Defensive Robot (DR) :

1. **Overall dimensions** (L x W x H) :
   At start : 892 x 892 x 910 mm
   During Game time : 1013 x 1020 x 910mm
2. **Estimated weight :** 21.1 kg
3. **Materials used :** Stainless Steel AISI 304, Aluminium 6061, Nylon-66, Glass fibre, Carbon fibre, Mild steel, etc.
4. **Type of drive :** Four Wheel Holonomic Mecanum wheel Drive.

A Four-wheel mecanum drive is selected as its rich manoeuvrability will help DR to **travel swiftly inside the Inner area**. “Planetary DC geared motor 250W 750RPM 18V DC” with rated torque of **3.83 Nm** is used for the drive. Wheels used are of diameter **150 mm**.

This drive is **semi-autonomous**. The manual mode of this drive is controlled wirelessly via a **PS4 controller**. For autonomous mode, the robot uses feedback from gyroscope and laser distance sensors. **Gyroscope** is used to maintain the stability of robot during navigation and its angular orientation in desired yaw angle, while **Laser distance sensors (class 2)** are used to sense the position of robot w.r.t. game field.

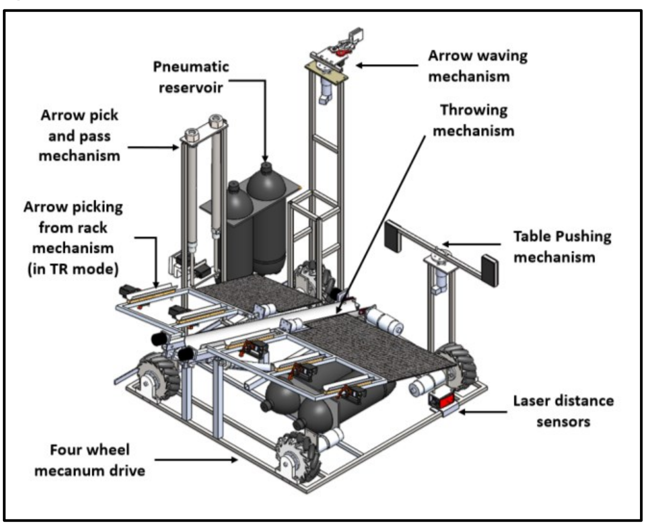

Fig 1: Defence Robot

5. **Arrow Pick and Pass Mechanism** :

Introduction:

The **objective of the task** is *to pick an arrow from the ground and pass it to the Throwing Robot (TR)*. A **servo actuated angular gripper** is used to pick the arrow from ground. This gripper will be lifted up using a pneumatic piston and rotated using a servo motor to align the arrow while passing.

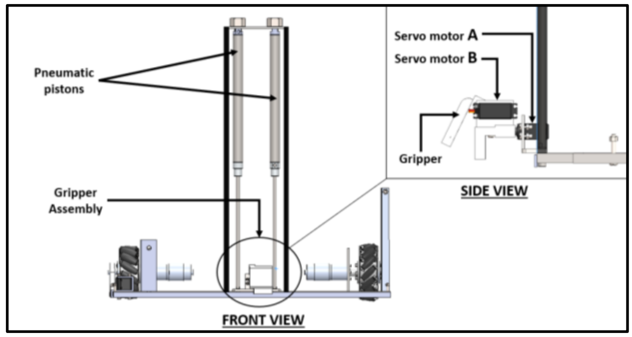

Fig 2: Arrow Pick and Pass Mechanism

Working of mechanism :

1. DR moves towards the arrow fallen in the Inner area and aligns the gripper for picking.
2. The gripper grips the arrow near to its head.
3. The arrow now in the gripper is lifted up at a height of 250 mm using pneumatic pistons.
4. The gripper is rotated using ‘*Servo motor A*’ to orient the arrow in the head down position.
5. DR aligns with TR for passing the arrow.
6. The gripper on the receiving mechanism of TR grips the arrow and at the same time, gripper on the passing mechanism of DR releases the arrow for a successful pass.

This process is illustrated by following figure:

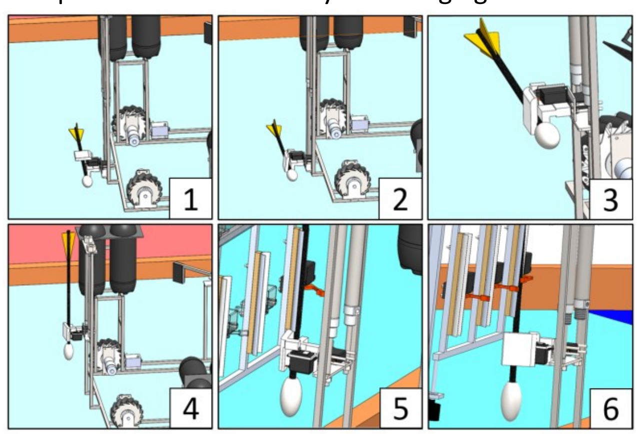

Fig 3: Working of Arrow Pick & Pass Mechanism

Calculations/ Justification:

Weight of arrow is $\boldsymbol{W_a = 1.05N}$. To ensure that gripped arrow doesn’t drop out from gripper,

$$F_g(gripping\ force) > \frac{W_a}{\mu} \times FOS(factor\ of\ safety)$$

$F_g > 14N$ *(considering μ=0.15 for rubber & FOS =2)*

The end point of the gripper is at a distance of **50mm(** r_g **)** from pivot point. Hence, minimum torque required for motor to grip the arrow is,

$$T_g = F_g \times r_g = 14 \times 0.05 \approx 0.7Nm \rightarrow (i)$$

To satisfy the requirement, a **servo motor with 0.98 Nm torque** is selected for gripping. Weight of the gripping and rotating assembly along with the arrow is $\boldsymbol{W_{gr} = 4.9N}$. Hence, to lift this assembly, required force is 4.9N. Thus, a **pneumatic piston** of bore $\emptyset 20\,mm$, stroke 250 mm, operated at 0.2 N/mm^2 is selected which will **provide a force of** $\boldsymbol{88.12N}$. The weight of gripping assembly ($\boldsymbol{W_g}$) (with arrow) is ***3.25N*** and its C.G. is $\boldsymbol{50\,mm(r_a)}$ from Pivot point. Hence the torque required is calculated as,

$$\boldsymbol{T_{ro} = W_g \times r_a = 0.16Nm}.$$

To satisfy the requirement, A **servo motor with 0.98 Nm torque** is selected for rotating.

6. Arrow Interception Mechanism :

Introduction:

The **objective of the task** is *to wave only one arrow to intercept Arrows which the opponent team throws to the II-type or III-type Pot Table*. The mechanism consists of a **gripper actuated by servo motor** which holds the arrow near its head. It is attached to a **DC motor with encoder** to perform oscillatory motion.

Working of mechanism :

1. In the setting time before game starts, one arrow will be loaded in the gripper for arrow waving.
2. While intercepting the opponent's arrows, the DC motor will start rotating to oscillate the arrow with an angle of 45°.

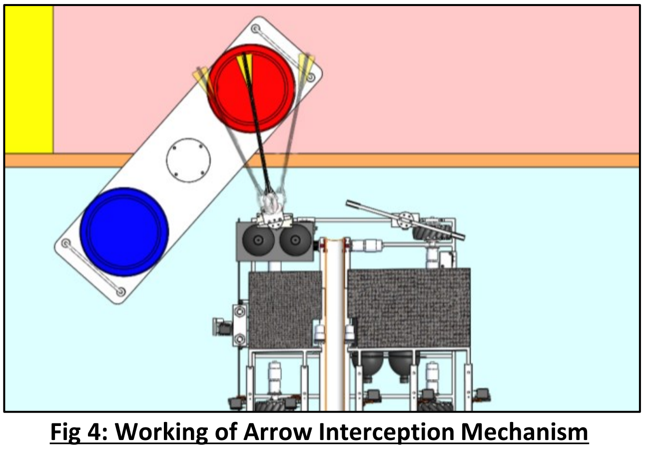

Fig 4: Working of Arrow Interception Mechanism

Calculations/ Justification:

The torque required to grip the arrow is **0.7 Nm** (from equation i). To satisfy the need, a servo motor with 0.98 Nm torque is selected for gripping. The **C.G. of the arrow** is located at **150 mm** from tip of the head, i.e. it lies close to the head. Hence, the arrow is held near to its head so that the torque required is reduced significantly as compared with when held near the plum wings. **C.G. of the rotating assembly** is located at **100 mm(r_i)** from axis of rotation.

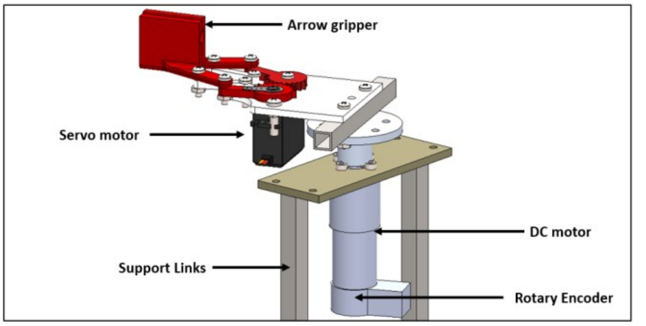

Fig 5: Arrow Interception Mechanism

Weight of rotating assembly with arrow is, $\boldsymbol{W_i = 3.012N}$. Hence, Torque required,

$$\boldsymbol{T_i = W_i \times r_i = 0.301Nm}$$

To satisfy this requirement, a **DC motor with 1 Nm torque** is selected for arrow waving. The gripper is **at a height of 850mm** from the ground. Hence, it can intercept the arrows thrown at both II-Type and III-Type Pot Table. As the arrow will be gripped near to its one end, the remaining length covers the opening of the II-Type and III-Type Pot. This ensures that the **rule 2.4.2(b-ii) is followed.** Also, DR does not contact with pot table as shown in **Fig 4**.

7. Table Pushing Mechanism:

Introduction:

The **objective of the task** is *to turn the II-type or III-type Pot Table, and prevent the opponent's arrow from entering their respective pots*. The mechanism consists of **two plates** coupled with a **DC Motor**. (**ref Fig 7**)

Working of mechanism :

1. DR aligns the mechanism with the handle of pot table. The DC motor rotates at certain angle by taking feedback from the encoder.
2. When the DR is near to II-type pot table, the link is rotated at certain angle such that only plate A will push the handle of II-type pot table.
3. When the DR is near to III-type pot table, the link is rotated at certain angle such that only plate B will push the handle of III-type pot table.

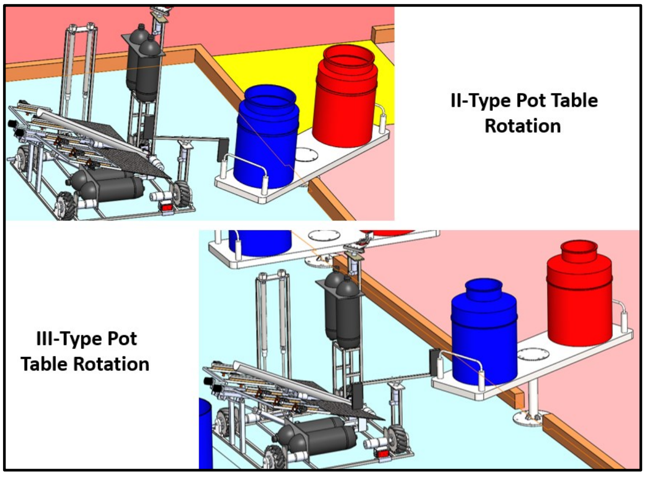

Fig 6: Working of Pot Table Pushing Mechanism

Calculations/Justification:

The mechanism is designed in such a way that, it can be used to rotate both the types of pot table with single actuator. Motor is rotated by taking feedback from encoder to prevent other plate from hitting the pot table. While pushing the pot table, pushing plates are outside the periphery of robot which **satisfies rule 2.4.2(c).**

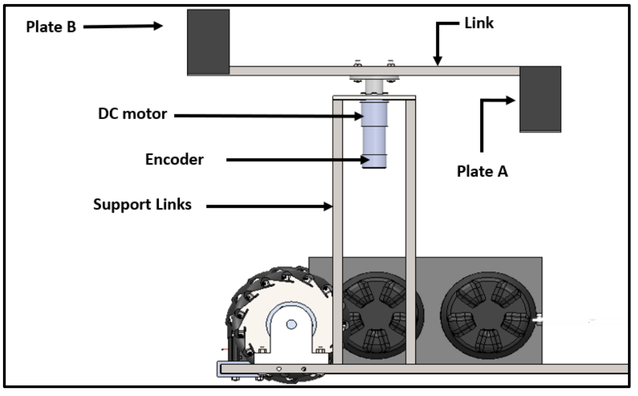

Fig 7: Pot Table Pushing Mechanism

The resisting torque **(T_r)** of the pot table is 7 Nm (as per **rule 2.1(c)**). Hence, the **force required to rotate the pot table is $F_p \approx 24N$**.

The length of the link from axis of rotation **(r_p) is 0.15 m.** Therefore, the required torque for pushing ,

$$T_p = F_p \times r_p = 3.6Nm.$$

To satisfy this requirement, a **planetary geared DC motor** with a rated torque of 3.9 Nm is used.

Throwing Robot (TR) :

1. **Overall dimensions** (L x W x H) :

   At start : 956 x 825 x 390 mm
   During Game time : 956 x 825 x 797mm

2. **Estimated weight :** 20.5 kg
3. **Materials used :** Stainless steel AISI 304, PVC, ABS, Aluminium 6061, Nylon-66, Carbon fibre, Rubber etc.
4. **Type of drive :** Four wheel Swerve Drive.

The four wheel swerve drive is selected because of its fast and precise movement. Traction wheels provide **more friction resulting in higher acceleration**. This helps TR to travel with faster speed. Also each wheel is steered individually to enhance the steering control.

This drive is **semi autonomous**. The manual mode of the drive is controlled wirelessly via a **PS4 controller**. For autonomous mode, the robot uses feedback from **laser distance sensors and Gyroscope**. The **Rotary encoders** are attached to each wheel for sensing individual wheel velocity to calculate robot velocity.

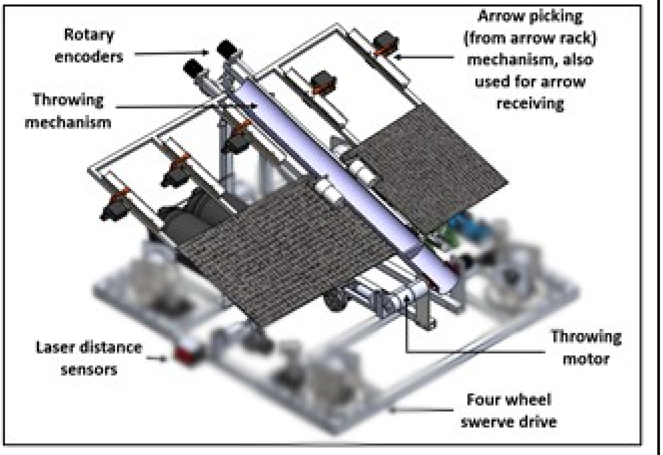

Fig 8: Throwing Robot

5. **Arrow Picking (from Arrow Rack) Mechanism :**

Introduction:

The **objective of the task** is *to pick arrows from arrow rack and load it on the throwing mechanism*. The **links actuated by servo motors** are used for picking the arrows from arrow rack. A pneumatic piston and DC motors are used to align the mechanism for loading. (**ref Fig 10**)

Working of mechanism:

1. Initially the flaps are opened with the help of DC motors and the mechanism is raised by retracting the Piston.
2. The mechanism is aligned with arrow rack such that the five arrow holders face the five arrows.
3. The arrows are gripped in the arrow holders using servo actuated links.
4. The robot moves away from the arrow rack so that the arrows will be held in the arrow holders.
5. Piston is actuated and motors are rotated to align the picking mechanism for loading.
6. Servo actuated links will release the arrows one at a time to load them on throwing mechanism.

This process is illustrated by following figure:

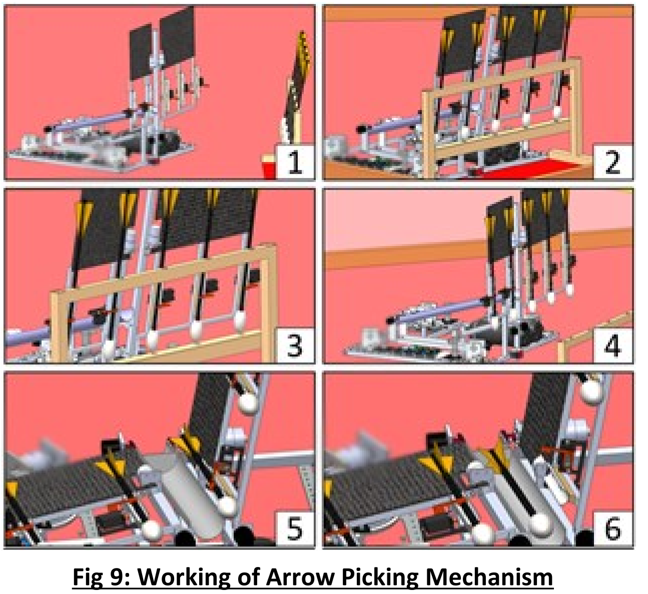

Fig 9: Working of Arrow Picking Mechanism

Calculations/ Justification:

The dimensions and mounting position for **servo actuated links** are selected in such a way that while gripping the arrows, they **don't disturb rest of the arrows and the arrow rack**. The five arrow holders are at a distance of 200 mm apart from each other so that they align with all the 5 arrows at same time. Hence, all the arrows from arrow rack can be **picked up simultaneously.**

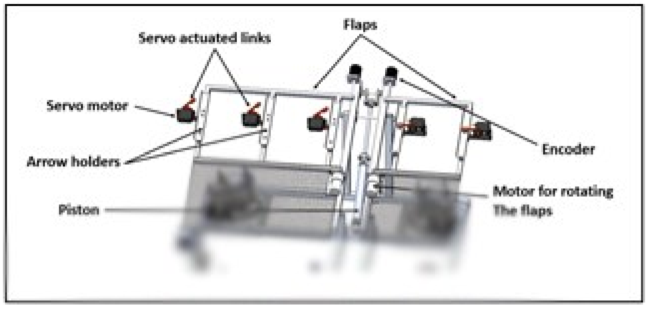

Fig 10: Arrow Picking (from Arrow Rack) Mechanism

The torque required to grip the arrow is **0.7 Nm** (from equation i). To satisfy this requirement, a servo motor with 0.98 Nm torque is selected for gripping. **C.G. of the bigger flap is at a distance of 226 mm(r_f)** from axis of rotation. Weight of the flap with arrows, $W_f = 11.77N$. Hence, Torque required to rotate the flap,

$$T_f = W_f \times r_f = 2.66Nm$$

To satisfy this requirement, DC motor with rated torque of 3.0 Nm is selected.

Weight of both the flaps including the arrows is **29.43 N (W_{fa})** and its **C.G. is at 50mm(d_f)** from pivot. The piston is mounted at **100mm(d_p)** from pivot point to get desired rotation of assembly. Force required to rotate assembly is calculated by,

$$(Required\ Force\ ) = \frac{W_{fa} \times d_f}{d_p}$$

$$Required\ Force = \frac{29.43 \times 0.05}{0.1} = 14.715N$$

Considering the factor of safety, a pneumatic piston of stroke length 200mm and bore Ø25mm, operated at 0.2 N/mm^2 pressure, which can generate a force of 98 N is selected.

The arrows are simply rested on the arrow rack. Therefore, when TR moves away from the arrow rack after gripping the arrows, arrows come out of the arrow rack without disturbing it. This ensures that **FAQ Q5-8 is followed.**

6. Arrow receiving mechanism :

Introduction:

The **objective of the task** is *to directly receive the arrows delivered by DR*. For this task, the same mechanism of 'Arrow Picking from Arrow Rack' is used.

Working of mechanism:

This process is illustrated by following figure:

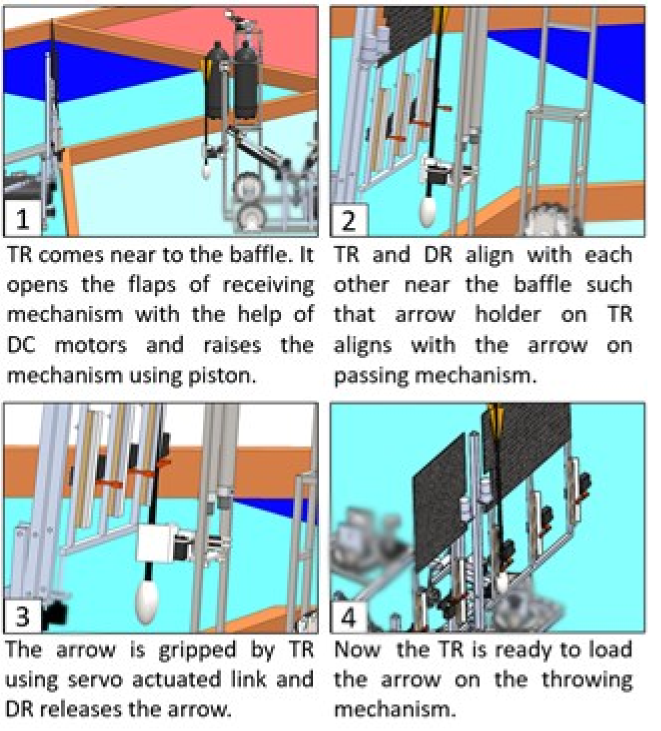

Fig 11: Working of Arrow Receiving Mechanism

Justification:

For receiving arrows from DR, the **same mechanism of 'Arrow Picking from Arrow Rack' is used.** This eliminates the need of an extra mechanism. As this mechanism can store 5 arrows, TR can receive multiple arrows from DR. Once the arrow is received by TR, it can be directly loaded on throwing mechanism. While receiving the arrows, TR doesn't enter the space above the inner area to ensure that **rule 2.4.1(a)** is followed.

7. Arrow throwing Mechanism :

Introduction:

The **objective of the task** is *to throw Arrows into the respective team's Pot, setting on any Pot table from the team's Outer Area*. A **semi-circular PVC section rotated using a DC motor** is used for the mechanism.

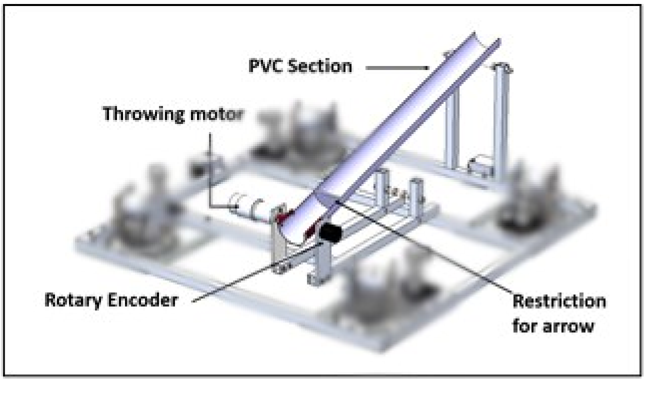

Fig 12: Arrow Throwing Mechanism

Working of mechanism:

1. The PVC section is initially at 15° (w.r.t horizontal) with a arrow loaded on it.
2. This section is rotated by a DC motor to an angle of 80°(w.r.t horizontal) to throw the arrow.
3. Due to the combined effect of tangential and radial force, the arrow attains required velocity to complete the trajectory.

This process is illustrated by following figure:

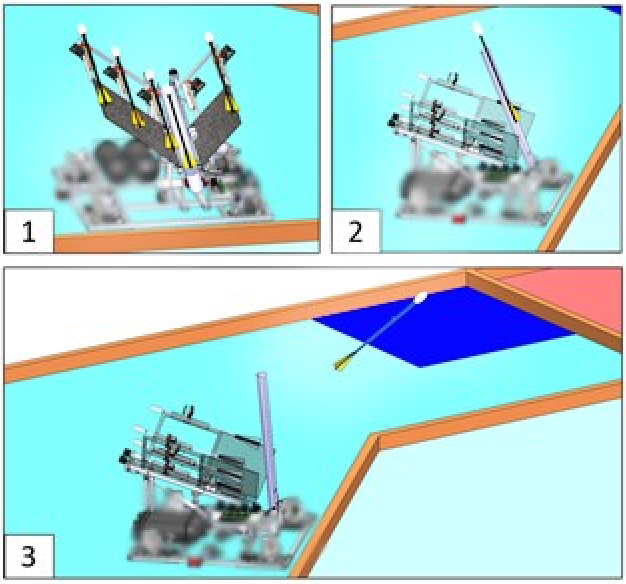

Fig 13: Working of Arrow throwing mechanism

Justification/Calculations :

The radius of the **semi-circular section of PVC pipe** is selected to ensure that arrow doesn't move sideways, maintaining its orientation for throwing. Variable range of throwing is achieved by varying the throwing velocity by changing rotational speed of the motor. The selected length of the PVC section is 740 mm, so that the arrow is completely confined within the section and some part remains for its linear motion to attain radial velocity.

Considering the arrow as a point mass, the **launching height of the C.G of arrow is 0.898 m** from the ground. **Maximum throwing range(R) is** considered as **9 m.** The PVC section sweeps an angle of 80°. Based on the calculations, the **angle of projection(θ) is 10°** (w.r.t horizontal) (**ref Fig 14**).

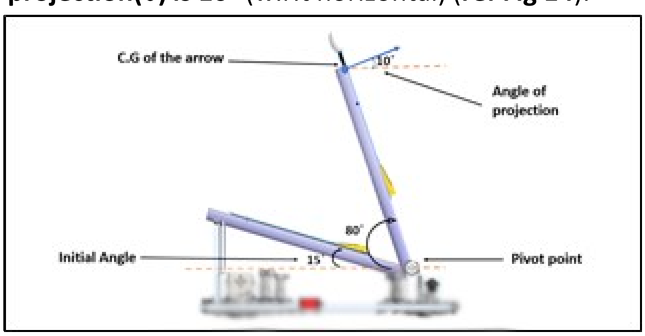

Fig 14: Initial and Launching stage

By the formula for projectile trajectory,

$$y = x.\tan\theta - \frac{g}{2 \cdot {v_t}^2 \cdot (\cos\theta)^2} \cdot x^2$$

Substituting the parameters, velocity **(v_t)** is calculated to be **14.73 m/s**. The **C.G. of the throwing mechanism** (when arrow is loaded) is at a distance of **0.760 m (r_t)** from the axis of rotation. The **weight of mechanism (W_t) is 2.03 N**. Hence, the required **angular velocity (ω_t) and torque (T_t) for throwing** is,

$$\boldsymbol{\omega_t} = \frac{v_t}{r_t} = \frac{14.73}{0.760} = 19.38\frac{rad}{s} \approx \mathbf{185}\,\boldsymbol{rpm}$$

$$\boldsymbol{T_t = W_t \times r_t = 1.54\ Nm}$$

To satisfy these requirements, A **Planetary DC geared motor with 4 Nm torque and 750RPM** is selected. For different Pot settings, the approximate required RPM is tabulated below.

Pot Type	Height of Pot opening w.r.t ground (m)	Max Range (m)	Launch velocity calculated (m/s)	RPM required
I	0.50	4.00	8.56	100
II	0.60	9.00	14.73	185
III	0.80	7.00	13.63	172

Table 1: Desired parameters for each Pot

The C.G. of arrow is near its head. Hence, when thrown in air, arrow tends to rotate about its C.G. Due to this property, the head of the arrow enters first into the pot **(ref Fig 15).**

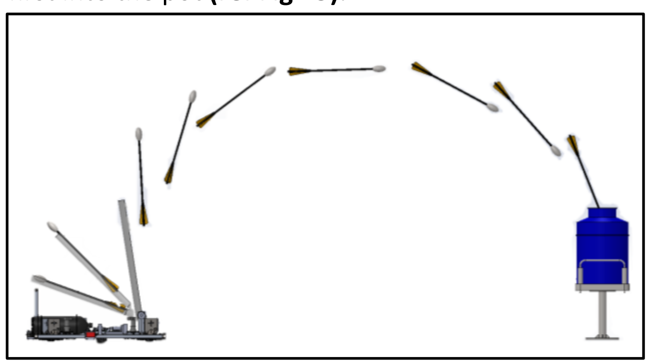

Fig 15: Trajectory of Arrow

The relation between RPM of motor and throwing distance of mechanism was found out by plotting a graph on MATLAB (**ref Fig 16**).

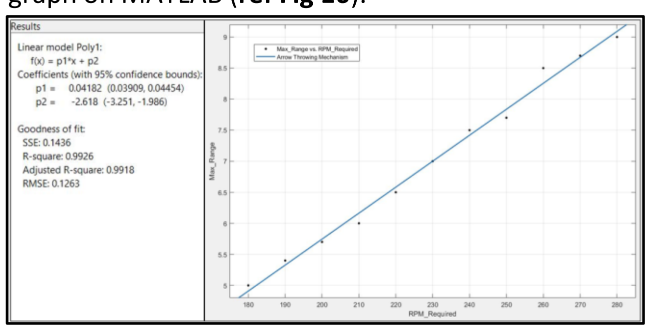

Fig 16: Graph of RPM vs Throwing Range

END OF DOCUMENT