STEWART PLATFORM

by

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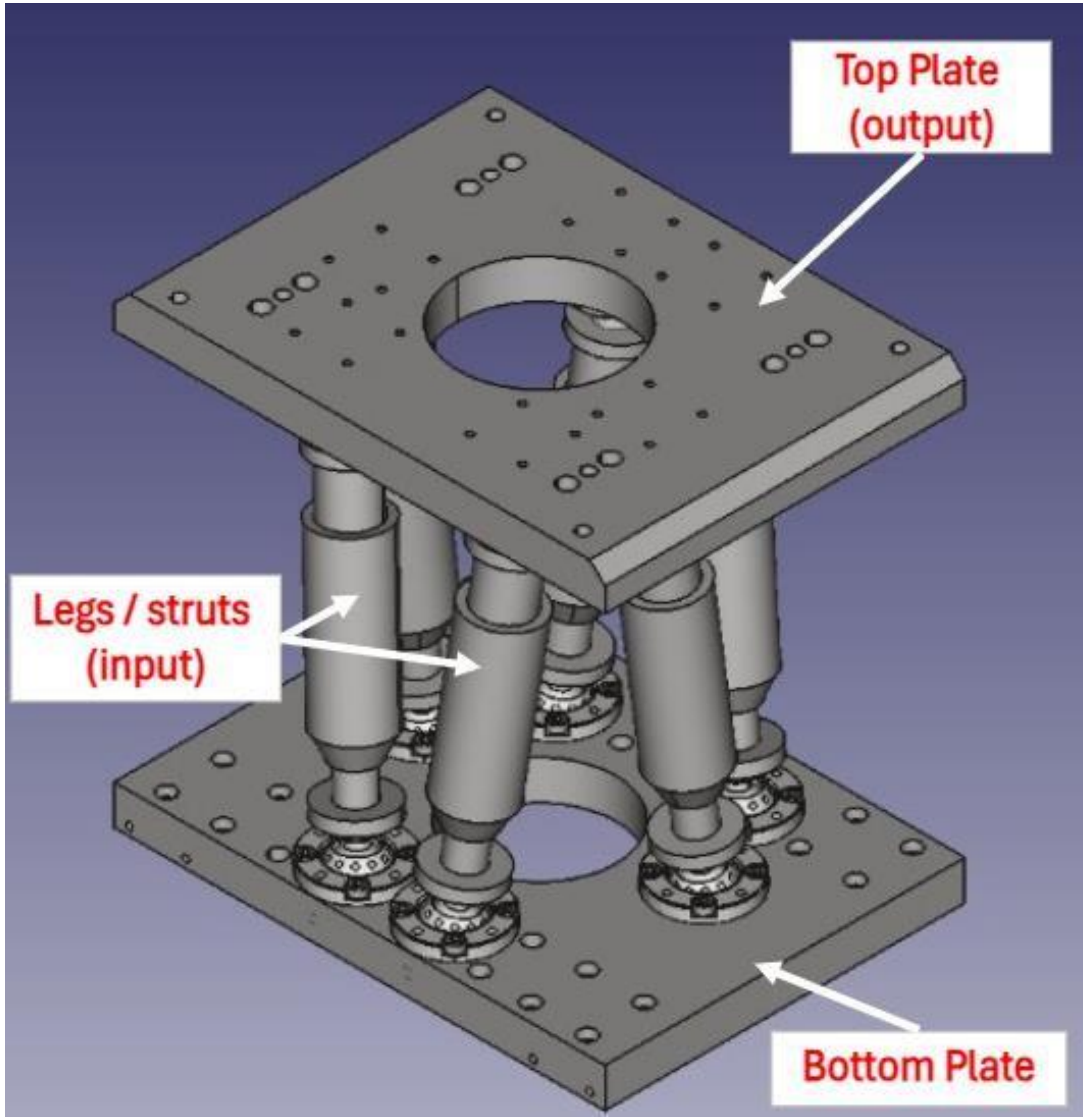
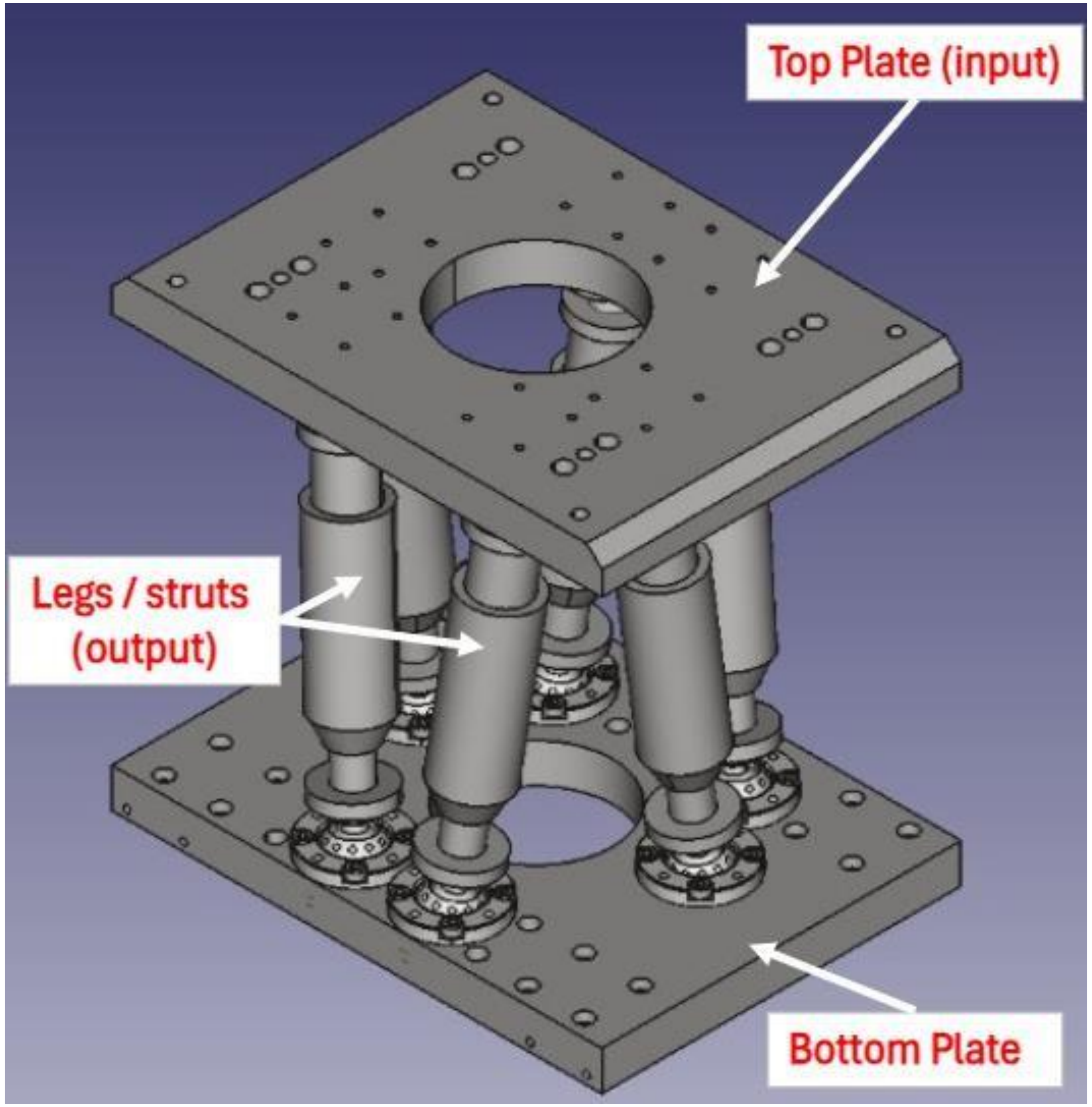
Forward Kinematics

- **Forward kinematics** involves determining the position and orientation of the top platform given the lengths of the six struts. This means calculating where the top platform is and how it is oriented in 3D space based on the known strut lengths.
- Steps:
  - **Input:** Known lengths of the six struts.
  - **Process:** Use geometric and trigonometric relationships to compute the position (x, y, z) and orientation (roll, pitch, yaw) of the top platform.
  - **Output:** The position and orientation of the top platform.
  - Forward kinematics for a Stewart platform is generally complex due to the non-linear relationships between the strut lengths and the platform's pose.



Inverse kinematics

- **Inverse kinematics** involves determining the required lengths of the six struts to achieve a desired position and orientation of the top platform. This means calculating how each strut should extend or retract to move the top platform to a specific pose.
- Steps:
  - **Input:** Desired position (x, y, z) and orientation (roll, pitch, yaw) of the top platform.
  - **Process:** Use the geometric and trigonometric relationships to compute the lengths of the struts.
  - **Output:** The lengths of the six struts.
  - Inverse kinematics is typically easier to solve than forward kinematics for a
  - Stewart platform because it involves direct geometric relationships.



Summary:

Forward Kinematics:

Strut lengths -> Position and Orientation of Top Plate

Inverse Kinematics:

Position and Orientation of Top Plate -> Strut lengths

https://github.com/kodandachalla/Hexapod_Forward_Kinematics

https://github.com/kodandachalla/Hexapod_Inverse_Kinematics

Calibration using CMM*

- Fixed Platform
- Moving Platform

Corner points and leg center points are Recorded

Note: calibration points numbering is different from assembly points numbering

*CMM (Coordinate Measuring machine)

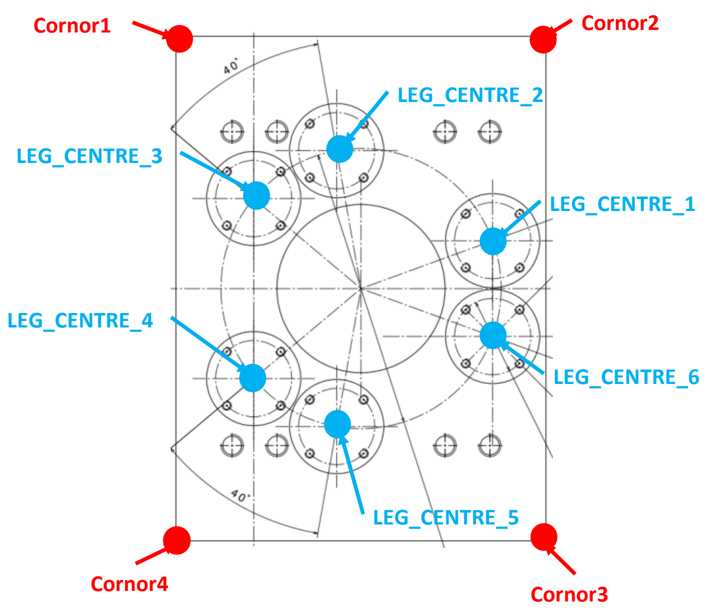
Fixed Platform:

CORNOR1	THEO/<-82.5,112.5,0>,<-1,0,0>	ACTL/<-82.468,112.527,0.002>,<-0.9999997,0.0000663,0.000812>
CORNOR2	THEO/<82.5,112.5,0>,<0,0,1>	ACTL/<82.493,112.516,-0.132>,<-0.0007324,0.0030107,0.9999952>
CORNOR3	THEO/<82.5,-112.5,0>,<0,0,1>	ACTL/<82.447,-112.499,0.568>,<-0.000733,0.0000002,0.9999997>
CORNOR4	THEO/<-82.5,-112.5,0>,<0,0,-1>	ACTL/<-82.468,-112.465,0.702>,<0,0,-1>
LEG_CENTRE_1	THEO/<61.08,22.231,-11>,<0,0,1>	ACTL/<61.06,22.233,-10.803>,<0.0004847,0.0034285,0.999994>
LEG_CENTRE_2	THEO/<-11.287,64.013,-11>,<0,0,1>	ACTL/<-11.3,64.009,-10.898>,<0.0009114,0.0037219,0.9999927>
LEG_CENTRE_3	THEO/<-49.793,41.781,-11>,<0,0,1>	ACTL/<-49.825,41.784,-10.779>,<0.0012924,0.0036046,0.9999927>
LEG_CENTRE_4	THEO/<-49.793,-41.781,-11>,<0,0,1>	ACTL/<-49.834,-41.765,-10.52>,<0.00109,0.003147,0.9999945>
LEG_CENTRE_5	THEO/<-11.287,-64.013,-11>,<0,0,1>	ACTL/<-11.327,-63.988,-10.504>,<0.0006666,0.0030836,0.999995>
LEG_CENTRE_6	THEO/<61.08,-22.231,-11>,<0,0,1>	ACTL/<61.058,-22.228,-10.654>,<0.0005216,0.0032783,0.9999945>
CENTRE_CIRCLE_CENTRE	THEO/<0,0,0>,<0,0,1>	ACTL/<0.015,0.025,0.285>,<0.000489,0.0030945,0.9999951>

Moving Platform:

Text Document

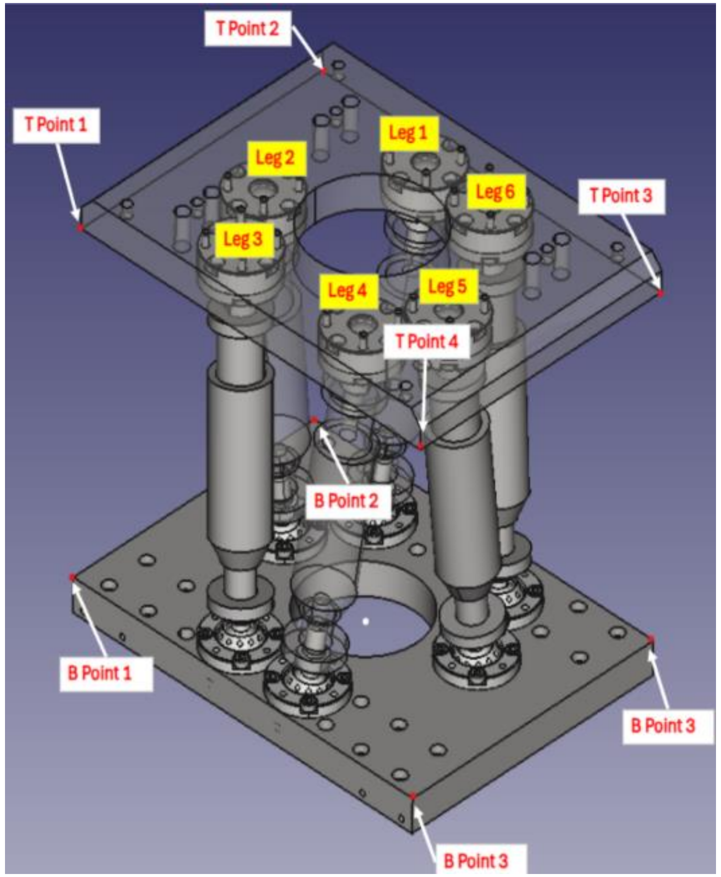
CORNOR1	THEO/<-82.5,112.5,0>,<0,0,-1>	ACTL/<-82.474,112.483,-0.029>,<0,-0.0015488,-0.9999988>
CORNOR2	THEO/<82.5,112.5,0>,<0,0,-1>	ACTL/<82.459,112.49,-0.407>,<0.0011578,-0.0015488,-0.9999981>
CORNOR3	THEO/<82.5,-112.5,0>,<0,0,-1>	ACTL/<82.466,-112.432,-0.052>,<0.0011577,0.0000006,-0.9999993>
CORNOR4	THEO/<-82.5,-112.5,0>,<0,0,-1>	ACTL/<-82.474,-112.517,0.326>,<0,0,-1>
LEG_CENTRE_1	THEO/<58.731,21.376,-11>,<0,0,1>	ACTL/<58.704,21.364,-11.243>,<0.0020898,0.0016651,0.9999964>
LEG_CENTRE_2	THEO/<-10.853,61.55,-11>,<0,0,1>	ACTL/<-10.873,61.536,-11.135>,<0.0022517,0.0015893,0.9999962>
LEG_CENTRE_3	THEO/<-47.878,40.174,-11>,<0,0,1>	ACTL/<-47.907,40.162,-11.017>,<0.0019364,0.0015196,0.999997>
LEG_CENTRE_4	THEO/<-47.878,-40.174,-11>,<0,0,1>	ACTL/<-47.912,-40.187,-10.888>,<0.0023093,0.0016937,0.9999959>
LEG_CENTRE_5	THEO/<-10.853,-61.55,-11>,<0,0,1>	ACTL/<-10.875,-61.556,-10.94>,<0.0023827,0.0017795,0.9999956>
LEG_CENTRE_6	THEO/<58.731,-21.376,-11>,<0,0,1>	ACTL/<58.708,-21.383,-11.171>,<0.0021745,0.0016568,0.9999963>
CENTRE_CIRCLE_CENTRE	THEO/<0,0,0>,<0,0,1>	ACTL/<0.013,-0.024,-0.04>,<0.0025942,0.0016802,0.9999952>



Calibration of Platforms

Moving Measured Points

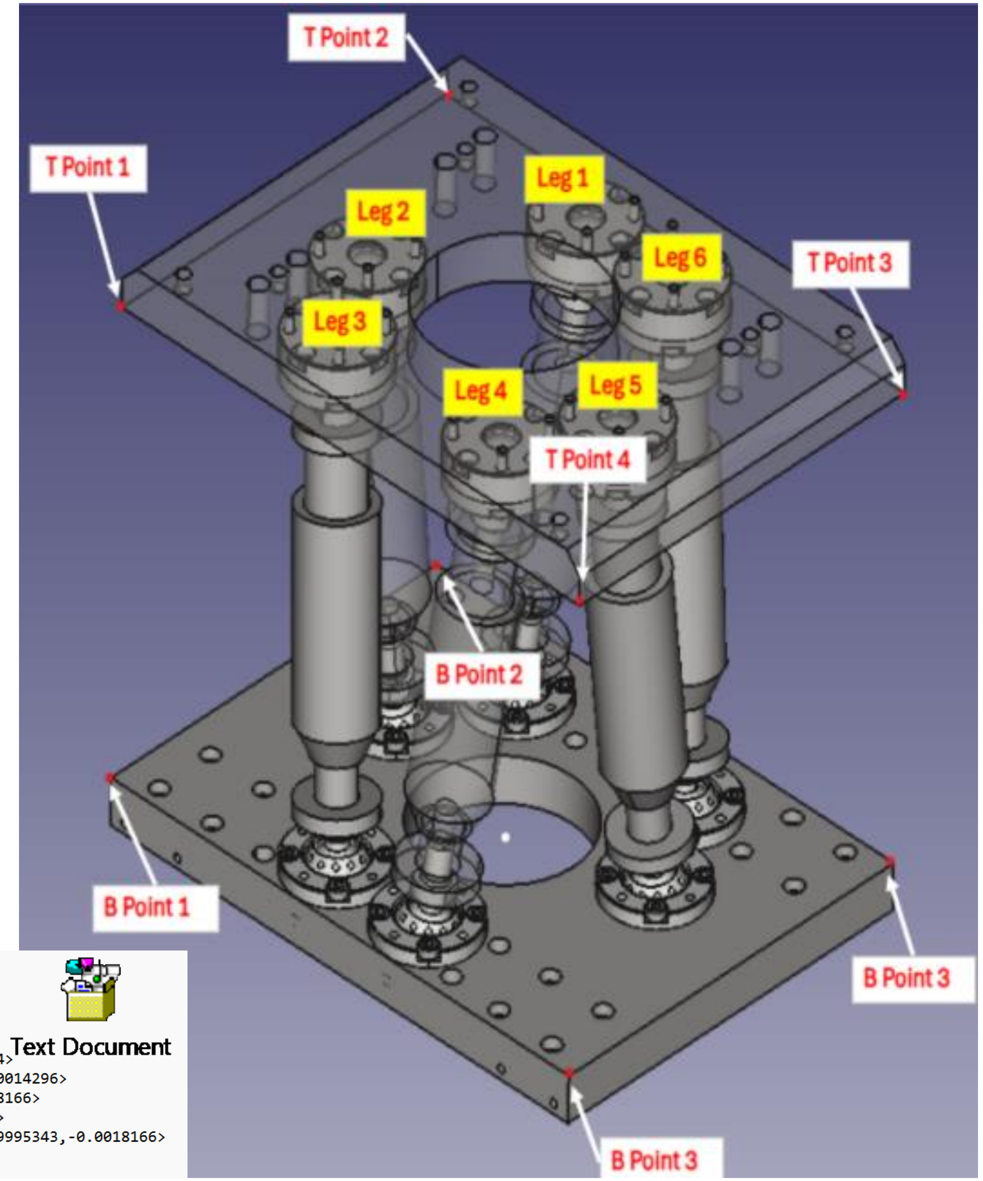
Platform Calibration points are different from assembly Points



Fixed platform		Moving platform	
leg 1	Leg_centre_4	leg 1	Leg_centre_6
leg 2	Leg_centre_5	leg 2	Leg_centre_5
leg 3	Leg_centre_6	leg 3	Leg_centre_4
leg 4	Leg_centre_1	leg 4	Leg_centre_3
leg 5	Leg_centre_2	leg 5	Leg_centre_2
leg 6	Leg_centre_3	leg 6	Leg_centre_1

Calibrated assembled Hexapod and captured following data

Kept all legs gauges at *Zero position (Case 1)**, and captured B points and T points (fig) using CMM

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Stewart Platform (Hexapod): All Legs at Zero:

B1                 THEO/<-82.5,112.5,0>,<1,0,0>                 ACTL/<-82.478,112.495,-0.004>,<0.9999997,0.0000846,0.0007034>
B2                 THEO/<82.5,112.5,0>,<0,-1,0>                 ACTL/<82.454,112.508,0.112>,<0.0002142,-0.9999999,-0.0004765>
B3                 THEO/<82.5,-112.5,0>,<0,-1,0>                ACTL/<82.502,-112.489,0.004>,<0.0002142,-0.9999999,-0.0004765>
B4                 THEO/<-82.5,-112.5,0>,<-1,0,0>               ACTL/<-82.478,-112.513,-0.112>,<-0.9999997,-0.0001421,-0.0007034>
P1                 THEO/<-82.5,112.5,181.195>,<-1,0,0.0000022>         ACTL/<-78.089,115.325,180.165>,<-0.9995178,0.0310181,0.0014296>
P2                 THEO/<82.5,112.5,181.194>,<0,1,-0.0000003>          ACTL/<86.773,110.209,179.929>,<0.0305042,0.999533,0.0018166>
P3                 THEO/<82.5,-112.5,181.195>,<0,0,-1>          ACTL/<79.912,-114.609,179.521>,<-0.0049809,0.0024965,-0.9999845>
P4                 THEO/<-82.5,-112.5,181.195>,<0,-1,0.0000003>               ACTL/<-84.943,-109.583,179.756>,<-0.0304627,-0.9995343,-0.0018166>
```

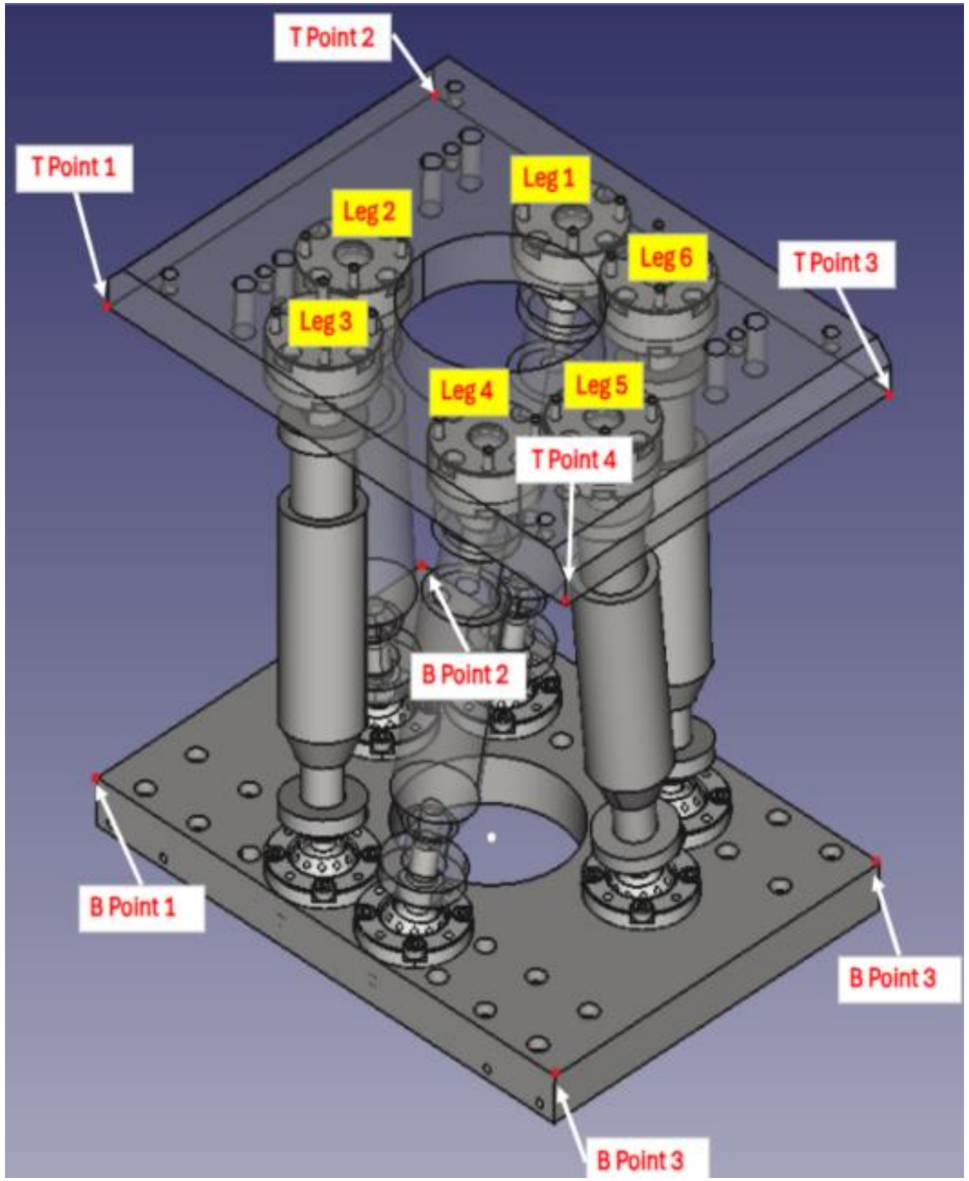
Text Document

CMM Coding: https://github.com/kodandachalla/Hexapod_Calibration

CMM Coding

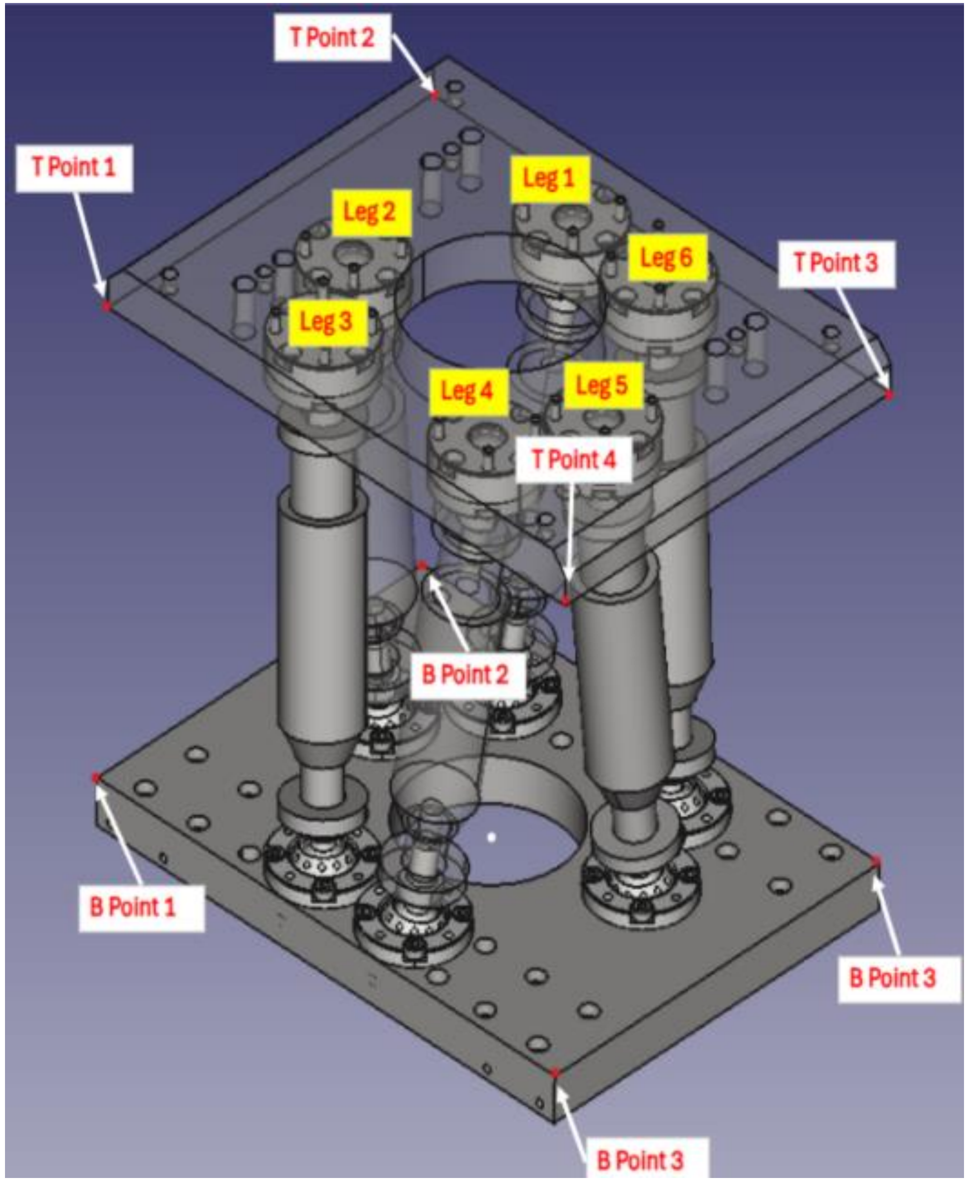
- Take points along the four sides and Top surface of the Fixed platform using CMM.
- Using the intersection of the four side planes and the top plane, locate the four corner points (B points fig) of the top plane of the bottom platform.
- Remember origin at center of rectangle

Repeat for top platform



Matlab Projection

- Construct Top Plane of the Fixed platform using B points (fig) from assembly calibration
- Calculate rotational matrix at center of Fixed platform and project Calibrated Fixed leg points on the plane
- Construct Bottom Plane of the Moving platform using T points (fig) from assembly calibration
- Calculate rotational matrix at center of Moving platform and project Calibrated Moving leg points on the Plane



Legs length calculation

In the global coordinate measure the distance between fixed platform and moving platform gives leg lengths

MATLAB Command Window

```
>> load('Calibration_results.mat')
>> legs1

legs1 =

  180.7243  180.5463  181.5145  180.8529  181.0489  180.4685
```

Checking

Case 1: **Kept all gauges at Zero position**

Calculate leg lengths using inverse kinematics (MATLAB) and store it as legs1

Case 2: Adjust leg lengths manually as needed and note down increments / decrements in length:

Leg 5 and 6 increased by 4mm

Repeat all steps of case 1 and Calculate leg lengths using inverse kinematics (MATLAB) and store it as legs2

Verify change:

Case 1 Lenths + increments / decrements = Case 2 Lenth

Conclusion

- Model predicts the change in leg lengths perfectly

- Model Works

https://github.com/kodandachalla/Hexapod_Calibration

MATLAB Command Window

```
>> load('Calibration_results.mat')
>> legs1

legs1 =

  180.7243   180.5463   181.5145   180.8529   181.0489   180.4685

>> legs2

legs2 =

  180.7056   180.5515   181.5194   180.8481   185.0625   184.4675

>> legs2-legs1

ans =

   -0.0186    0.0052    0.0049   -0.0048    4.0136    3.9990
```

THANK YOU
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