Robot Platform Design - Reach, Stability and Structural Analysis Report

Base Frame Design

➢ <u>Material Selection:</u>

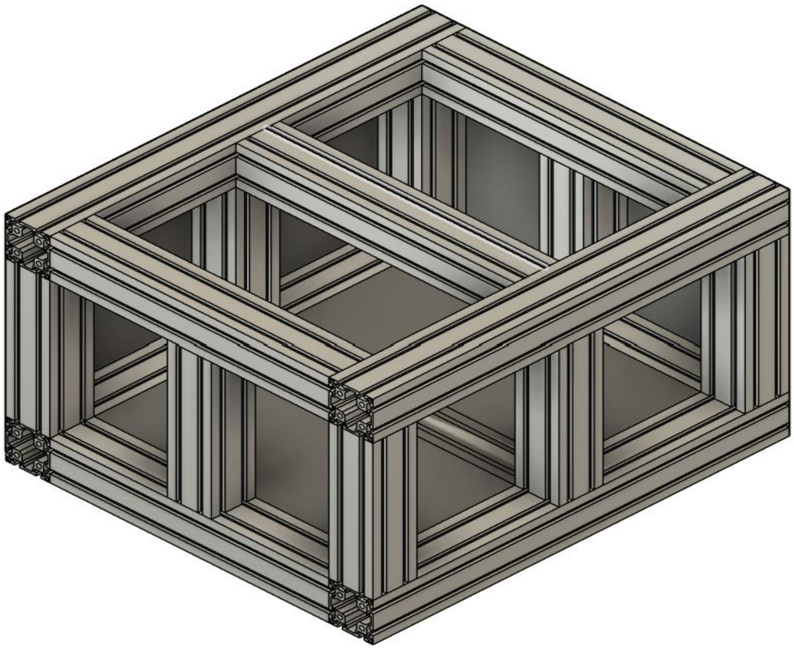
✓ **Aluminium Profiles** were selected of size **90*90mm** cross section.

- **Justification:**

Aluminium was selected due to its lightweight nature and quick assembly using bolting method making it quicker to assemble and easy on the wheels to carry as compared to MS which is much denser than aluminium and thus much heavier and it would require welding.

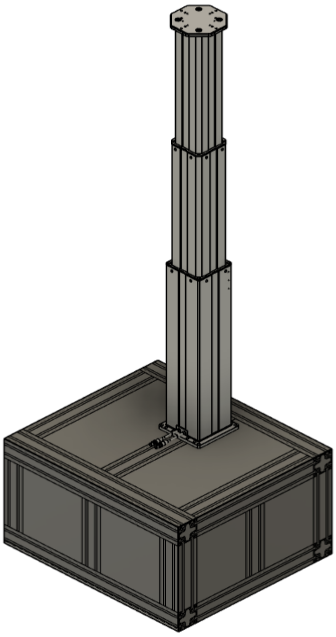
MS sheets of 1.5mm were added to the sides and 2mm plates were added to top and bottom to cover the structure thus adding torsional stiffness to the frame which otherwise aluminium is weak at.

➢ <u>Chassis Design:</u>



✓ The chassis is designed with horizontal and vertical column arrangement to distribute load evenly along the edges of the frame. In the centre of the horizontal columns reinforcement vertical columns are added to add rigidity and strength to the chassis. Also, as can be seen MS sheets are used to cover the chassis as well as provide torsional stiffness and space to place components. MS sheets will be bolted to the aluminium profiles.

Component Integration



- Lift Integration:

✓ The Lift was intentionally Placed on the horizontal beam so that the load of the lift and the robotics arm can be taken on directly.

✓ Also, if you notice the lift is 150mm away from the centre of the frame it is to help maintain stability and bring the cg close to the centre to avoid tipping more on that in the structural stability analysis part.

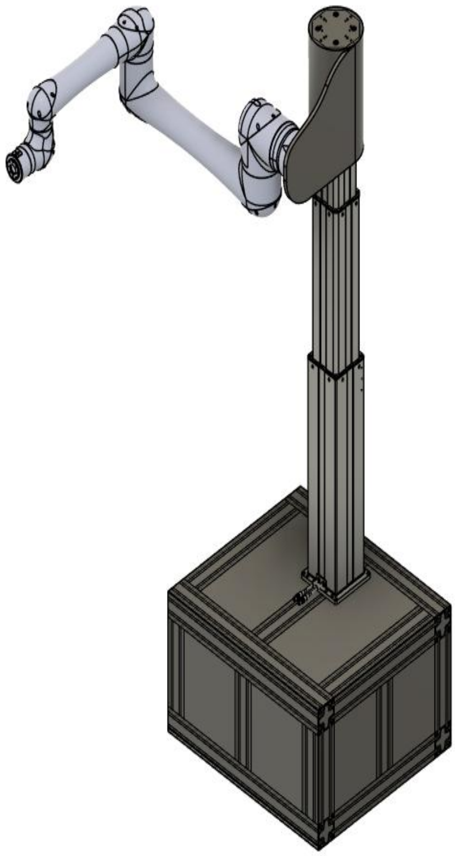
✓ The lift selected for this application is **Ewelix FA-C00-2400-601** which provides retracted height of 825 and extended height of 1925mm respectively.

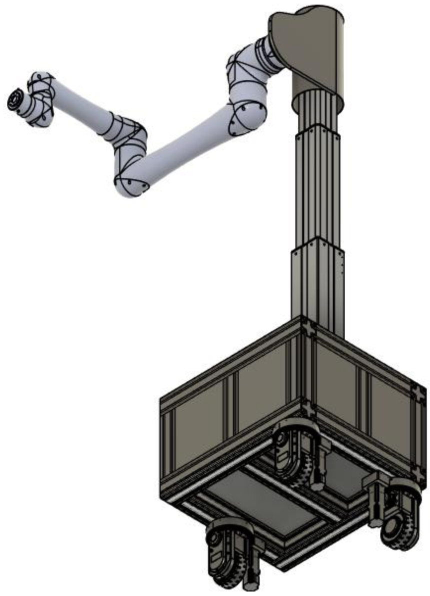
- Robotics arm Integration:

✓ The robotics Arm was mounted sideways 270mm away from the lift centre rather than on top of the lift this was done to not allow robotic arm to topple during acceleration, braking or operation and to allow the arm to cover the entire effective reach of 12ft by 4ft.

✓ To achieve the Effective reach, we had mounted Robot below the lift top surface this was done to allow robotic arm to reach the ground when lift is fully retracted because of wheels + frame + retracted lift length not allowing robot to reach the ground level and then easily reach the 12ft when lift is fully extended.

✓ This setup also helped in bringing the cg below because of the offset of 500mm from the lift top surface.





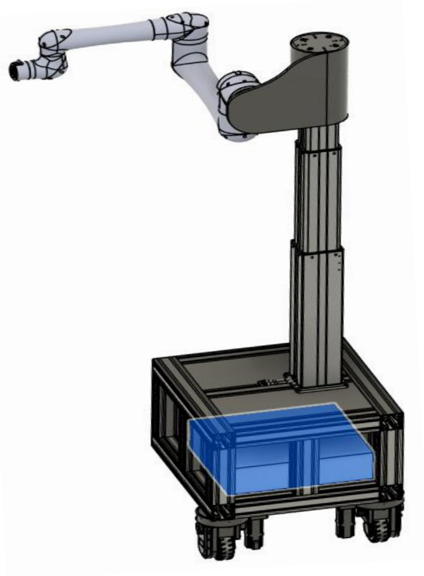
➢ Wheels Integration:

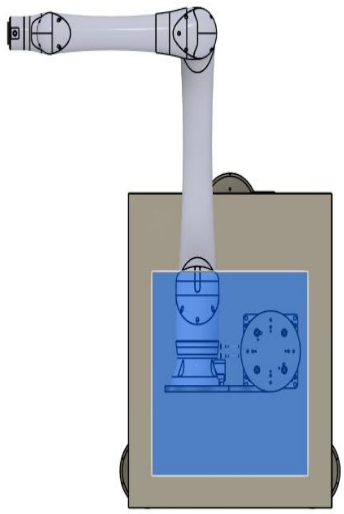
✓ Wheels are placed on the extreme ends of the chassis. This decision is made to move the 850mm length in forward motion giving narrower width of 750mm. This will help in moving around the narrow areas of sites.

✓ The wheel placement is decided upon the cg calculations and efforts were made to keep cg in centre to avoid toppling of the arm when fully extended. With this configuration right wheel is subjected to lift load and dynamic movement while left wheel handles robot movement thus balancing the body.

➢ Battery Integration:

✓ The Battery placement was strategically decided to put the weight as low as possible and to keep it away from robotic arm and near the rear side to distribute the load and counter the tipping issue.





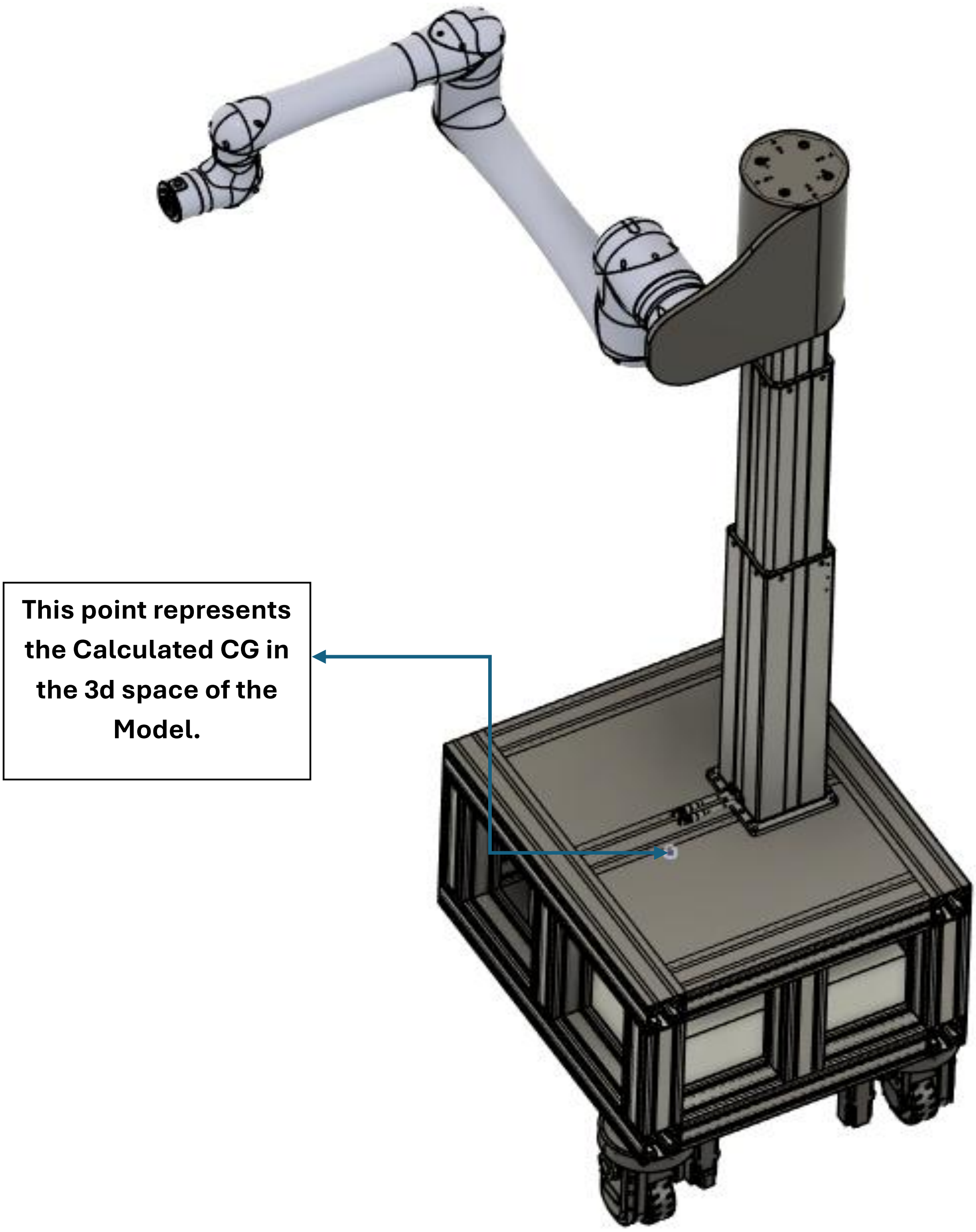
✓ The battery represented in the CAD file is based on the dimensions that I found for 5.8kwh battery with a weight of 60kg and it may differ based on battery selection and type of battery used.

Determining Centre of Gravity

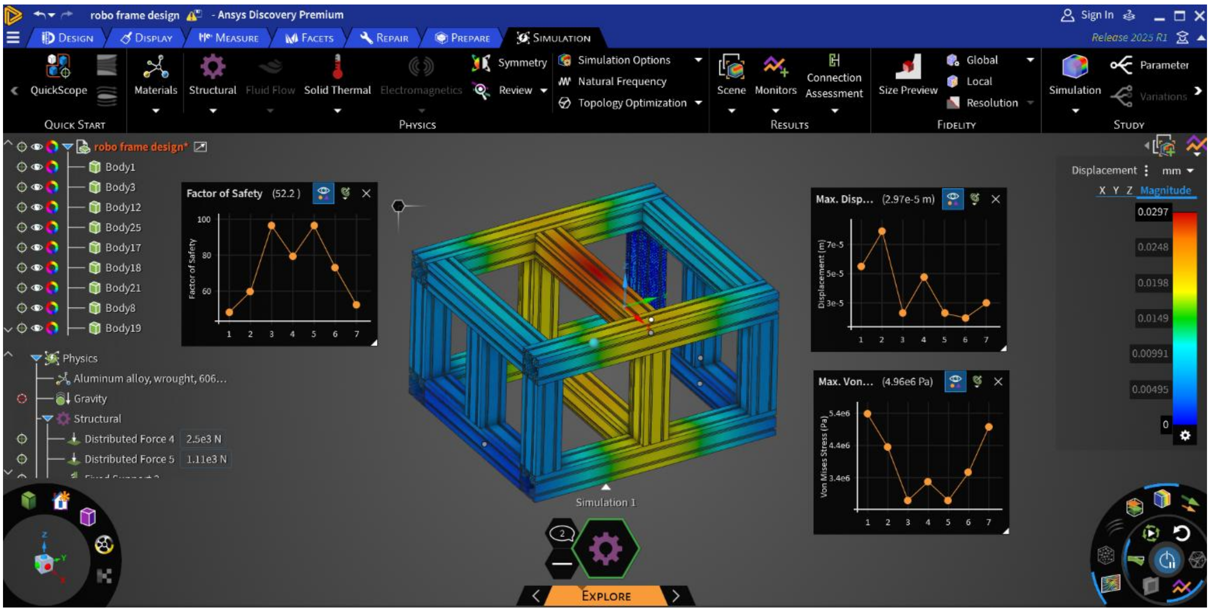
Component	Mass (kg)	X (mm)	Y (mm)	Z (mm)	m·X	m·Y	m·Z
Chassis	65	425	375	387.5	27625	24375	25187.5
MS Plates top	10	425	375	275	4250	3750	2750
ms plate bottom	10	425	375	775	4250	3750	7750
ms plate side 1	5	425	0	525	2125	0	2625
ms plate side 2	5	850	375	525	4250	1875	2625
ms plate side 3	5	425	750	525	2125	3750	2625
ms plate side 4	5	0	375	525	0	1875	2625
Robot Arm payload	45	425	-380	2350	19125	-17100	105750
Lift	30	425	525	2120	12750	15750	63600
Battery Pack	60	375	335	440	22500	20100	26400
front wheel	29	800	375	137.5	23200	10875	3987.5
Left rear wheel	29	100	50	137.5	2900	1450	3987.5
Right rear wheel	29	100	650	137.5	2900	18850	3987.5
misc items	23						
Total (Tm)	350				128000	89300	253900
Centre of Gravity	X [m.x/Tm]	Y [m.y/Tm]	Z [m.z/Tm]				
	365.7143	255.1429	725.4286				

- ✓ Table above shows the CG (Centre of Gravity) values Based on the weight, cg of individual components and distance from the Reference axis that is on the left-hand bottom side of the base frame where **x axis along 850mm, y is along 750 mm and z is vertical**.
- ✓ The CG calculations are done based on robot arm fully extended and lift too fully extended.
- ✓ The found values of CG are as Follows:
- **CGx = 366mm**
- **CGy = 256mm**
- **CGz = 725mm.**

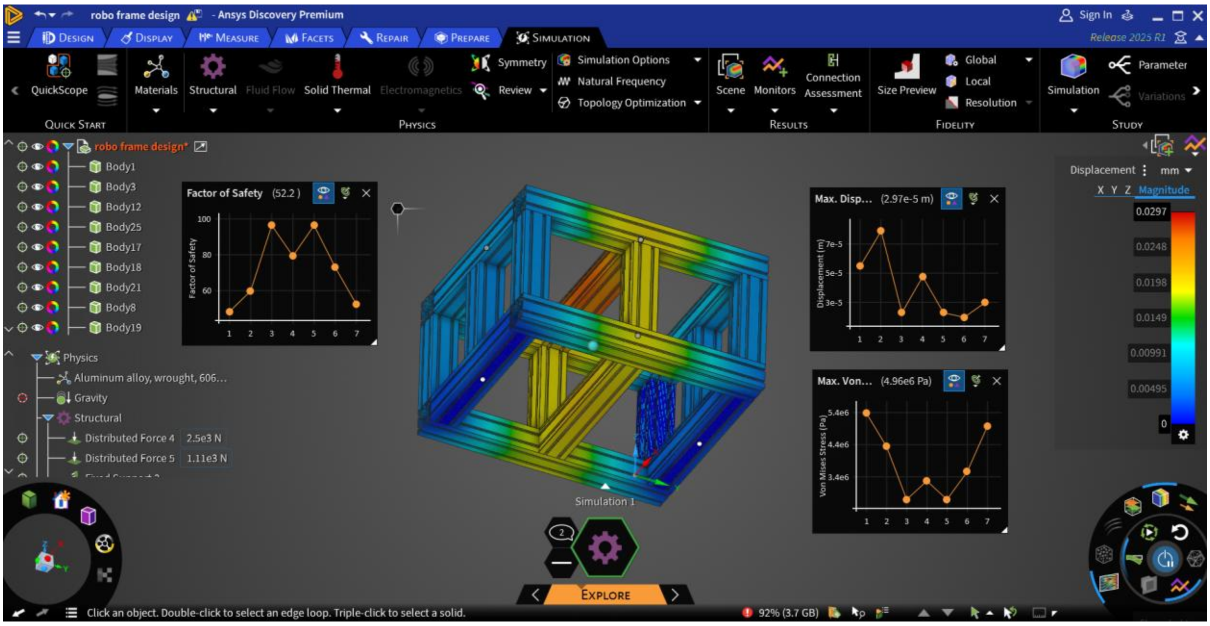
Representation of Centre of Gravity in CAD File



Structural Stability Analysis in Ansys



✓ The above Ansys Simulation confirms that the frame is having a **factor of safety around 52** which is way greater and is obviously safe.



✓ Therefore, it can be concluded that the frame can handle the load on it and **deflect at max 0.0297mm**.

Calculations for Design Validation:

1. Load distribution on wheels:

Total load = 350kg * 9.81 = 3433.5N

CG value: CGx = 366mm, CGy = 256mm, CGz = 725mm

Total force to be divided among = FW + LW + RW

Taking moment along x axis:

FW * 700 = Total weight * 366

FW = 1303.7N

Therefore, LW + RW = 3433.5 – 1303.7

LW + RW = 2129.8N

Similarly, Taking moment along Y axis:

3433.5 * 206 = RW * 600 – FW * 325

RW = 467.51N

Hence, LW = 2129.8 – 467.51

LW = 1662.29N

Since all reactions are positive, the tipping effect is minimum.

2. Forces due to Acceleration:

Max speed of motor = 32m/min = 0.533m/s

a) Acceleration = v /t = 0.533/ 2

   Acceleration = **0.267m/s2** [Assuming 2 sec for attaining speed]

b) Force due to acceleration:

   F = mass of robot * Acceleration

   F = 50 * 0.267 = **13.325N**

c) Moment due to Acceleration:

   M = f * h = 13.325 * 0.725 [0.725 for moment along vertical axis]

   M = 9.66 NM [This moment will try to tip the robot backward]

d) Resisting Moment:

   Rm = mass of body * g * 0.266 [cgx – rear wheel pivot point (100)]

Rm = 3433.5 * 0.266

Rm = 913.311 NM

Since M < Rm therefore the body will be stable and wont tip backward even when accelerating.

3) <u>Lift Dynamic Load:</u>

Dynamic moment of the lift = 210 NM

Also, h = distance from cg to lift centre = 0.269m

Dynamic moment = Df * h

Df = Dynamic moment / h = 210 / 0.269

Df = 781N

This signified that with lift moving it adds additional 781N towards the right wheel which helps bringing the CG towards the Centre thus again making the Design Stable and advantageous.

4) <u>Robot Arm movement Analysis on the base Frame:</u>

Distance from robotics arm base: j4, j5, j6 = 710, 1250, 1350mm respectively.

Robo base from CG = -30mm

Thus, distance of robot arm from base frame CG: j4, j5, j6 = 680, 1220, 1320mm.

Taking their combined movement,

Mcombined = (34.8 * 0.68 + 26 * 1.220 + 11 * 320) = 69.9NM

Restoring Moment = Amr weight * g * distance of cg from left wheel

Rm = 350 * 9.81 * 0.206 = 707.301 Nm

Since Mcombined < Rm it is evident that the robot arm wont tip along the left wheel and thus the design is safe.

Taking inertial moment for dynamic case:

Md = I * a * d [where a = 3.14rad/sec2 for each joint]

Md = [(1.28 * 3.14 * 0.68) + (0.9 * 3.14 * 1.220) + (0.3 * 3.14 * 1.320)]

Md = 7.42 Nm

Once again Md < Rm which signifies that the design is safe.

Conclusion

- ✓ The arm extension forces cg to the point where we have currently did all the calculations but we can use software based restrictions on movement like if we get robot arm extended completely we can tell software to restrict it to 75% only and let the Amr dynamically position itself such that robot arm full extension can be avoided and thus stability can be achieved with cg more towards the centre.
- ✓ Aluminium profiles used were of 90mm section which is giving us FOS of 73 which is far greater than standard but because there were a lot of unknown components which could have added extra weight and thus for safety I had designed it with these sections. We can also use 60*60mm profile but then we will have to use counterweights on the opposite side of robot to not allow cg drift away from the centre.
- ✓ Based on all the calculations and simulations we can safely say that the Design is rigid, stable and practically feasible for the given Application.

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