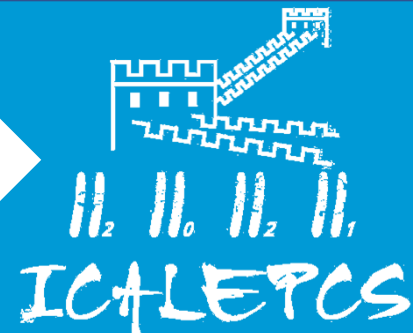


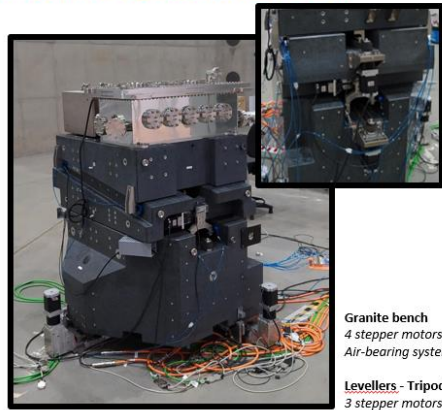
THE MIRROR SYSTEM BENCHES KINEMATICS DEVELOPMENT FOR SIRIUS LNLS

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M. A. L. Moraes, A. Y. Horita

Brazilian Synchrotron Light Laboratory (LNLS), Campinas, Brazil

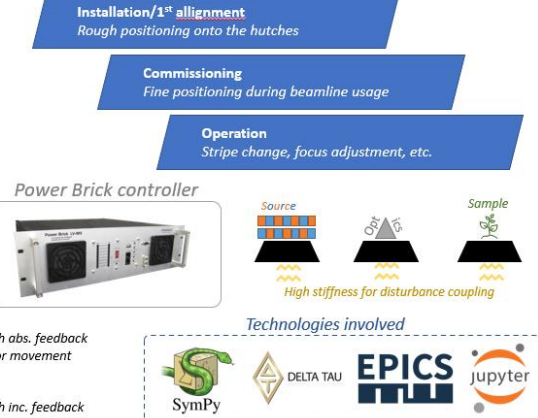


GRANITE BENCH OVERVIEW

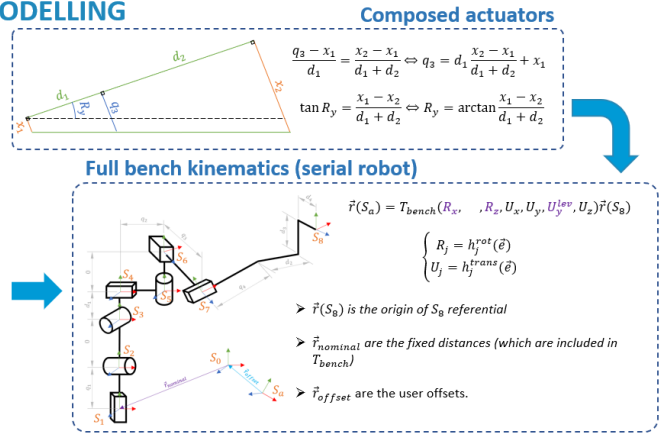
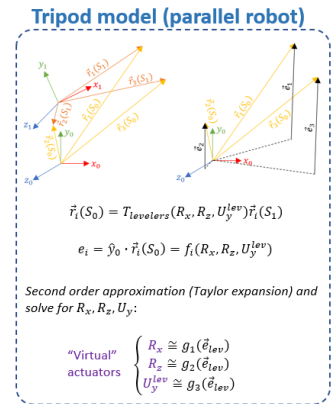


Granite bench
4 stepper motors with abs. feedback
Air-bearing system for movement

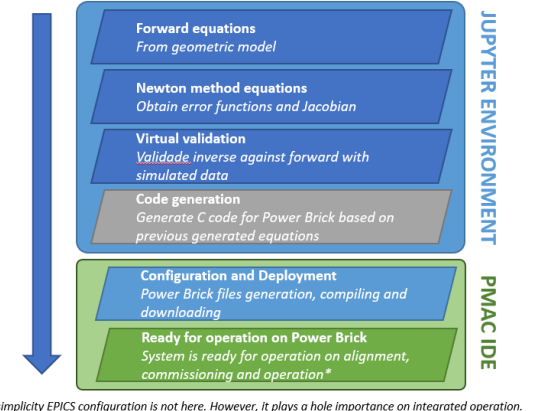
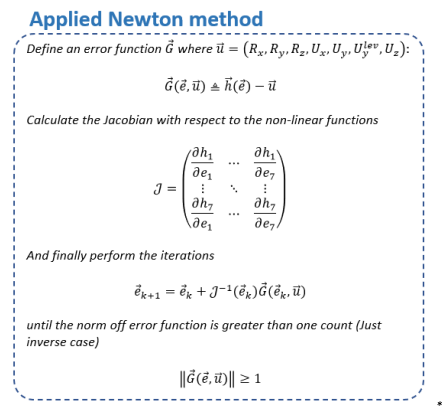
Levellers - Tripod
3 stepper motors with inc. feedback



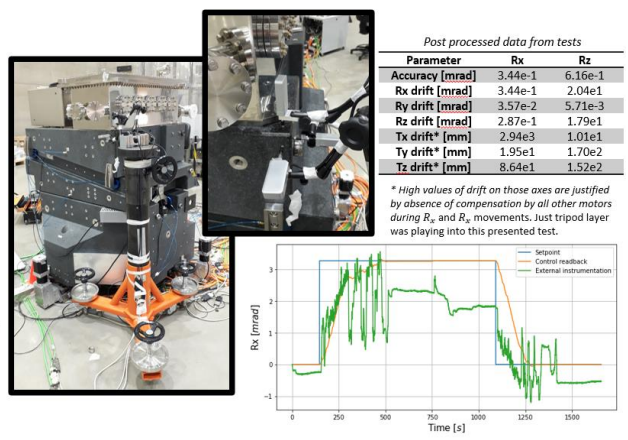
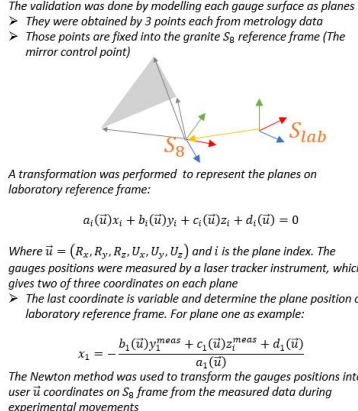
FORWARD KINEMATICS MODELLING



INVERSE KINEMATICS AND DEPLOYMENT WORKFLOW



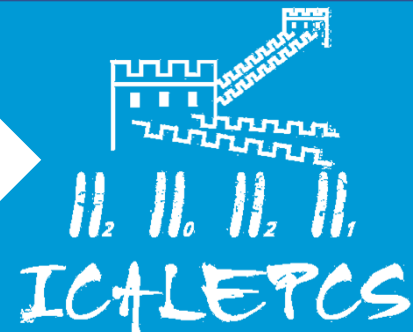
KINEMATICS VALIDATION



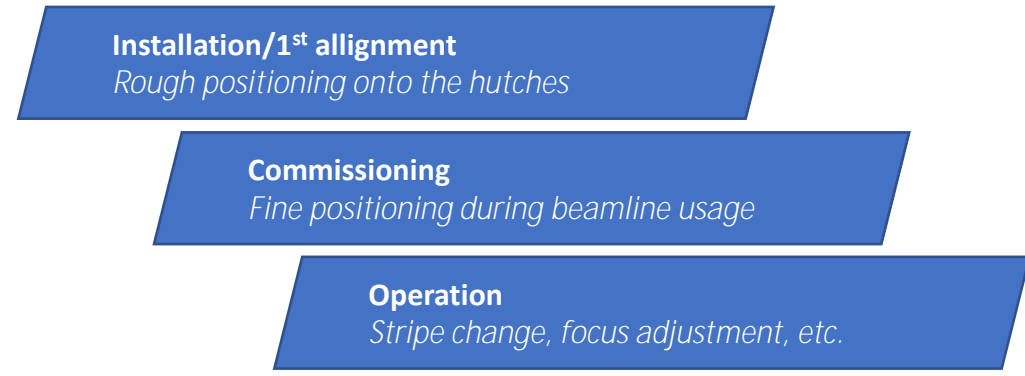
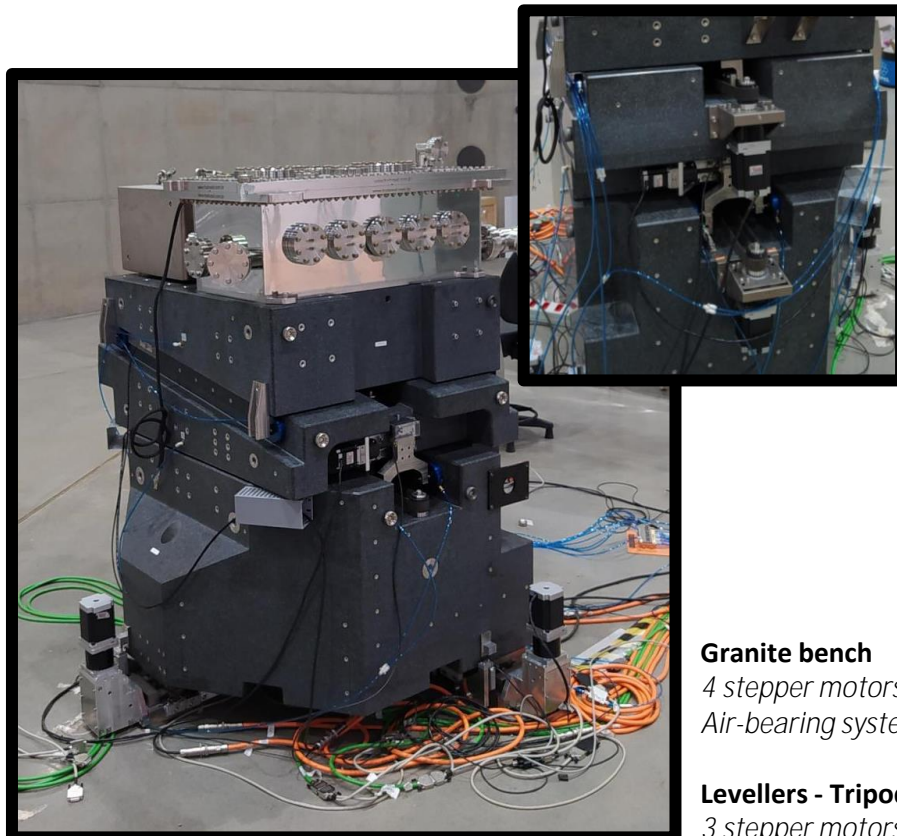
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GRANITE BENCH OVERVIEW



Power Brick controller



Granite bench
4 stepper motors with abs. feedback
Air-bearing system for movement

Levellers - Tripod
3 stepper motors with inc. feedback

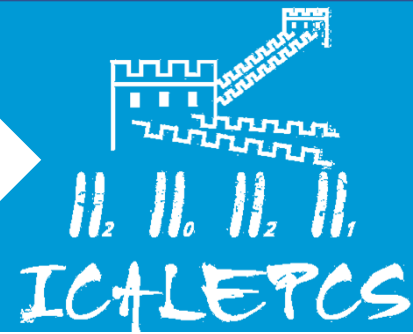
Technologies involved



THE MIRROR SYSTEM BENCHES KINEMATICS DEVELOPMENT FOR SIRIUS LNLS

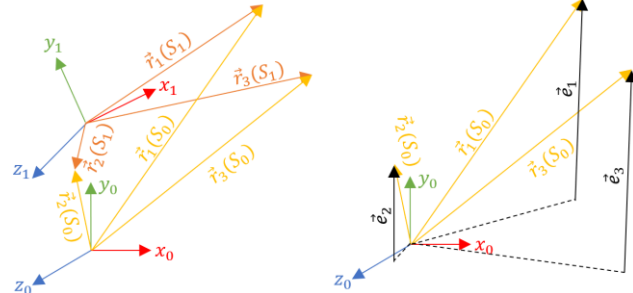
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FORWARD KINEMATICS MODELLING

Tripod model (parallel robot)



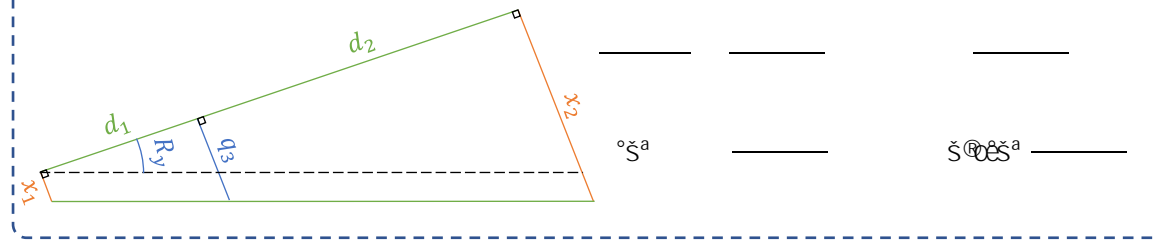
()

Second order approximation (Taylor expansion) and solve for :

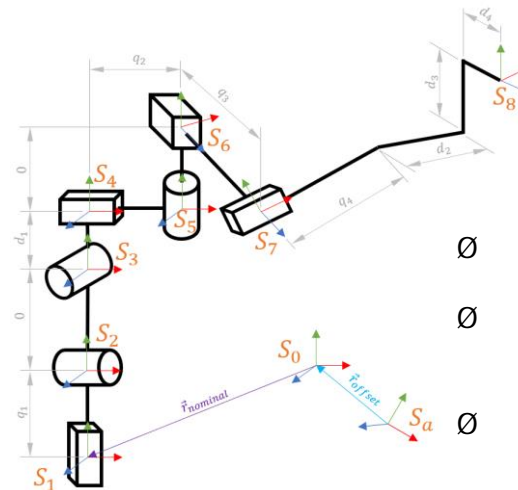
“Virtual” actuators



Composed actuators



Full bench kinematics (serial robot)

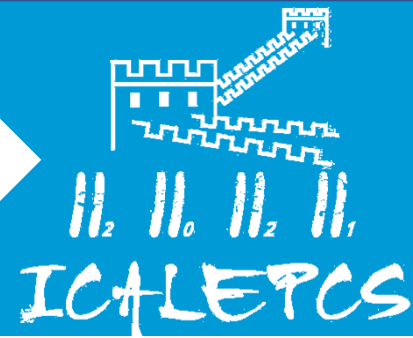


- \emptyset is the origin of referential
- \emptyset are the fixed distances (which are included in)
- \emptyset are the user offsets.

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INVERSE KINEMATICS AND DEPLOYMENT WORKFLOW

Applied Newton method

Define an error function where $\vec{r} = ($

$$(\vec{r}) = \vec{r}(\vec{c}) - \vec{r}_0$$

Calculate the Jacobian with respect to the non-linear functions

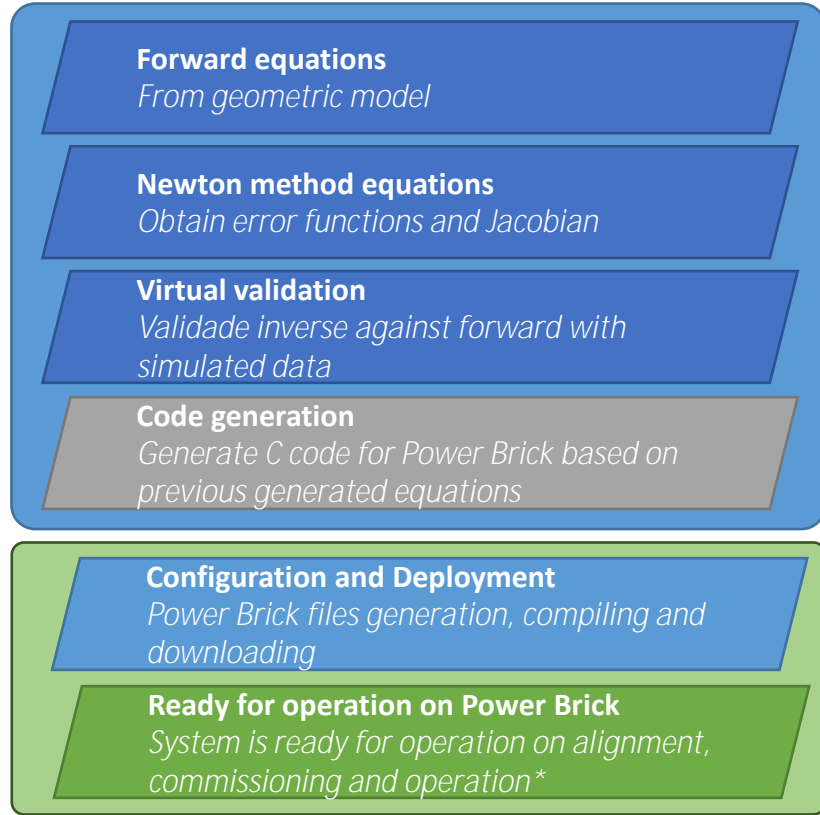
$$\begin{pmatrix} \frac{\partial r_1}{\partial c_1} & \frac{\partial r_1}{\partial c_2} \\ \frac{\partial r_2}{\partial c_1} & \frac{\partial r_2}{\partial c_2} \end{pmatrix}$$

And finally perform the iterations

\rightarrow

until the norm of error function is greater than one count (Just inverse case)

$$\|(\vec{r})\|$$



JUPYTER ENVIRONMENT

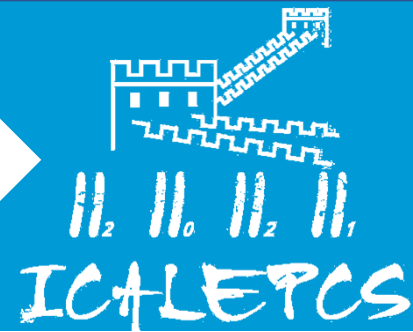
PMAC IDE

*For simplicity EPICS configuration is not here. However, it plays a hole importance on integrated operation.

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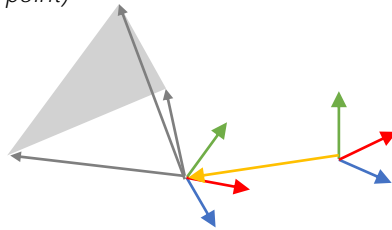
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KINEMATICS VALIDATION

- The validation was done by modelling each gauge surface as planes
- Ø They were obtained by 3 points each from metrology data
- Ø Those points are fixed into the granite reference frame (The mirror control point)



A transformation was performed to represent the planes on laboratory reference frame:

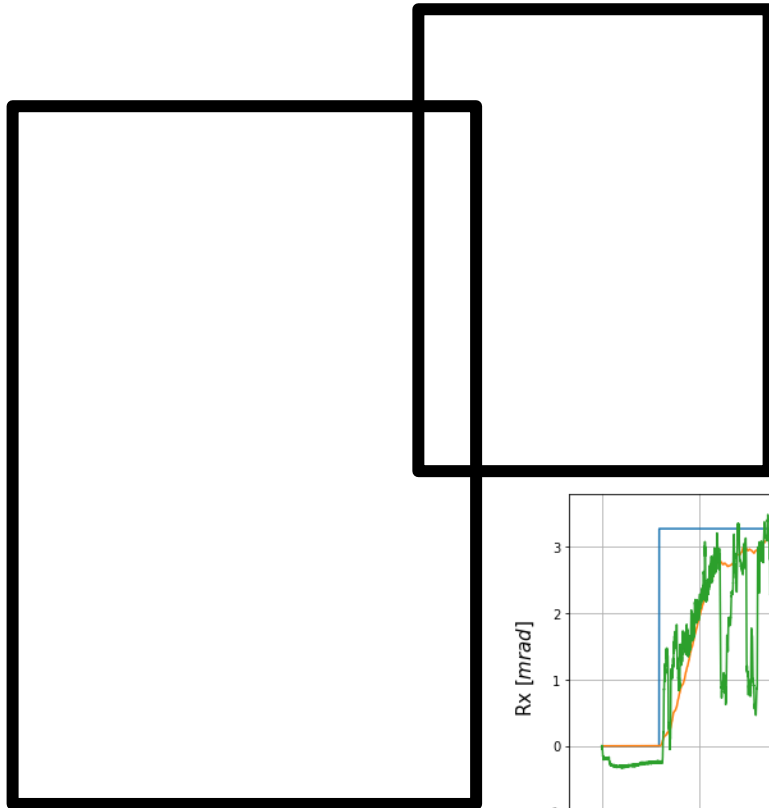
$$\vec{r}_i = \begin{pmatrix} x_i \\ y_i \\ z_i \end{pmatrix}$$

Where \vec{r}_i () and i is the plane index. The gauges positions were measured by a laser tracker instrument, which gives two of three coordinates on each plane

- Ø The last coordinate is variable and determine the plane position on laboratory reference frame. For plane one as example:

$$\vec{r}_1 = \begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix}$$

The Newton method was used to transform the gauges positions into user \vec{r}_i coordinates on frame from the measured data during experimental movements



Post processed data from tests

Parameter	Rx	Rz
Accuracy [mrad]	3.44e-1	6.16e-1
Rx drift [mrad]	3.44e-1	2.04e1
Ry drift [mrad]	3.57e-2	5.71e-3
Rz drift [mrad]	2.87e-1	1.79e1
Tx drift* [mm]	2.94e3	1.01e1
Ty drift* [mm]	1.95e1	1.70e2
Tz drift* [mm]	8.64e1	1.52e2

* High values of drift on those axes are justified by absence of compensation by all other motors during and movements. Just tripod layer was playing into this presented test.

