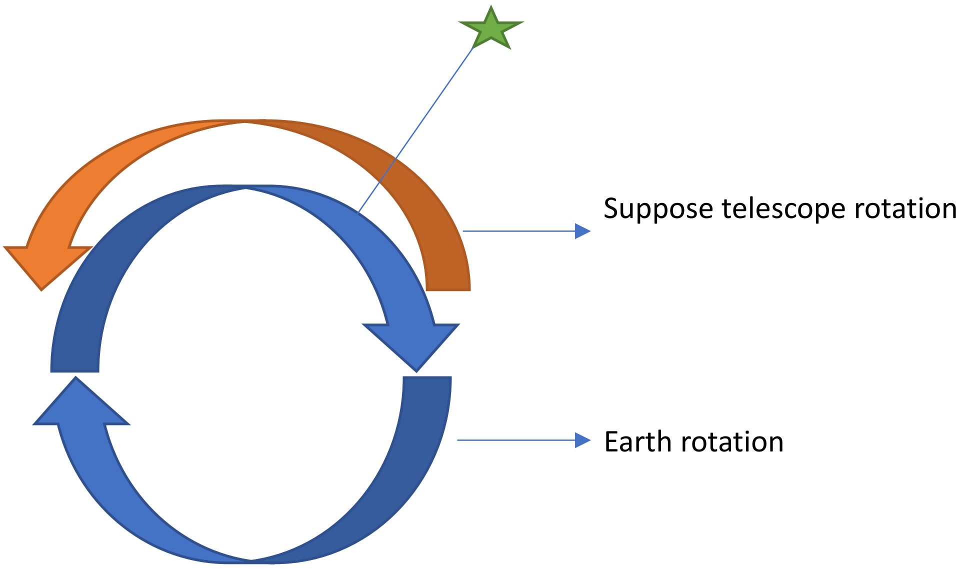
AIM: Automation of right ascension to compensate earth rotation for star gazing.

Telescope used: Celestron Astromaster 130eq refractor

Tripod Stand : Scope and mount head sits on it. It is used to adjust height of the telescope for user's comfort. Central accessory tray is set to fix the height of the telescope.

Equatorial mount : An equatorial mount of telescope is made up of a tripod and a mount head, which holds the telescope and moves it about on two axes, one called right ascension and the other called declination. Once the position of the star is located, its declination will not change but its right ascension will change according to the Earth's rotation. Due to rotation of earth image of star in sky is line rather than a point. Therefore, after every couple of minutes we need to rotate the fine tuner of right ascension axis to keep the object in the field of view of the telescope.



Compensation of earth rotation

Counter weighs : These are used to balance the torque due to the scope.

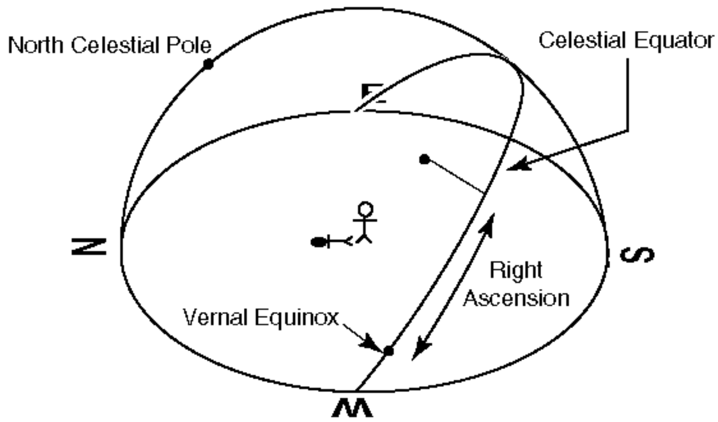
Declination fine tuning knob : It is used for fine movement of the declination of the telescope.

Right ascension fine tuning knob : It is used for fine movement of the right ascension of the telescope.

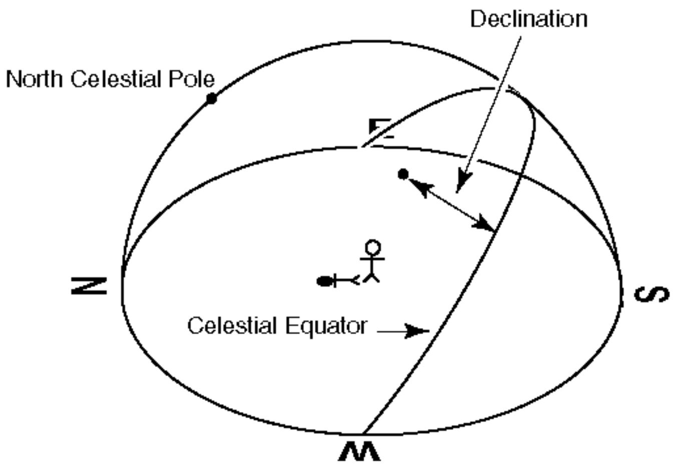
There are three axes in a telescope:-

> **1.Polar axis** : The polar axis of telescope should be aligned with earth's axis of rotation, called the north celestial pole. Most telescope have a latitude scale which we can set according to the latitude angle of our location. The latitude of Dharwad is 15.5˚.

2.Right Ascension axis : The Right ascension (RA) is like longitude. It locates where a star is along the celestial equator. The zero point of longitude has been chosen to be where the line straight down from the Greenwich Observatory in England meets the equator. The zero point for right ascension is the vernal equinox. To find the right ascension of a star follow an hour circle "straight down" from the star to the celestial equator. The angle from the vernal equinox eastward to the foot of that hour circle is the star's right ascension. Once the polar axis is fixed, then right ascension movement of telescope is done in opposite direction of earth rotation to compensate the earth rotation for stargazing.



3.Declination axis : Declination is like latitude. It reports how far a star is from the celestial equator. To find the declination of a star follow an hour circle "straight down" from the star to the celestial equator. The angle from the star to the celestial equator along the hour circle is the star's declination.



Once the declination of star is fixed, it changes very slowly. So we are only focusing on right ascension movement of telescope.

Problem in planet gazing

Planets have their own rotation orbit around the sun, their trajectory is complex to track. Thus for this project we only focus on star gazing because stars are almost stationary as viewed from earth.

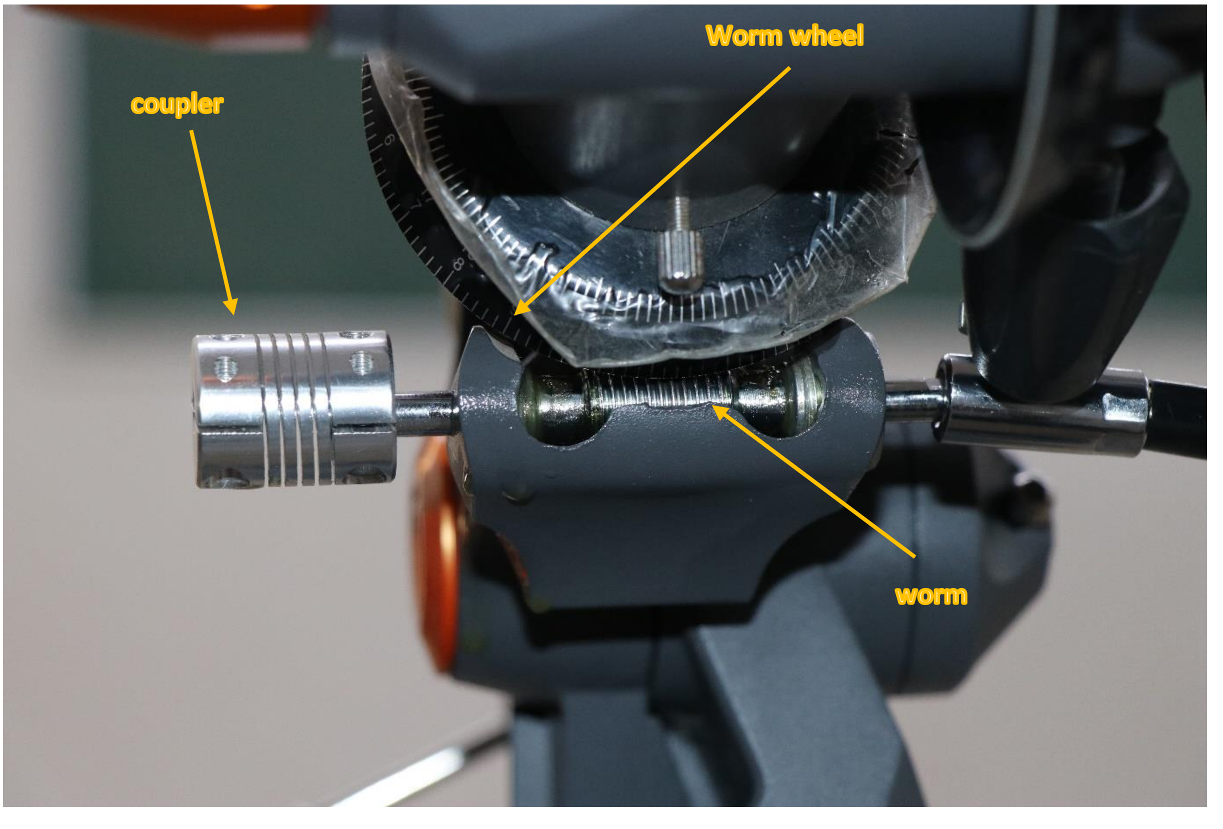
Angular velocity = angular velocity of earth - angular earth of object of telescope

As Angular velocity for stars is almost zero.

Thus for star gazing,

Angular velocity of telescope = angular velocity of earth

Measurement for speed required from motor



There are total n1 teeth in worm wheel and in one rotation of fine tuner n2 teeth goes forward.

Angle moved by telescope when one teeth goes forward = 360°/n1

So, angle moved by telescope in 360^0 rotation of fine tuner = (360/n1)*n2

By using unitary method,

For moving 1^0 telescope = (n1*n2)/360 ° revolution of fine tuner is required

(we already shown that-> Rate of telescope=rate of earth)

Rate of fine tuner is (360/24) *1/(360/n1) *n2 revolution per hour

By counting we got the values of n1=135 and n2=1

By solving,

Rate of telescope is 6 revolution per hour

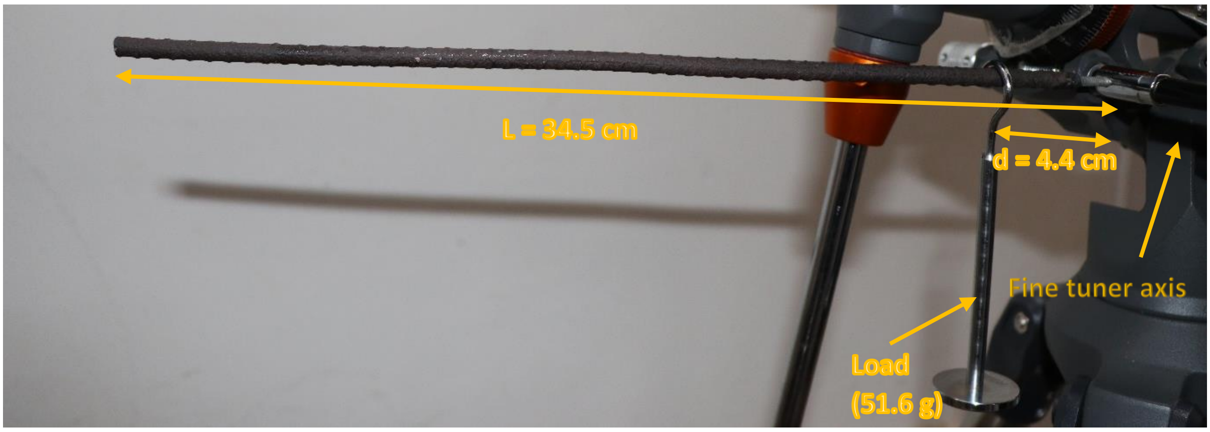
means, 1 rev per 10 min

means 0.6 degree per sec.

Rate of fine tuner =0.6 degree per sec

Measurement of torque required to rotate axis

We calculated speed required from motor in above motor. The next very crucial part is Is this motor provides sufficient torque?



Torque is given by= F.d

By measuring,

Length of rod = l = 34.5 cm

Mass of rod = m_r = 77.4 g

Mass of load = m_l = 51.4 g

Distance of load from pivot = d = 4.4 cm

By calculation,

Torque required to rotate axis = $((m_r*l)/2 + m_l*d)*g$ = 15.3 N cm

Rated Torque of motor = 41.16 N cm

SUMMARY

At first we calculated the angular speed at which we need to rotate the fine tuner for star gazing. Then we decided what mechanism should we use to automate the process of rotation of right tuner. We came up with an idea to rotate the fine tuner using a microprocessor as we had been introduced to Arduino in Hands on Engineering course. We researched about motor which can give correct torque and precision. At this point of time we split ourselves in two teams Mechanical team and Electrical team. Mechanical team took responsibility for designing of the box inside which we would keep our motor and other electrical equipment. Electrical team worked on the electrical circuit of the model. After each team’s target was achieved we decided to converge and work together for the final phase of the project which is attaching the motor to fine tuner right ascension axis.

MECHANICAL SUB-PART

KEY POINTS OF THE DESIGN

- The motor should be precise and powerful enough to provide torque (1.56 kg cm).
- A microprocessor will be used to control angular speed and the direction of rotation of the motor.
- A switch to change the direction of the rotation of motor. (Due to symmetry of the stand user can attach the motor on either side of the telescope so direction of rotation will differ in both the cases).
- All above components are kept inside a box such that internal circuit would not get damaged.
- The motor as well as the box containing all electrical equipment is mounted on telescope stand. Thus to reduce the damage to stand components used should be as light weight as possible.
- A battery to power the entire circuit. This battery should be kept outside box so that it can be easily removed for charging or replacing.

DETAILS OF THE COMPONENTS USED

- Motor :

We are using a Stepper motor – NEMA 17 rated torque : 4.2 kg cm* (torque measured in motors in in kg cm). This motor is sufficient to provide the needed torque, 1.56 kg cm. And the step angle (the least angle it can rotate) of this motor is 0.9º. Thus it can provide 1.8º rotation in 3sec.

- Microprocessor and Motor driver :

Since high processing power is not required and components should be light weight we decided to use Arduino Nano. Stepper motor driver for the stepper motor NEMA 17 is A4988 motor driver.

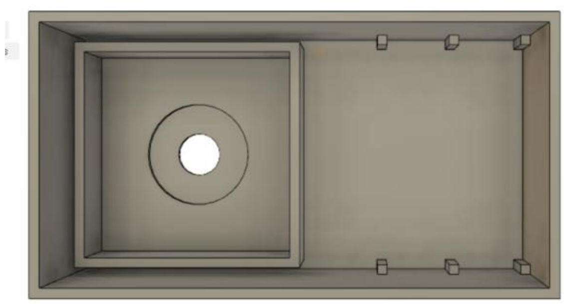
Aurdino Nano

A4988 stepper motor driver

(with heat tray)

- Box storing all electrical equipment :

The box which contains all electrical components and motor should be easily installable and light weight so that it does not damage the stand or disturb the alignment of any axis. The box will be 3-D printed. And will have slots for keeping motor secured. And screw for fitting electrical circuit bread board. Box will have power wires coming out of it. It contains two switches ; one main power switch and one switch to control direction, and two LEDs indication current direction of rotation.



- Battery

Battery used is rechargeable Li Polymer 11.1 V 3500mAh. It can provide sufficient power to the circuit. It is kept outside the box since it is heavy and it will be easy to remove/replace battery.

ELECTRICAL SUB-PART

The project uses an open loop control system to drive a stepper motor. After careful analysis of the torque required in the system Nema 17 stepper motor (4.2 kg cm) was chosen to be used in the project.

Lithium polymer batter of 11.1V   is used as power source.

To achieve an open loop control system an Arduino UNO microcontroller is used with an A4988 stepper motor driver. The stepper motor has 200 steps for one revolution. From previous calculations the motor is operated by 1 step in 3 seconds. Arduino open source software was use to program the microcontroller.

A4988 motor driver

- The driver consists of four pins for motor connection.
- Two pin for motor's power supply
- One 5V pin for microcontroller's power supply
- One pin to control stepping process of the motor.
- One pin to control the direction of rotation of the motor.

Relation between reference voltage (voltage between A4988 potentiometer and ground) is : V_{ref} X 2 = I

where, 2 is constant due resistance of analog of the A4988.

,I is the current supplied to the stepper motor.

Since the torque of the fine tuner is mainly due to friction it may change over time. Thus, we need the maximum torque out of the motor. The desired output of the motor (4.2 kg cm) is rated at 1.4 A (I_0).

Since the efficiency of the A4988 motor driver is 0.7,voltage – current relation becomes :

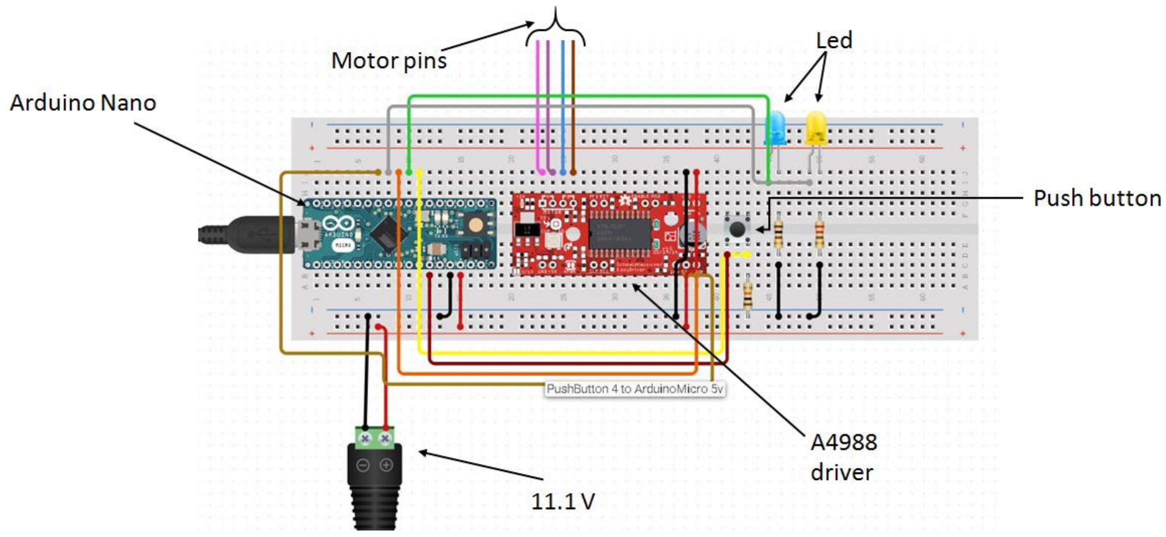
$V_{ref} * 2 * 0.7 = I_o$

Substituting, I_o =1.4 A, we get V_{ref} = 1 V

Thus, potential difference between A4988 potentiometer and ground should be 1V. This can be achieved by adjusting the A4988 potentiometer accordingly.

The motor is operated at a voltage of 11.1V and input current is maintained around 1.4 A.

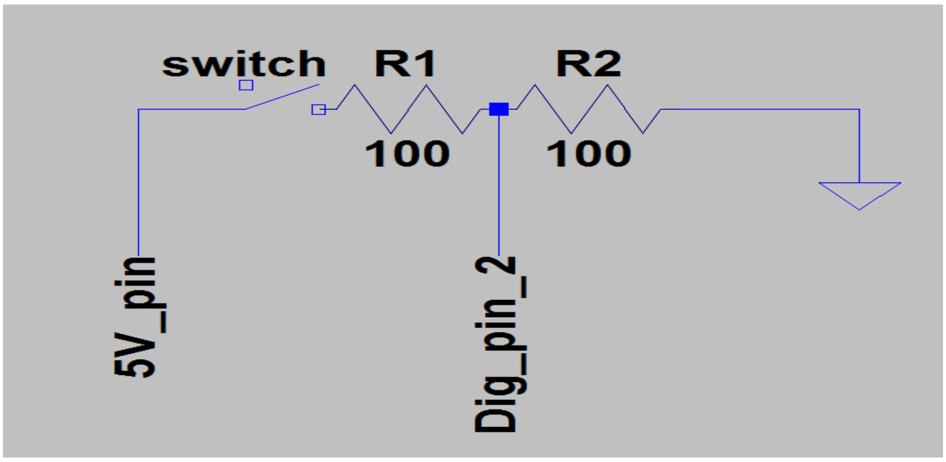
Circuit diagram :



As specified above the various pins from the A4988 motor driver are connected as below:

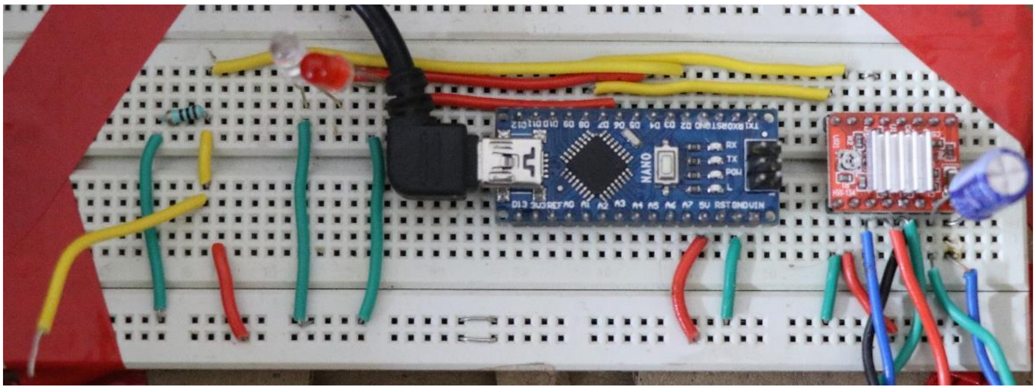
- Step pin to digital pin 10 of Arduino.
- Direction pin to digital pin 8 of Arduino.
- 5V pin of to 5V power supply pin in Arduino.
- The ground pin to common ground pin in Arduino.
- Motor power pin are connected in parallel to a 100uF capacitor to avoid voltage spikes.
  The pins are then connected to 11.1V LiPo battery.
- The four motor pins are connected to NEMA 17 motor.

The circuit also consists of one button switch control to allow the user to change the motors direction. The circuit diagram of the same is shown below.



The signals from the switch are received in digital pin two of the arduino. When the switch is closed high signal is received and when open low signal is received. The program uses this data to change the direction of the motor.

To indicate the direction of rotation two led are connected to the arduino in digital pin number 4 and 6. During clockwise rotation led in pin 6 glows and during anti-clockwise rotation led in pin 4 glows.



PROGRAM CODE FOR MICROPROCESSOR

```
const int steppin=10;//8
const int dir=8;//8
const int clo=6;
const int aclo=4;
const int sw=2;
int cur=6;
int bi=0;

void setup() {
  pinMode(8,OUTPUT);
  pinMode(10,OUTPUT);
  pinMode(clo,OUTPUT);
  pinMode(aclo,OUTPUT);
  pinMode(sw,INPUT);
  Serial.begin(9600);
}

void loop() {
  digitalWrite(dir,HIGH);
  int i;
  for(i=0;i<200;++i){
    bi=digitalRead(sw);
    Serial.println(bi);
    if(bi==1){
      digitalWrite(cur,LOW);
      if(cur==clo){
         cur=aclo;
```

```
        digitalWrite(dir,LOW);
      }
      else{
        cur=clo;
        digitalWrite(dir,HIGH);
      }
      digitalWrite(cur,HIGH);
    }
  digitalWrite(steppin,HIGH);
  delayMicroseconds(500);
  digitalWrite(steppin,LOW);
  delayMicroseconds(500);
  delay(3000);
  }
}
```

PROBLEMS FACED

- We had problems in choosing the right motor with right torque and sufficient enough precision.
- Selecting right electrical parts and waiting for the orders to be delivered took few days.
- We had to learn basics of Autodesk Fusion 360 for 3-D modelling by ourselves.
- We had to learn working of Stepper Motor and its Arduino coding by ourselves.
- Building a method for calculating torque was very difficult since we do not have a torque measuring device in institute.
- Fixing the box (containing all electrical devices) is still a problem which is yet to be solved.

PRECAUTIONS

- Oiling of the worm should be done frequently for smooth functioning.
- Friction may change due to environmental factors. Hence torque due to friction always keeps changing.
- All components should be ordered with spare parts and also the delivery date should be considered.

SCOPE OF IMPROVEMENT

- More precision

Current model may have error due to some factors like friction. To have more precision we can use better motor.

- More versatile w.r.t. different tripod stands

Our current design is attachable only to Celestron Astromaster 130 eq telescope's stand.

- Automation of other axes

Automation of other axes can also be done once Right Ascension's automation is compact enough.

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COMPUTER PROGRAM REFERENCES

Autodesk Fusion 360 for 3-D modelling

LT Spice and Autodesk stimulation for electrical stimulations