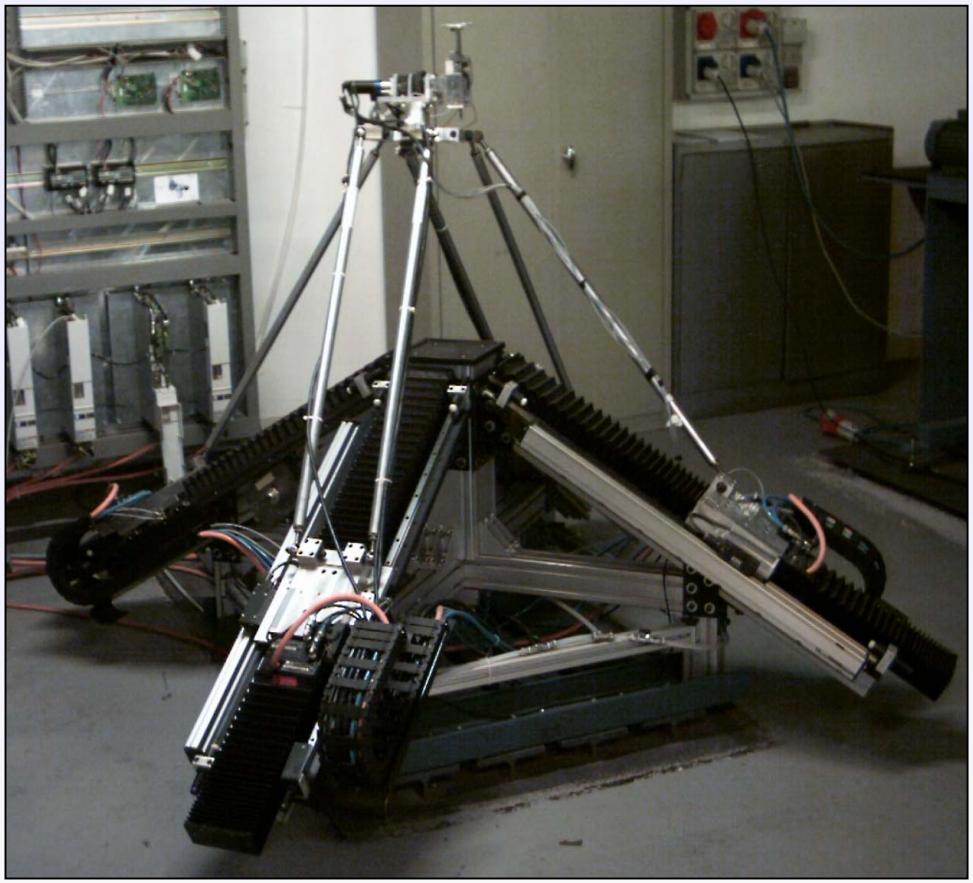
Università degli Studi di Brescia Facoltà di Ingegneria
Corso di Dottorato in Meccanica Applicata XVII Ciclo

Presentazione finale di
Diego Tosi

Progetto e Realizzazione di un Robot a Cinematica Parallela per Applicazioni Mediche



Specifiche di progetto

Robot medici

✓analisi dello stato dell'arte*

✓spazio di lavoro: 400x400x300 mm
✓inclinazione punta: +\- 40°
✓velocità
✓accelerazione

Progetti "METAFORE" e "RIME"

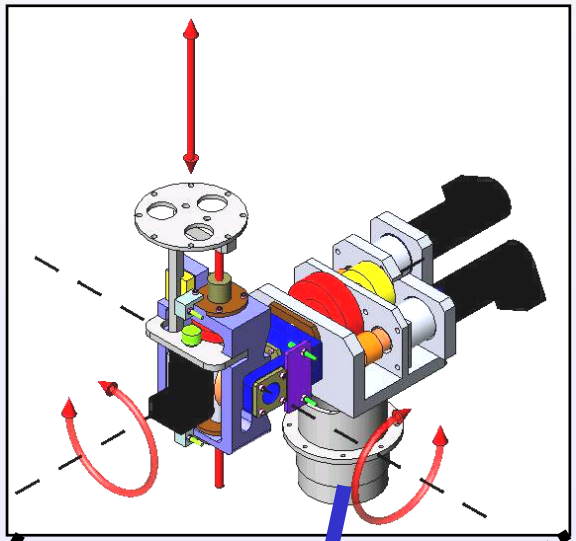
✓prototipo di robot per il fissaggio di viti peduncolari

*Tesi di laurea di D. Martini "***Catalogazione Comparata di Robot per Applicazioni medicali**", A.A. 2001/2002

Struttura cinematica ibrida

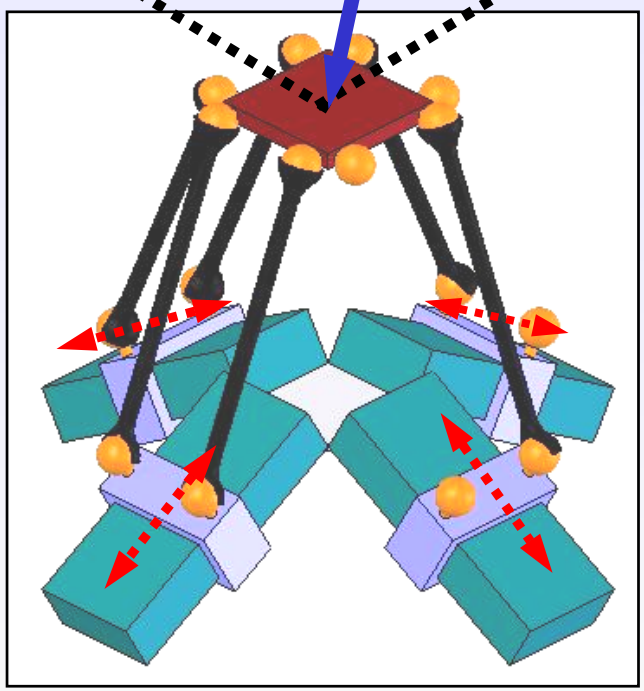
parte seriale

- ✓3 gradi di libertà
- ✓2 rot. + 1 trasl.

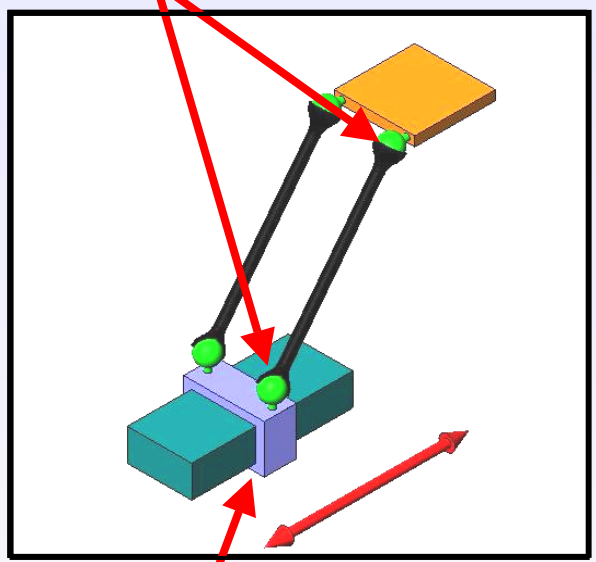


parte parallela

- ✓base moveable points
- ✓modulare
- ✓4 assi lineari
- ✓riconfigurabile
- ✓3 o 4 gradi di libertà
- ✓ridondante

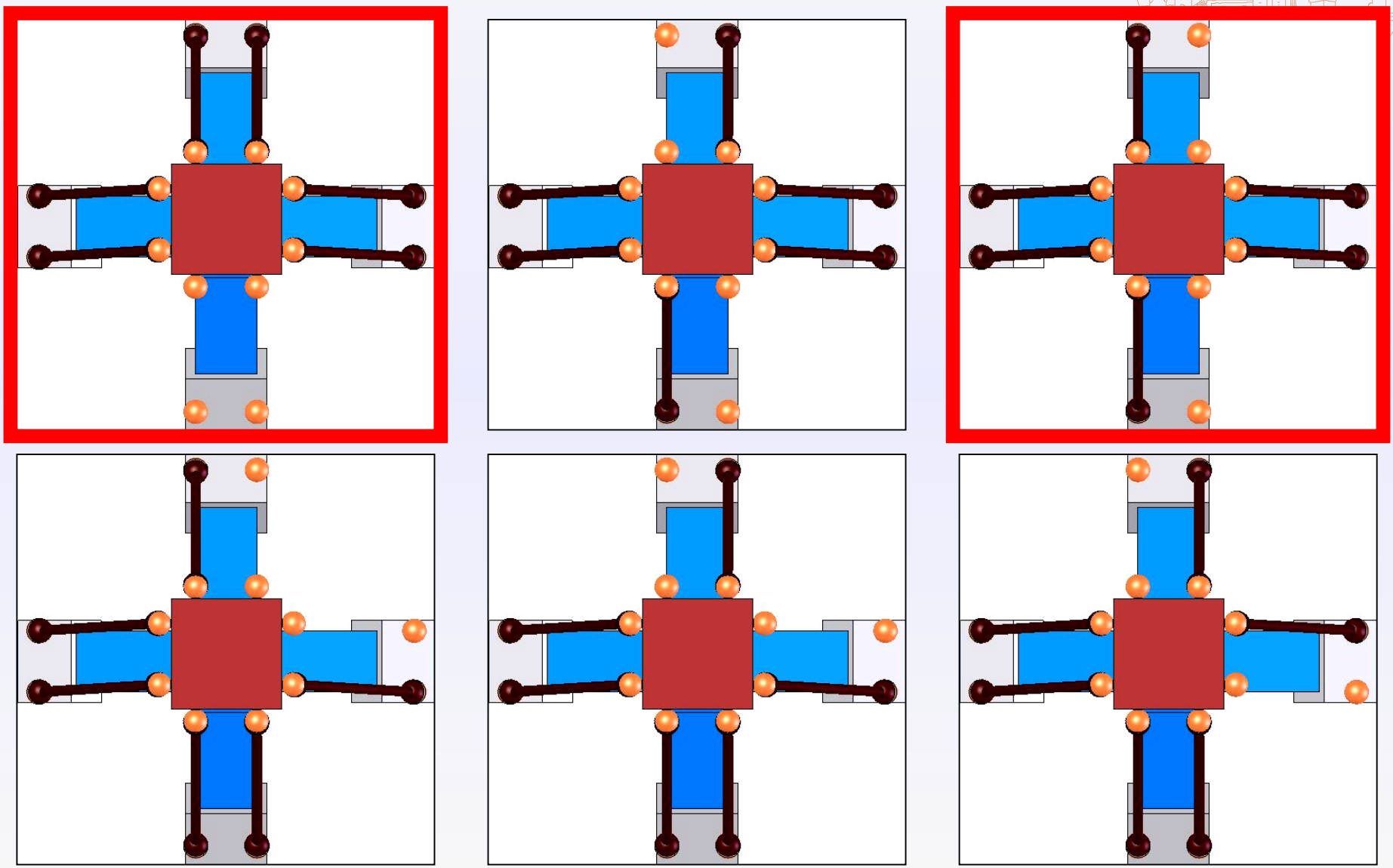


giunti sferici



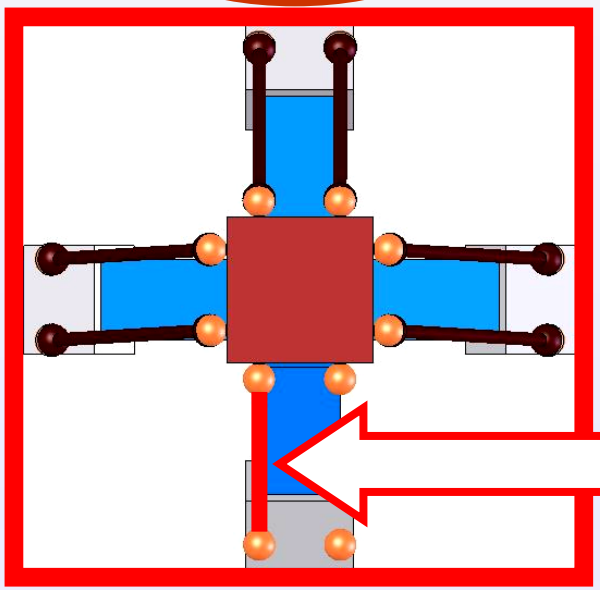
giunto prismatico

Riconfigurabilità



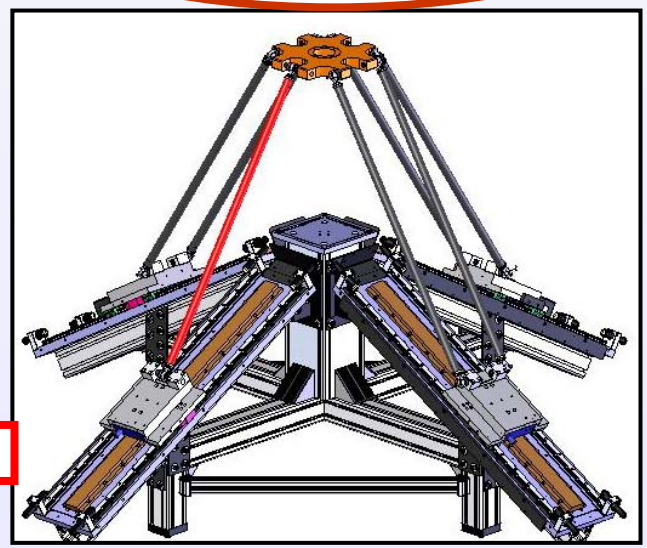
Riconfigurabilità

3 g.d.l.



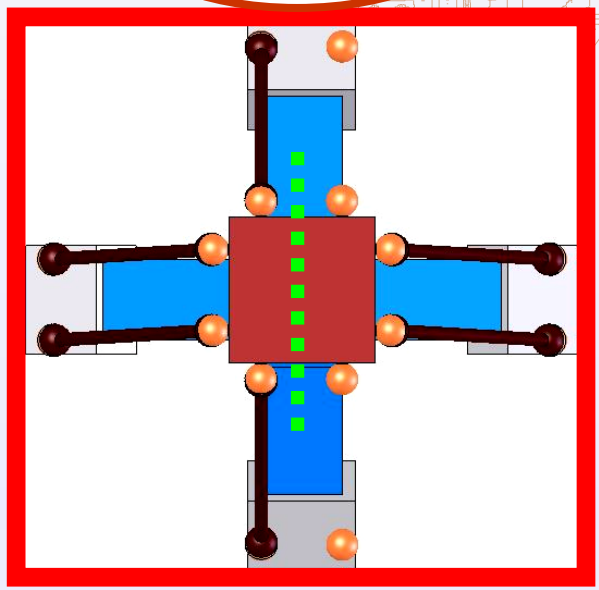
- ✓6 bielle su 3 motori
- ✓3 gdl
- ✓solo traslazioni

3 g.d.l. rid.



- ✓7 bielle su 4 motori
- ✓3 gdl iperstatica
- ✓4° motore controllato in forza
- ✓recupero dei giochi

4 g.d.l.



- ✓6 bielle su 4 motori
- ✓4 gdl
- ✓3 traslaz.+1 rotaz.
- ✓asse rotaz. fisso

Analisi struttura parallela

STUDIO CINEMATICO: POSIZIONI

Inversa

posizione piattaforma ⇨ posizioni motori

3 gdl e 4 gdl: risolta in forma chiusa

- ✓**Chiusura vettoriale**

$$\mathbf{O}_j + q_j\mathbf{n}_j + l\mathbf{w}_j = \mathbf{X}_p + \mathbf{a}_j \qquad \mathbf{r}_j = \mathbf{X}_p + \mathbf{a}_j - \mathbf{O}_j,$$
$$q_j = \mathbf{n}_j^T\mathbf{r}_j \pm \sqrt{(\mathbf{n}_j^T\mathbf{r}_j) - (|\mathbf{r}_j|^2 - l_j^2)}$$

Diretta

posizioni motori ⇨ posizione piattaforma

3 gdl: risolta in forma chiusa

- ✓**Geometria solida**
- ✓**Algebra matriciale**

$$\begin{cases} (\mathbf{Q'H})^T\mathbf{X}_p + \mathbf{k}_A = 0; \\ (\mathbf{Q'H})^T\mathbf{X}_p + \mathbf{k}_B = 0; \end{cases} \qquad \mathbf{X}_p = \mathbf{X}_A + \lambda(\mathbf{X}_B - \mathbf{X}_A)/|\mathbf{X}_B - \mathbf{X}_A|$$
$$(\lambda)^2 + 2\lambda(\mathbf{X}_A - \mathbf{Q'}_1)^T(\mathbf{X}_B - \mathbf{X}_A)/|\mathbf{X}_B - \mathbf{X}_A| + (|\mathbf{X}_A)|^2 - 2\mathbf{Q'}_1\mathbf{X}_A + cost_1)$$

4 gdl: risolta numericamente

- ✓**Equazione trascendente (8° grado)**
- ✓**Soluzione approssimata**
- ✓**Newton-Raphson su 2 equazioni**

$$Eq_a(\alpha, z) = (x(z,\alpha) - cost_a + a\cos(\alpha) - q_1\cos(\psi))^2 + y(z,\alpha)^2 + \\ + (z - cost_z - a\sin(\alpha) + q_1\sin(\psi))^2 - l^2$$
$$Eq_b(\alpha, z) = (x(z,\alpha) + b - b\cos(\alpha))^2 + (y(z,\alpha) - cost_a + a - q_2\cos(\psi))^2 + \\ + (z - cost_z + b\sin(\alpha) + q_2\sin(\psi))^2 - l^2$$

Analisi struttura parallela

MAPPATURA INDICI DI PRESTAZIONE

$$dQ = JdS$$

dQ spostamento motori

J matrice jacobiana

dS spostamento e rotaz. piattaforma

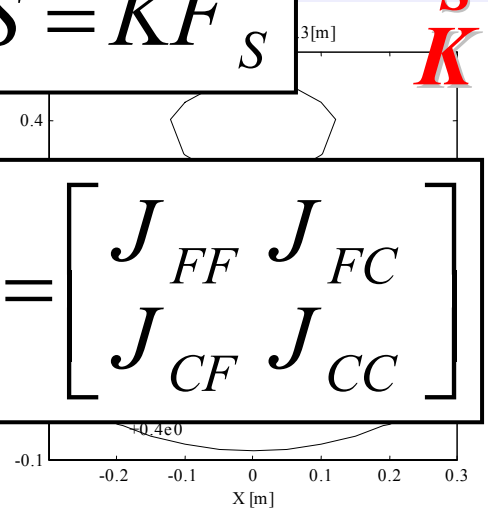
F_S forze e coppie sulla piattaforma

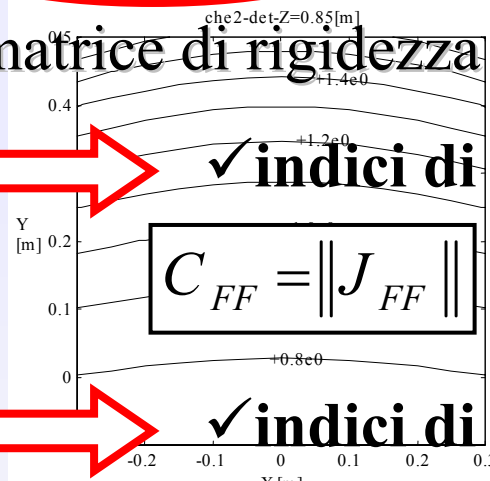
K matrice di rigidezza

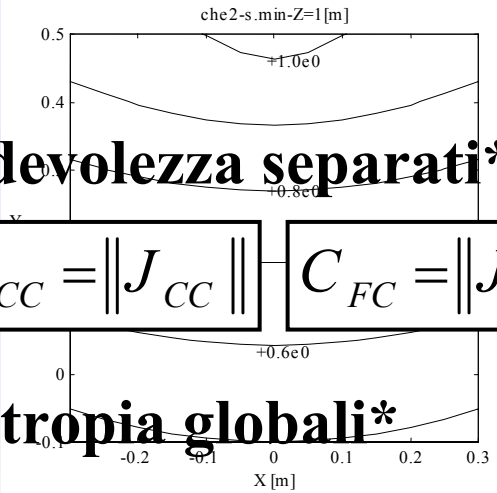
$$cond\ (J)$$
$$\det(J)$$
$$\sigma_{min}\ (J)$$
$$\sigma_{max}\ (J)$$

$$dS = KF_s$$

$$K = \begin{bmatrix} J_{FF} & J_{FC} \\ J_{CF} & J_{CC} \end{bmatrix}$$







✓**indici di cedevolezza separati***

$$C_{FF} = \|J_{FF}\| \qquad C_{CC} = \|J_{CC}\| \qquad C_{FC} = \|J_{FC}\|$$

✓**indici di isotropia globali***

$$c_f = \frac{\sigma_{max}(J_{FF})|F_{max}| + \sigma_{max}(J_{FC})|C_{max}|}{\sigma_{min}(J_{FF})|F_{max}| + \sigma_{min}(J_{FC})|C_{max}|}$$

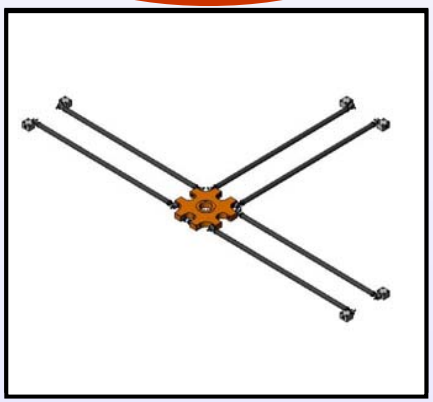
$$c_c = \frac{\sigma_{max}(J_{CC})|C_{max}| + \sigma_{max}(J_{CF})|F_{max}|}{\sigma_{min}(J_{CC})|C_{max}| + \sigma_{min}(J_{CF})|F_{max}|}$$

*I. Fassi, G Legnani., Tosi D., ***Kineto-Static Indexes for the Isotopic Design of Parallel Mechanisms***, 33rd ISR October 7-11,2002

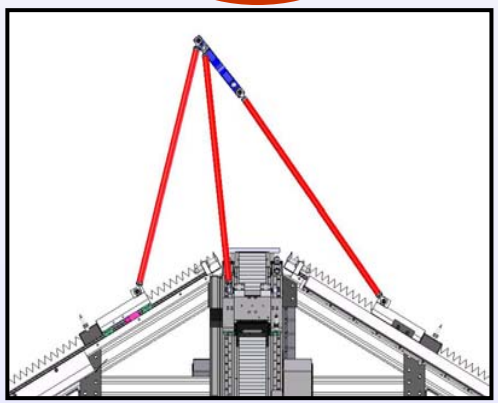
Analisi struttura parallela

CONFIGURAZIONI SINGOLARI

3 & 4 gdl



4 gdl

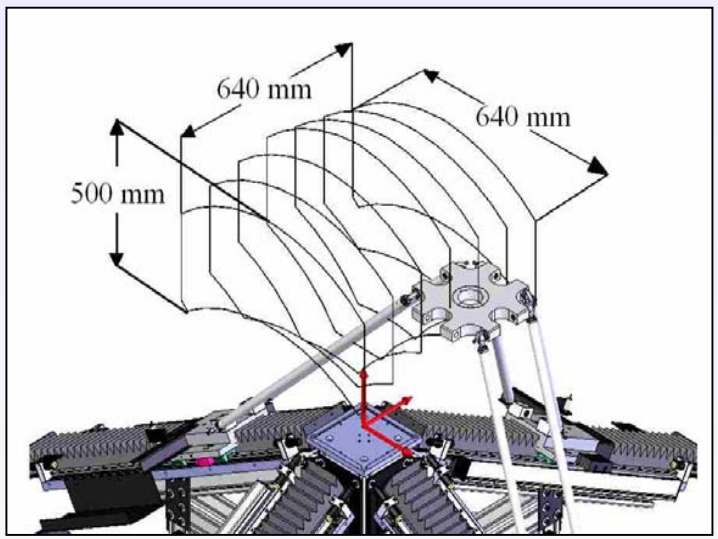


STUDIO DINAMICO

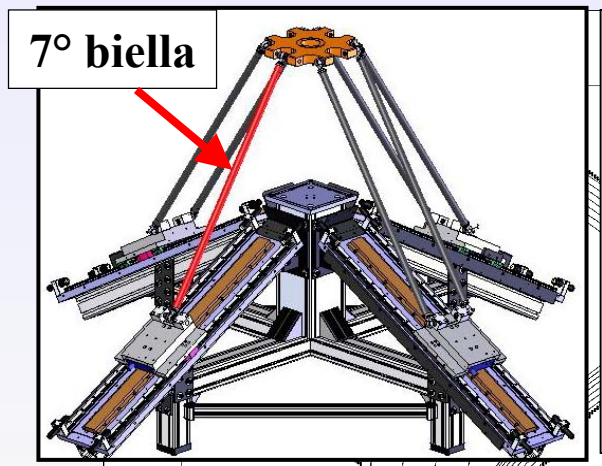
- ✓3 e 4 gdl
- ✓corpi rigidi
- ✓massa delle bielle
- ✓scelta degli attuatori lineari
- ✓modello dell'attrito

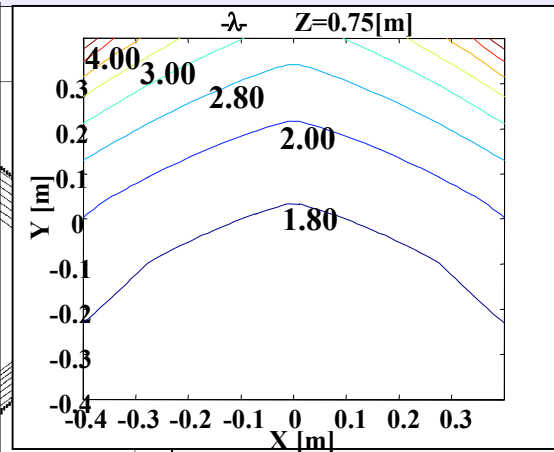
$$\mathbf{F}_m - (\mathbf{M}_m + \mathbf{J}^T\mathbf{M}_p\mathbf{J})\ddot{\mathbf{q}} + \mathbf{J}^T\mathbf{M}_p\dot{\mathbf{J}}\dot{\mathbf{q}} + (\mathbf{P}_n + \mathbf{J}^T\mathbf{F}_e) = 0$$

SPAZIO DI LAVORO



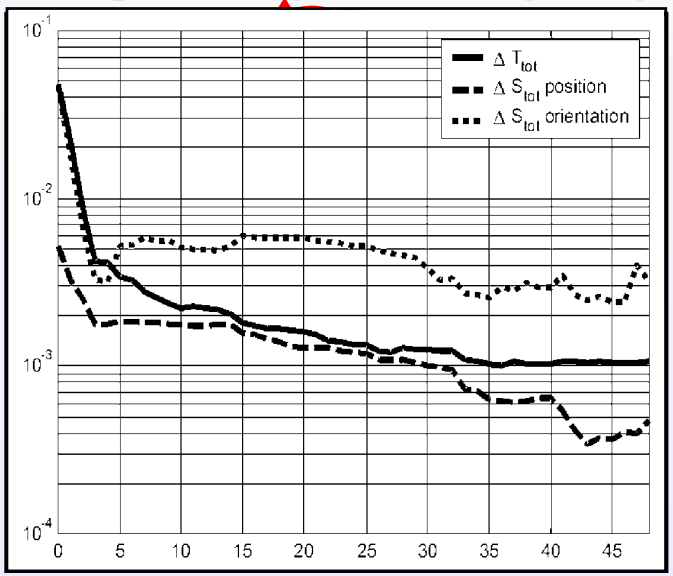
RECUPERO DEI GIOCHI





$\mathbf{F}_{rid} \simeq 2 \div 3\mathbf{F}$ esterna applicata

Calibrazione struttura parallela



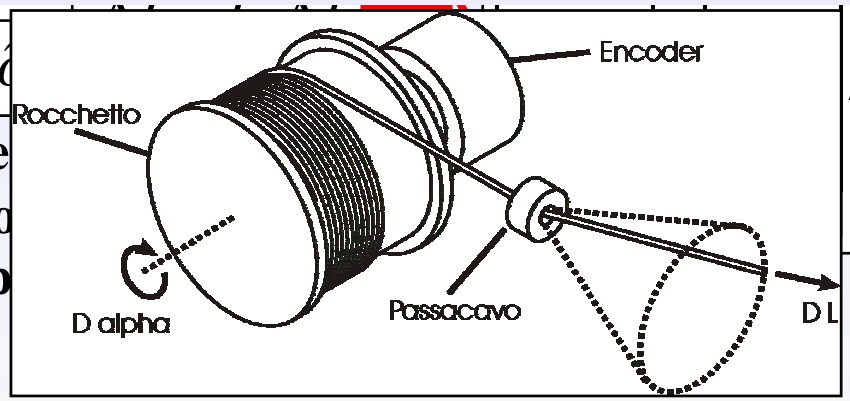
- ✓ modello parametrico M.C.P.C. 48 parametri di cui 36 interni
- ✓ sensori interni ed esterni inclinometri, ecoder sui giunti cardanici, 4° asse trascinato
- ✓ simulazione di calibrazione

ELIMINAZIONE DEI PARAMETRI TRAMITE SVD*

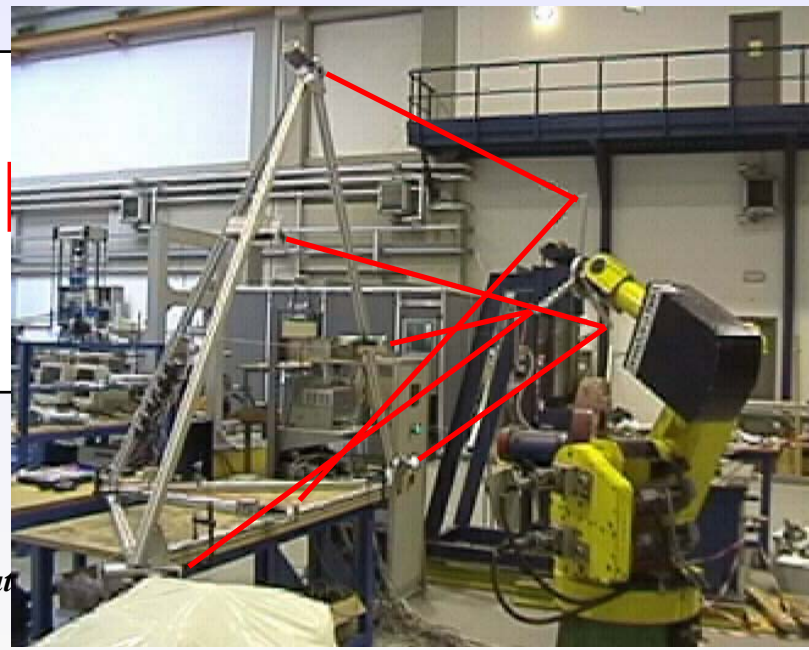
CALIBRAZIONE CON SENSORI A FILO*

$$\Delta S_i \cong$$

posa de
piattafo
p



ΔL

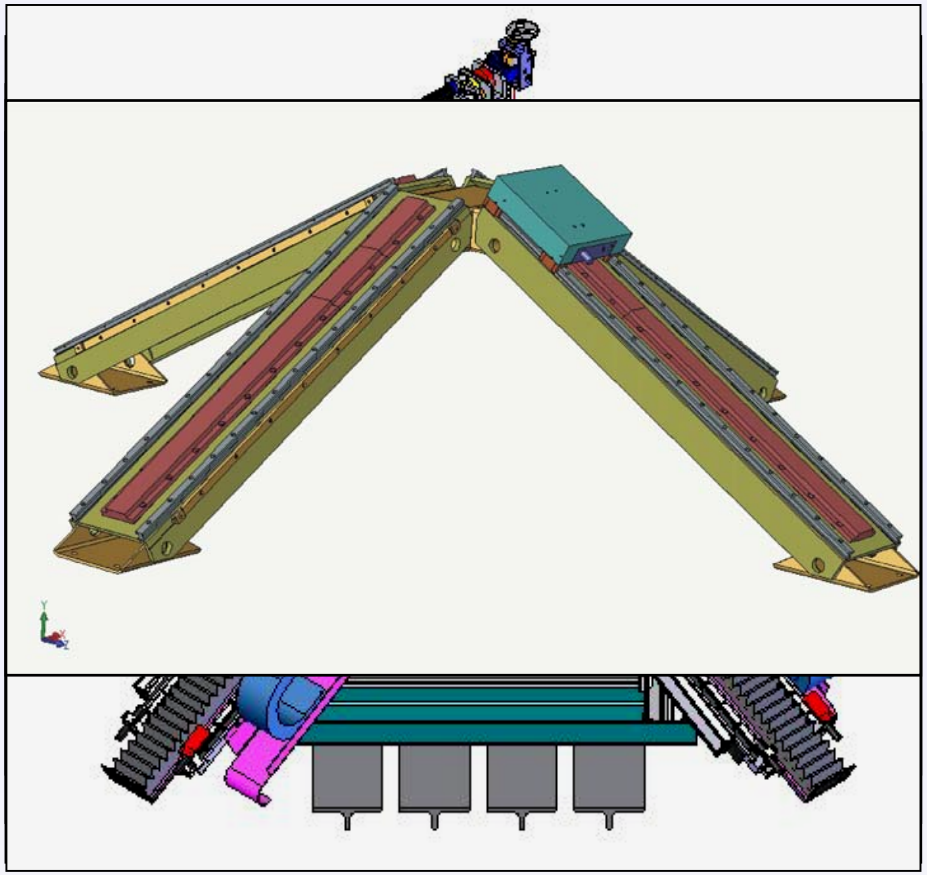


*D. Tosi, G. Legnani, *Calibration of a Parallel Serial Hybrid Redundant Manipulat*, Proc. of ISR 2003, Chicago, 2-5 June 2003

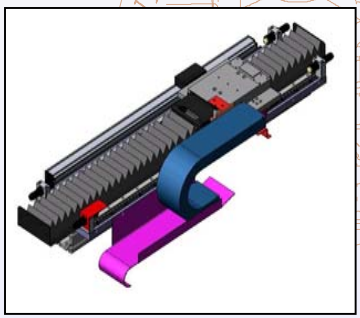
*G. Legnani, D. Tosi, G. Gritti, *Optimization of a low-cost wire sensor based calibration procedure for industrial robots*, Proc. of ISR 2004, Paris 23-26/3/04

Progettazione

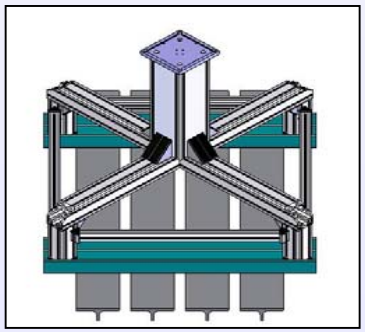
Progetto finale



- ✓Assi lineari

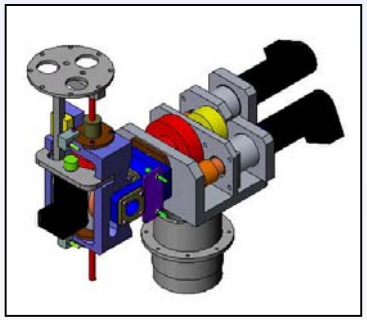


- ✓Telaio



- ✓Piattaforma

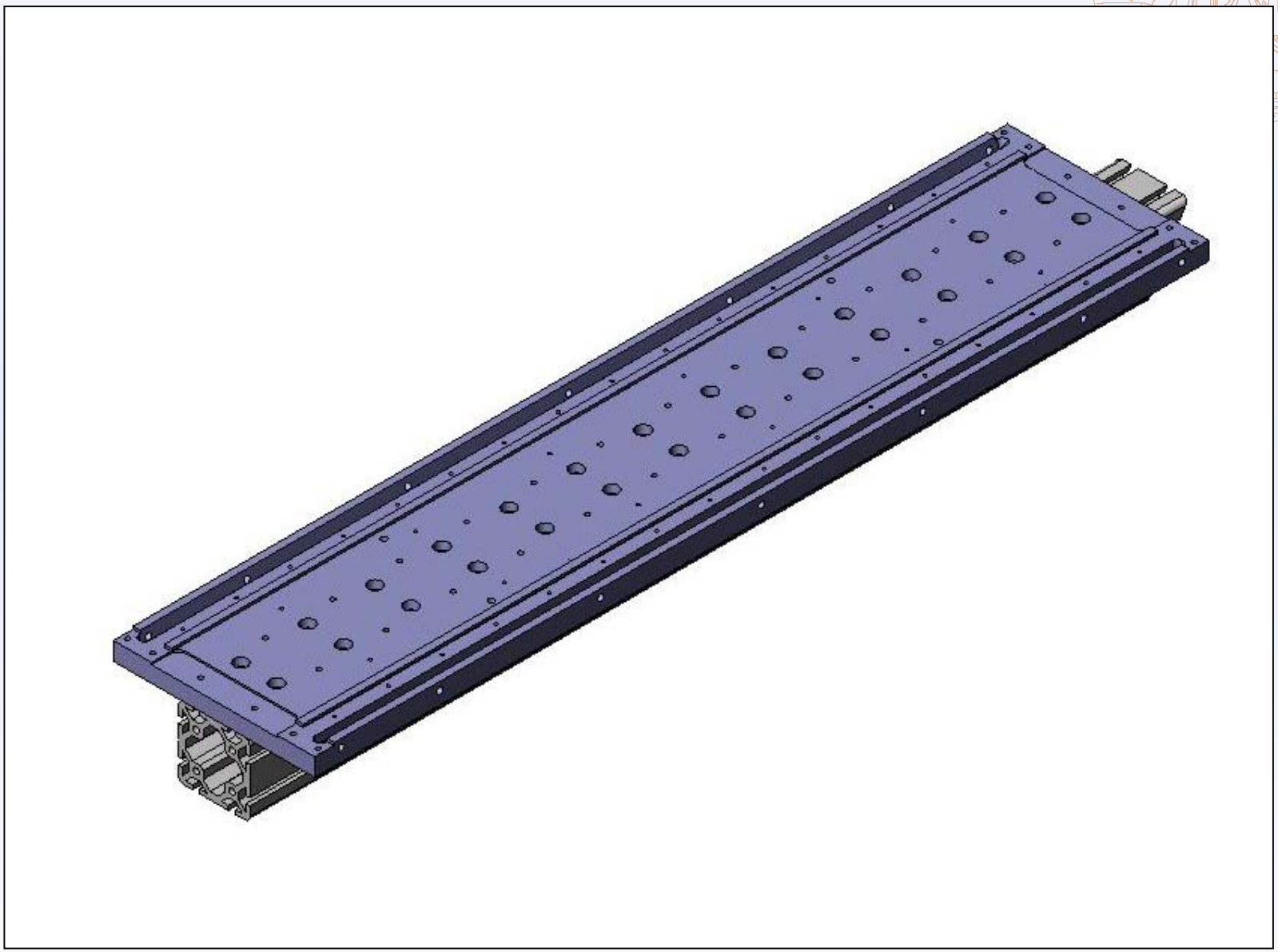
- ✓Polso seriale



H. Giberti, P. Righettini, D. Tosi, G. Legnani, R. Adamini, ***Progerro di "CHEOPE": un manipolatore ridondante ibrido palallelo-seriale***, Proc. of AIMETA 2003, Ferrara 9-12 Sept. 2003

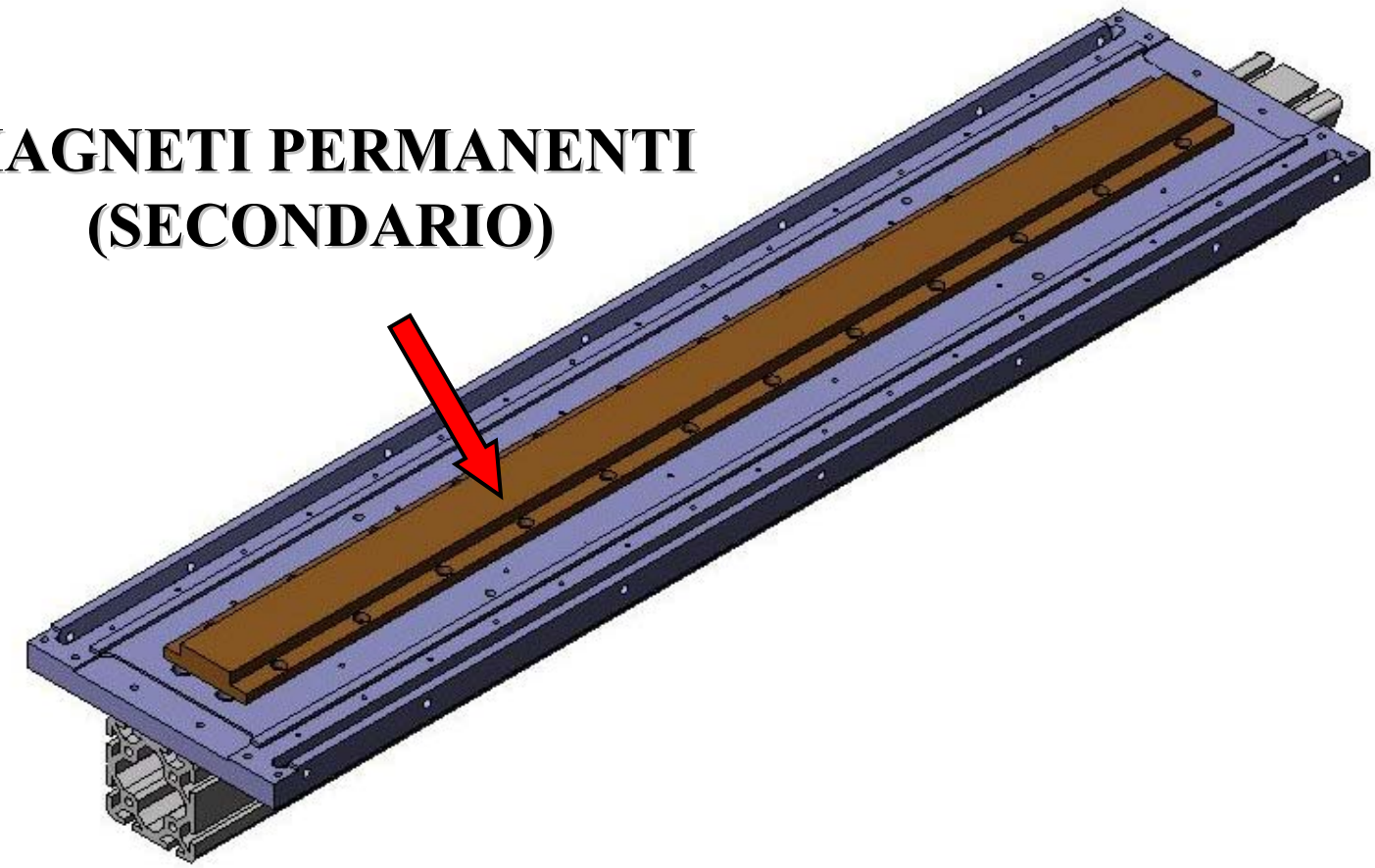
Progettazione

ASSE LINEARE



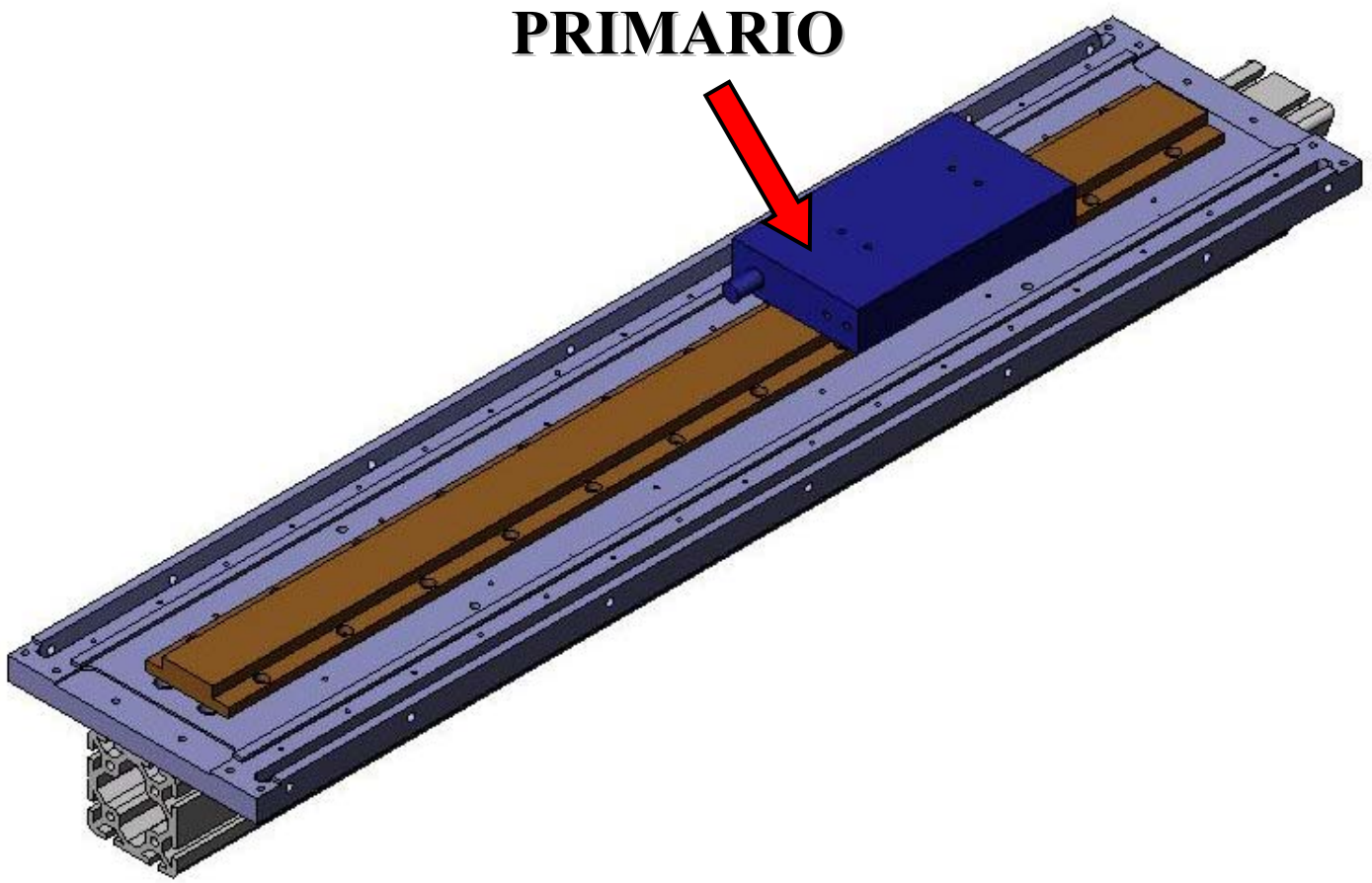
Progettazione
ASSE LINEARE

MAGNETI PERMANENTI (SECONDARIO)

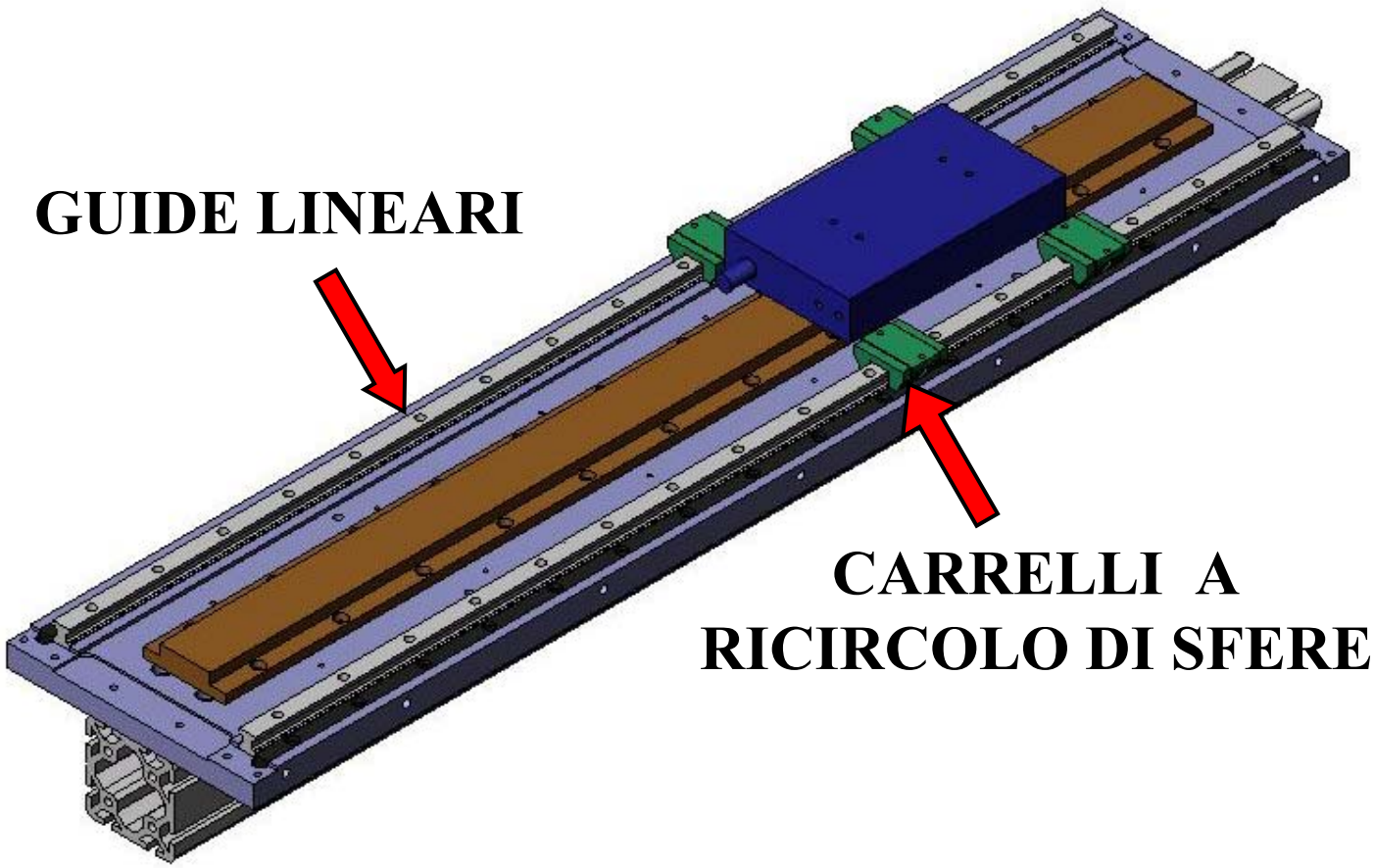


Progettazione

ASSE LINEARE

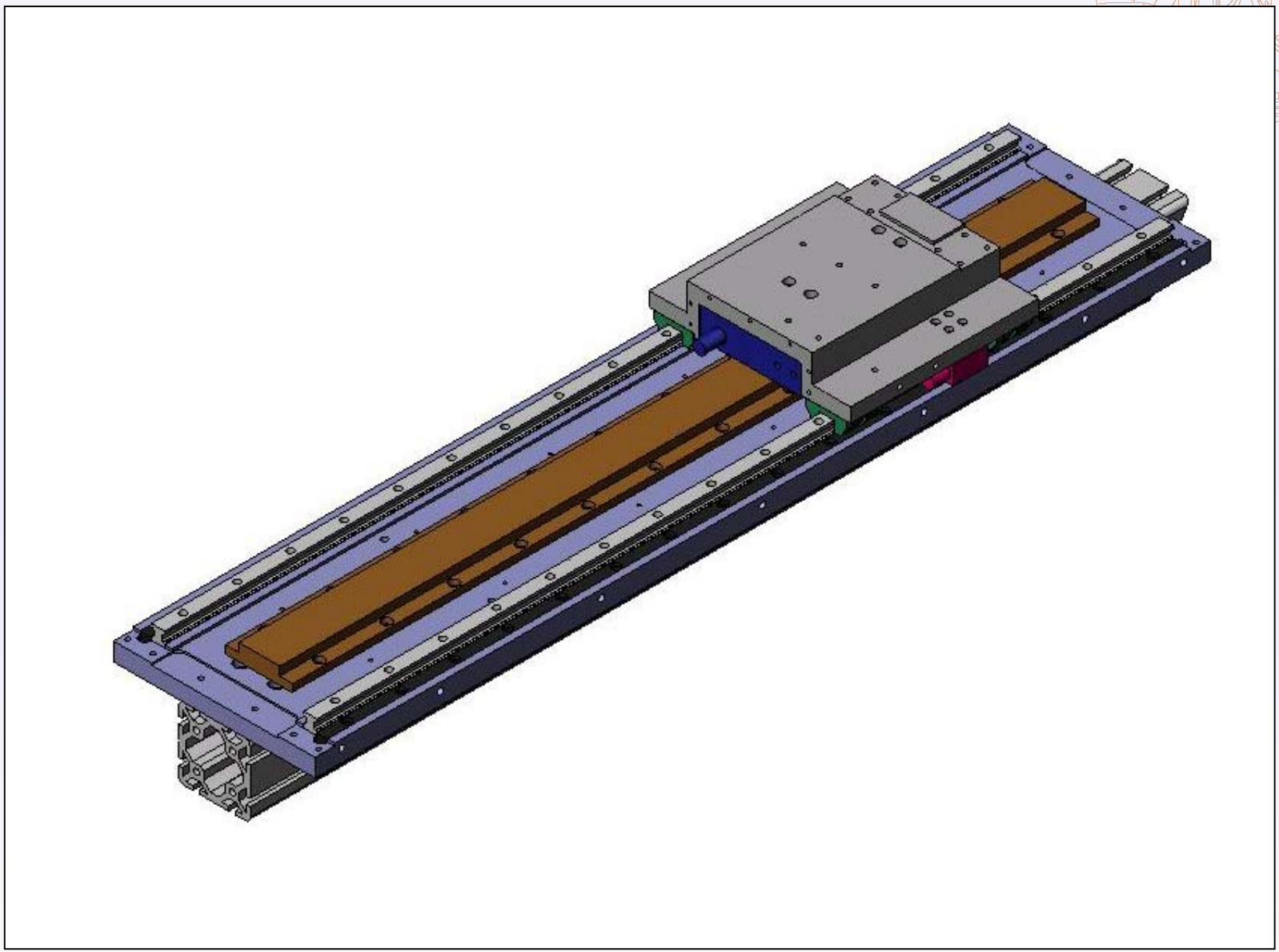


Progettazione
ASSE LINEARE



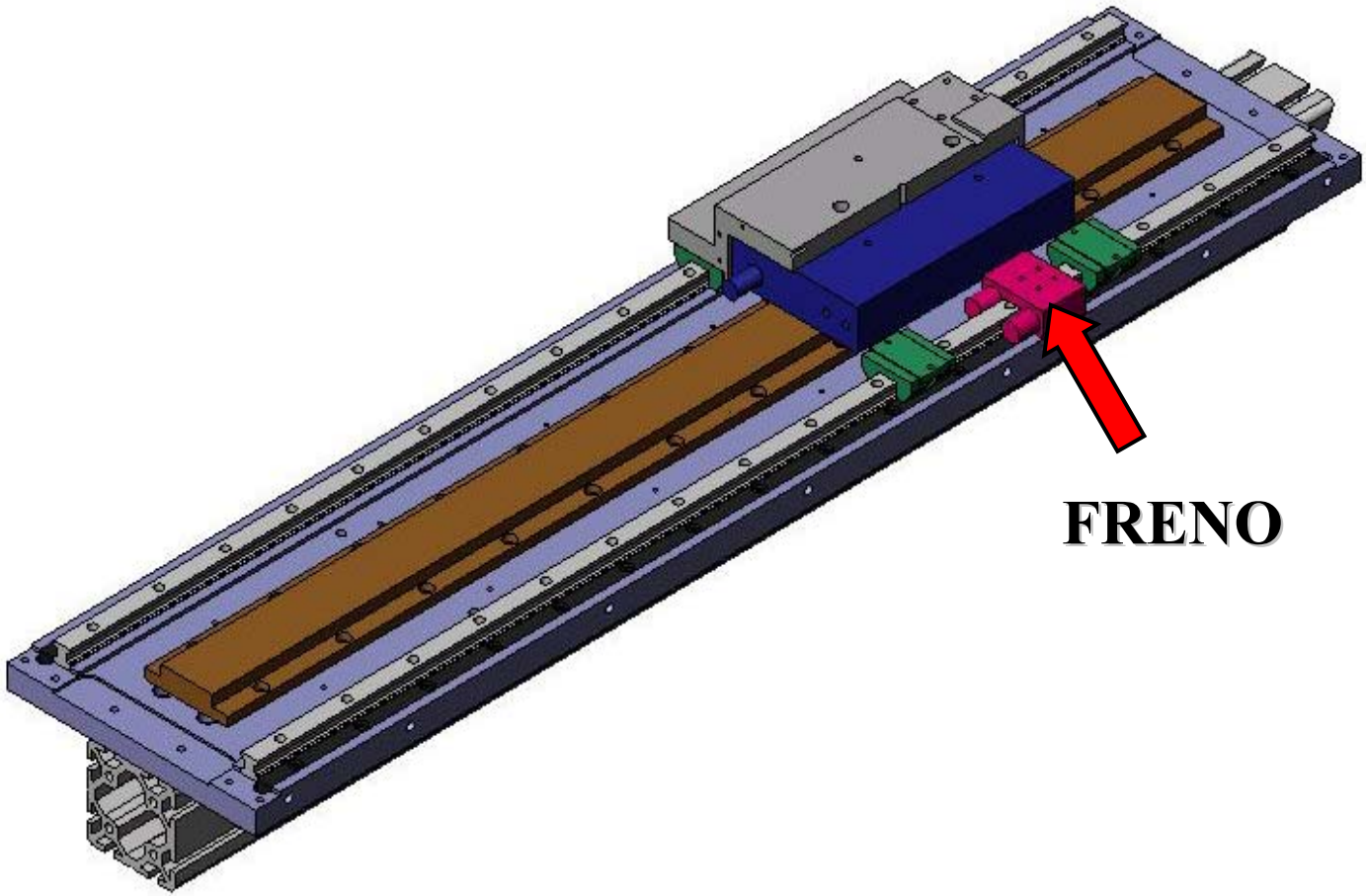
Progettazione

ASSE LINEARE



Progettazione

ASSE LINEARE

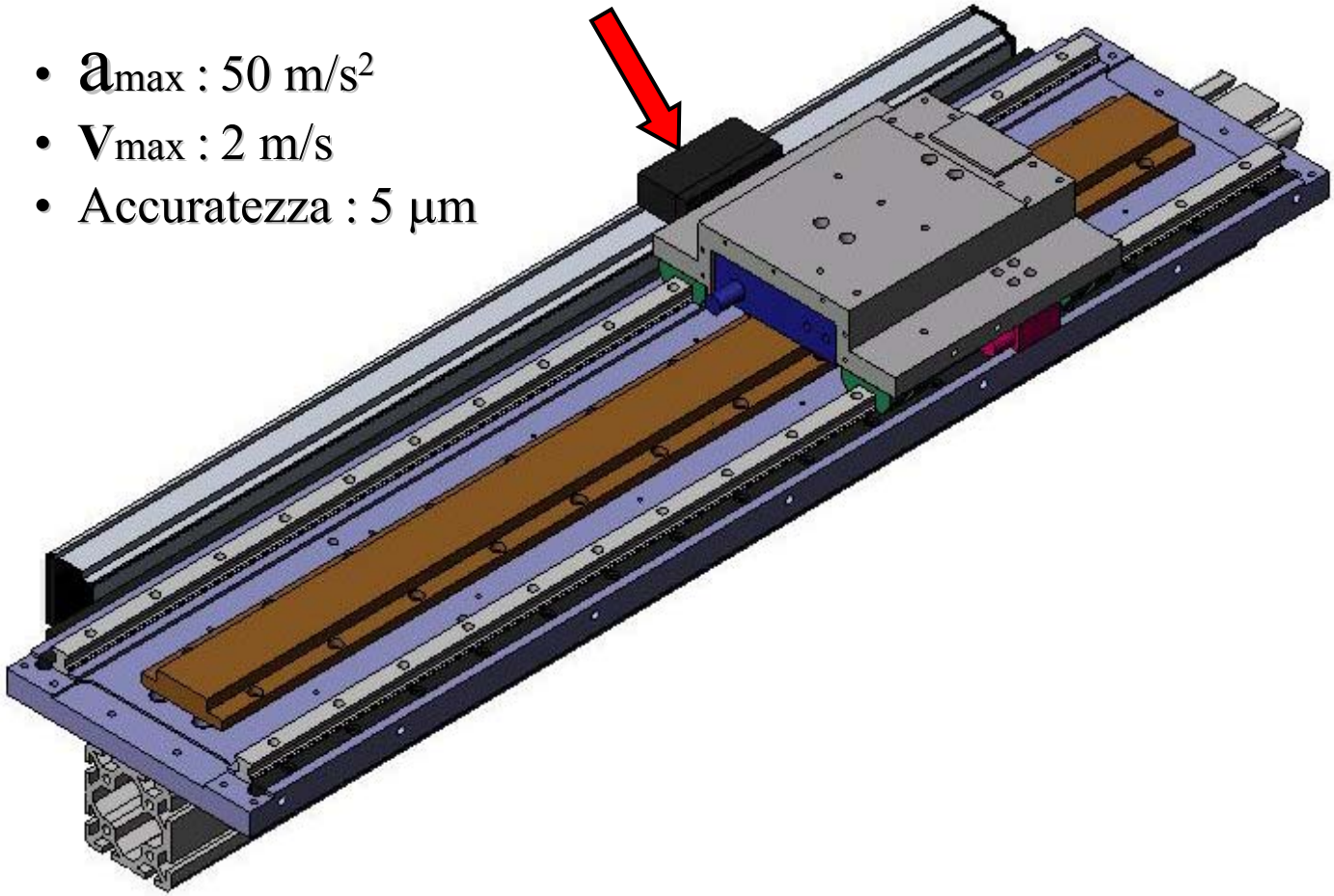


Progettazione

ASSE LINEARE

RIGA OTTICA

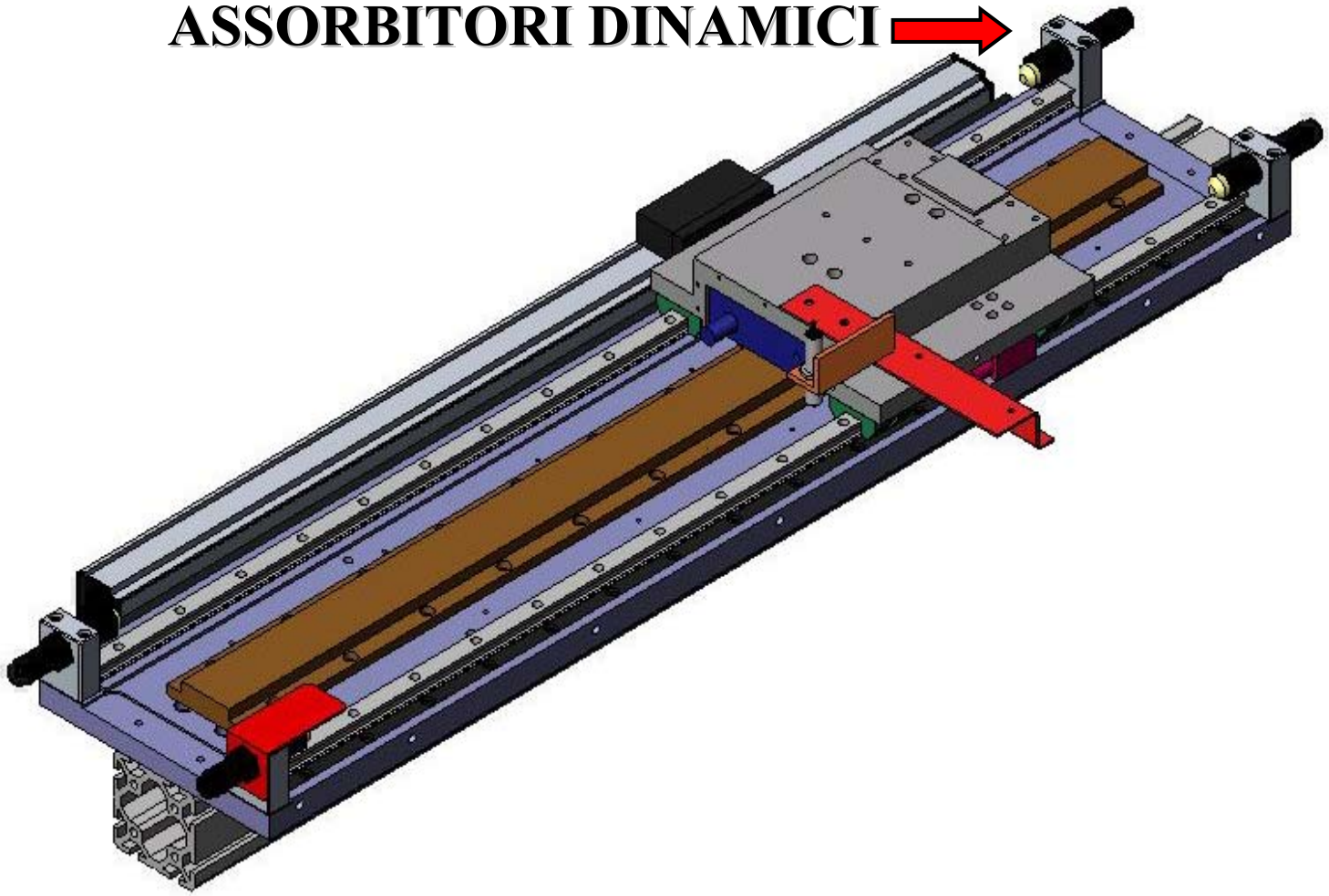
- a_{max} : 50 m/s^2
- v_{max} : 2 m/s
- Accuratezza : 5 μm



Progettazione

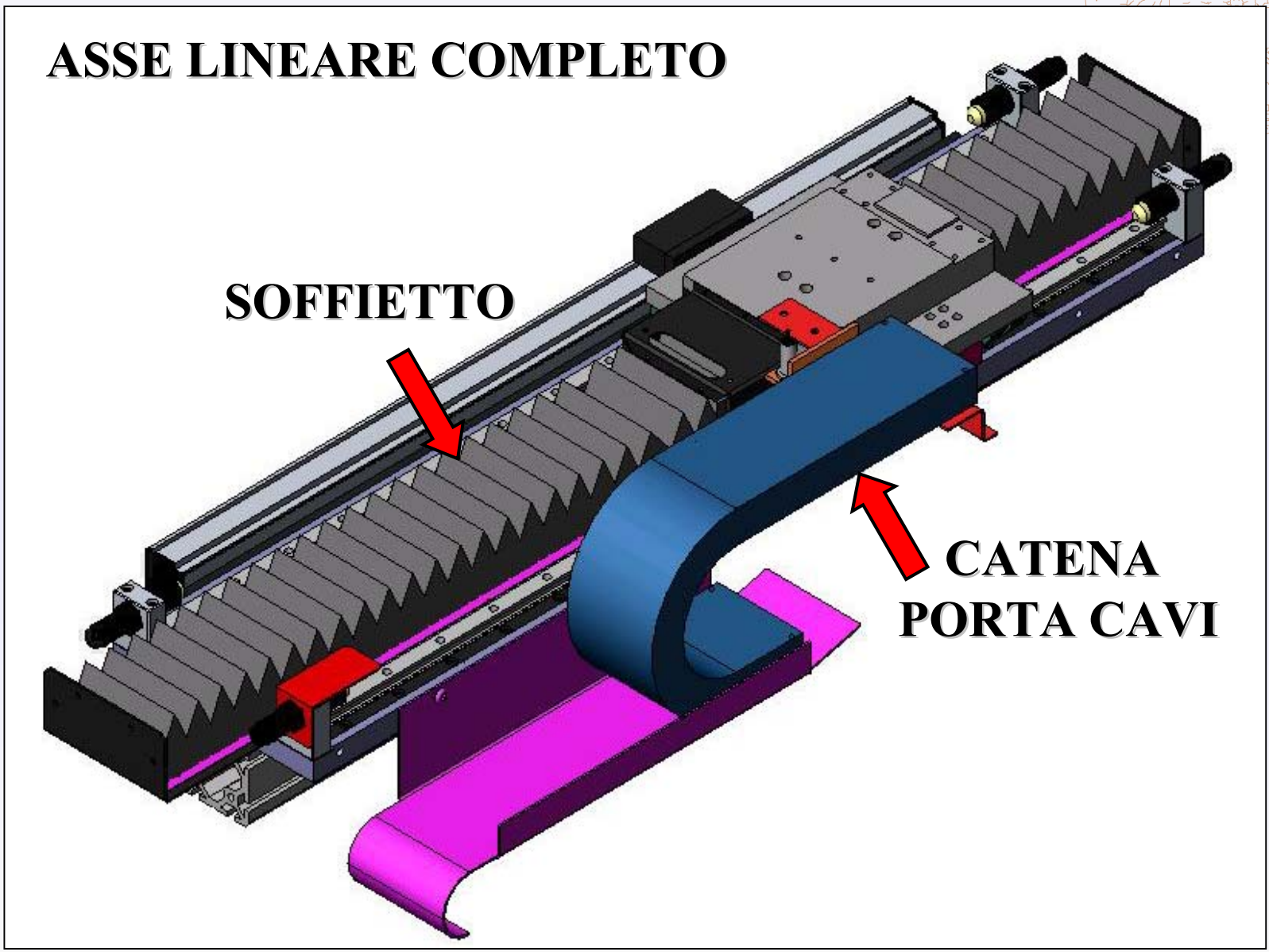
ASSE LINEARE

ASSORBITORI DINAMICI



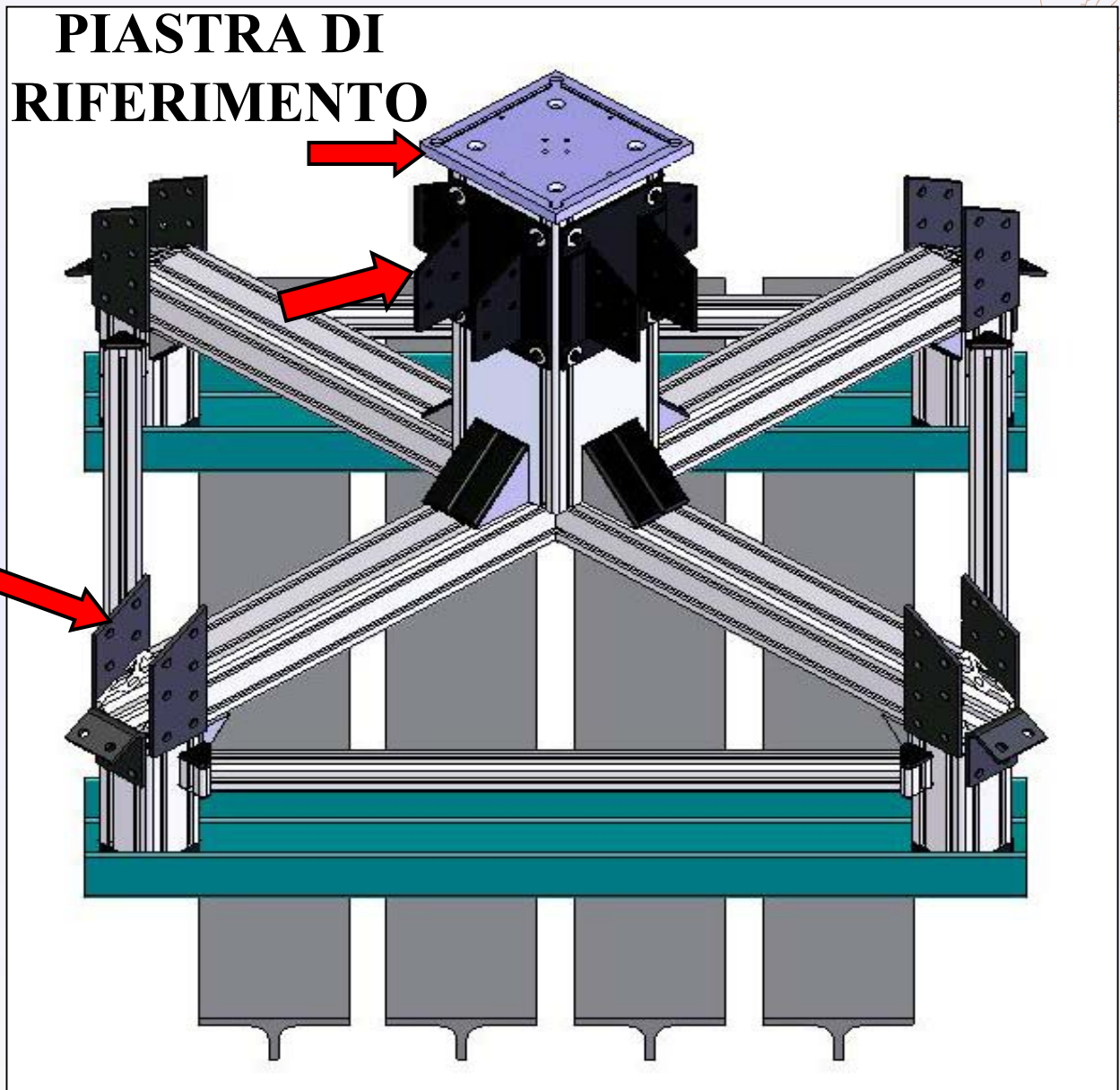
Progettazione

ASSE LINEARE



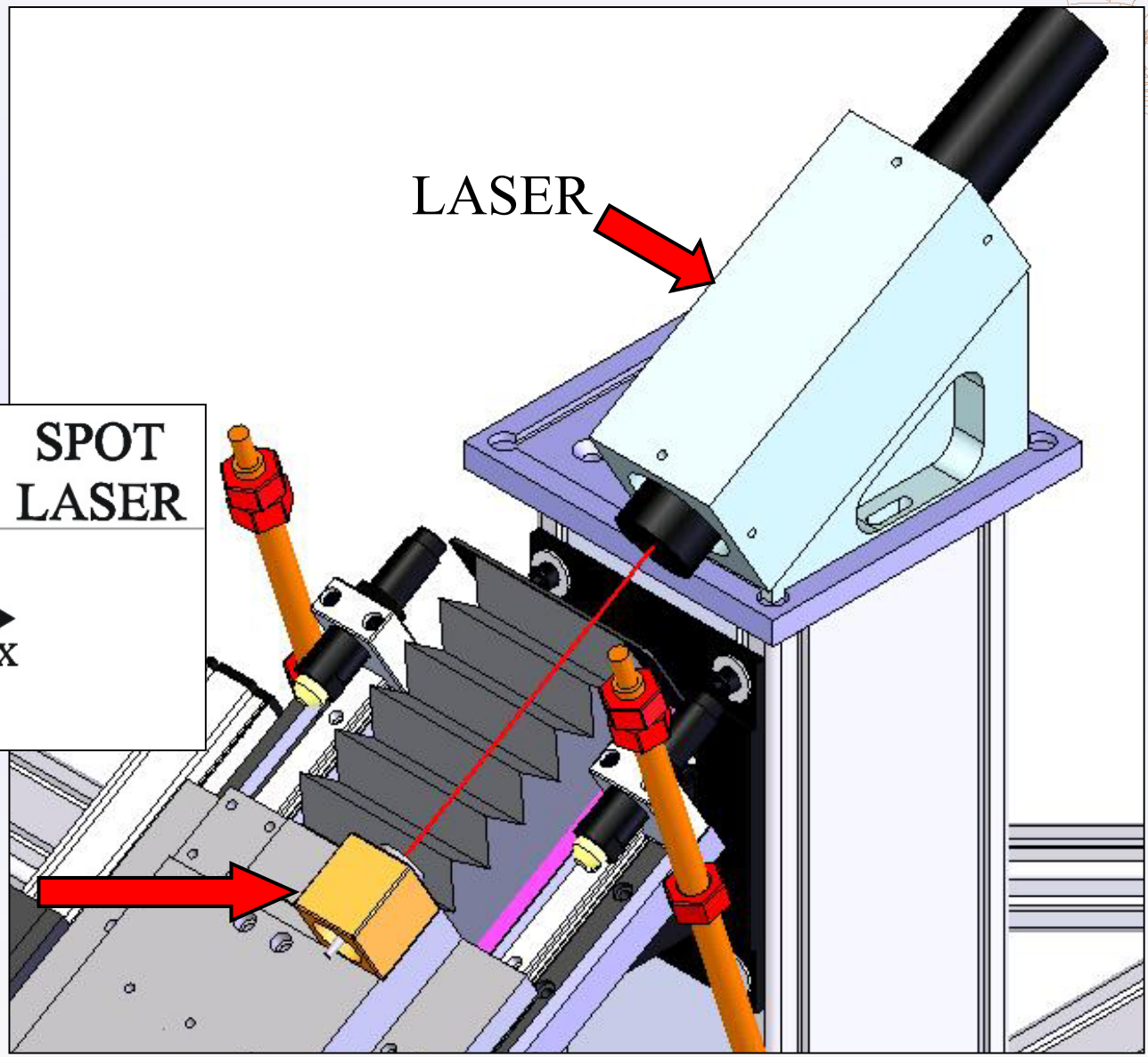
Progettazione

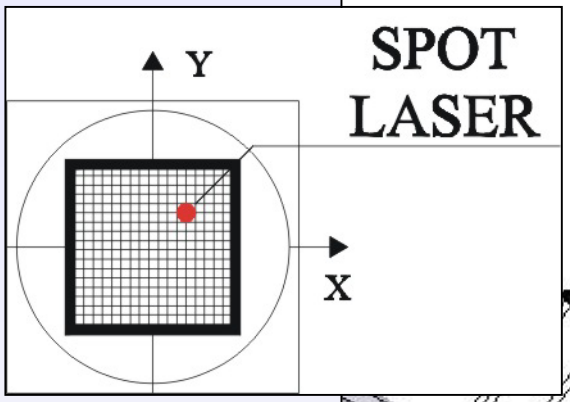
TELAIO



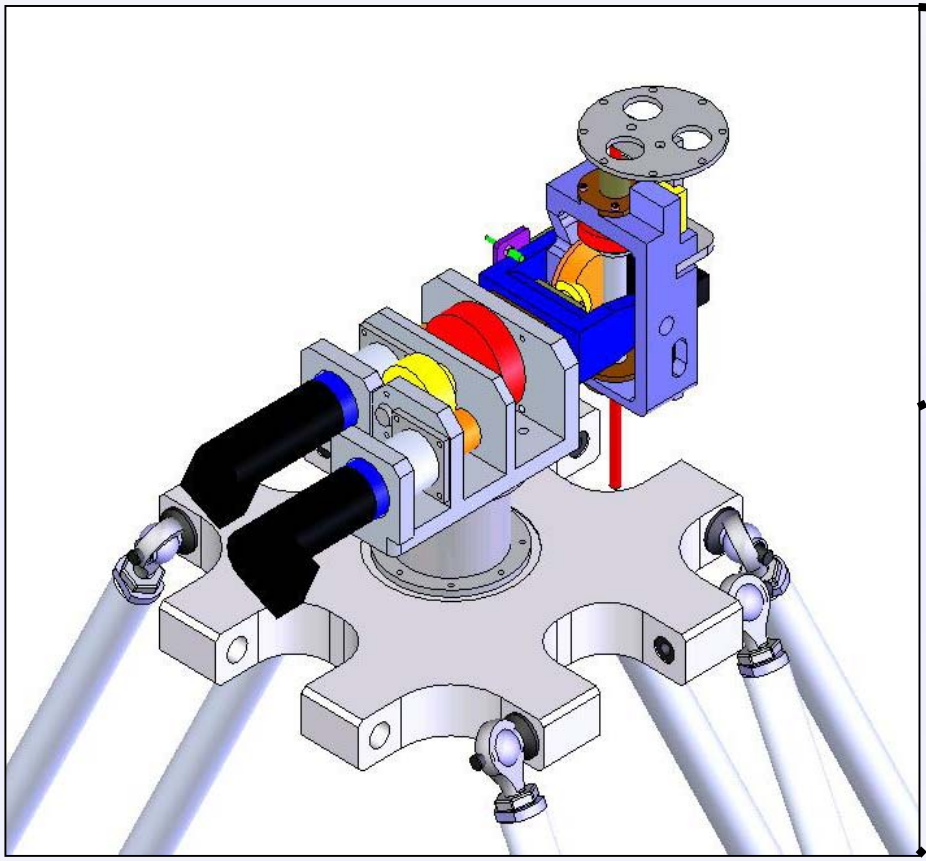
Progettazione

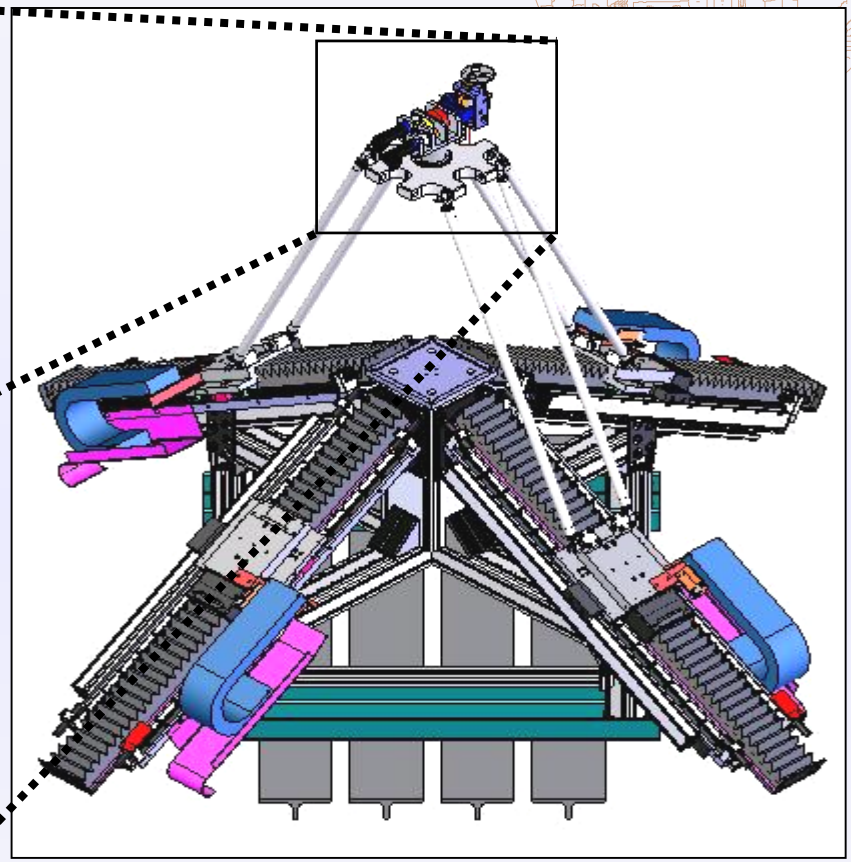
MONTAGGIO ASSI LINEARI





Progettazione
MONTAGGIO POLSO

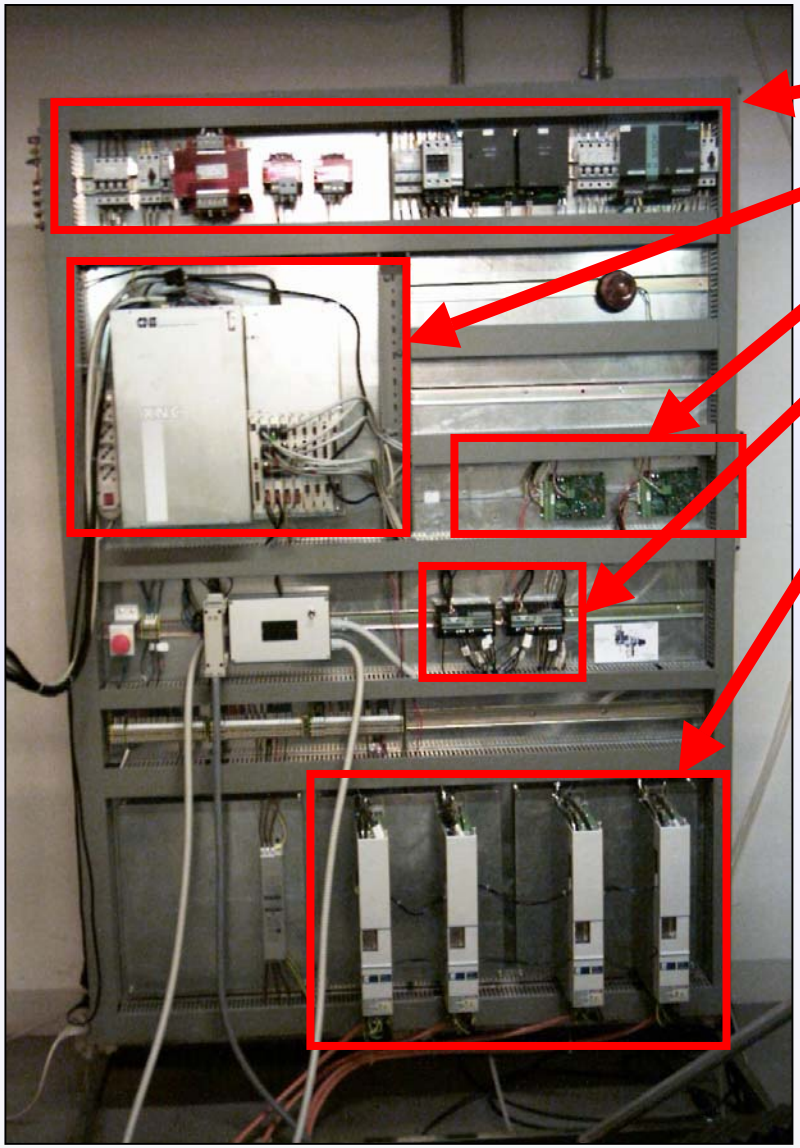




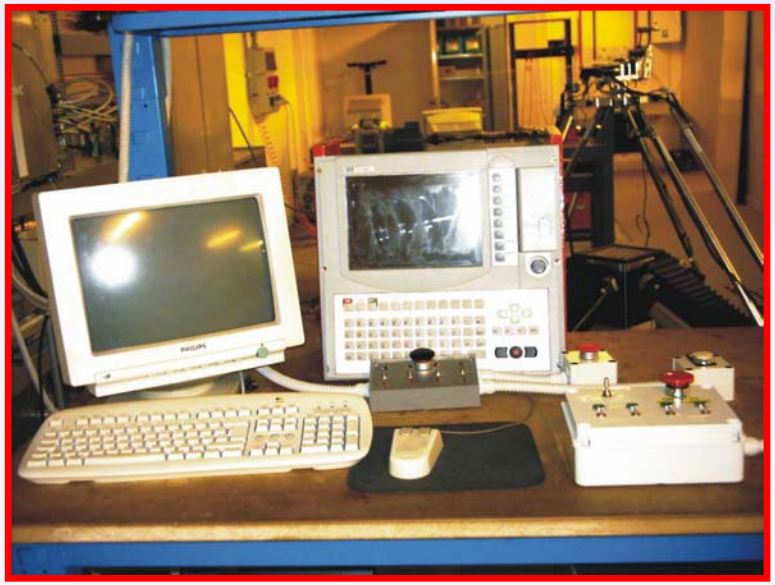
- ✓ampie rotazioni
- ✓gdl ridondanti
- ✓movimenti coordinati

Realizzazione

IMPIANTO ELETTRICO



- ✓Impianto di potenza
- ✓Controllore
- ✓Convertitori motori polso
- ✓I/O PLC gestione emergenze
- ✓Convertitori motori lineari
- ✓Interfaccia operatore



CHEOPE


Scarica il filmato:
http://robotics.ing.unibs.it/pagine/pkm/cheope.wmv