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1) For a right McPherson strut, attach local coordinate frames to each link for a fixed position of the steering rack. Clearly label all auxiliary points and vectors needed to form constraints.

2) Write a corresponding set of generalized coordinates $\{q\}$.

3) Symbolically write a constraint vector $\{\Phi\}$ for this mechanism using the vertical absolute translation driver for the strut-spindle assembly $y_3 - y_{3\_START} - y_{3\_VEL}\ t = 0$ for $y_{3\_VEL} = 4\ \text{cm}/\text{sec}$.

4) Numerically check the residuals of $\{\Phi\}$ using measurements from model hardware.

5) Symbolically write the corresponding Jacobian matrix $\lfloor \Phi_q \rfloor$.

6) Numerically evaluate the elements of the Jacobian and compute the determinant.

7) Program your constraints and Jacobian into a Newton-Raphson iterative algorithm to solve position kinematics at any desired time.

8) Symbolically write the velocity right-hand-side vector and program to solve for generalized coordinate velocities at any desired time.

9) Place your position and velocity algorithms within an outer loop to drive the strut-spindle assembly over $0 \le t \le 1$ sec. Plot toe-in angle versus vertical position of the strut-spindle assembly. Additionally plot all three components of global angular velocity of the strut-spindle assembly versus time.

EXTRA CREDIT
Symbolically write the acceleration right-hand-side vector and program to solve for generalized coordinate accelerations. Plot all three components of global angular acceleration of the strut-spindle assembly versus time.

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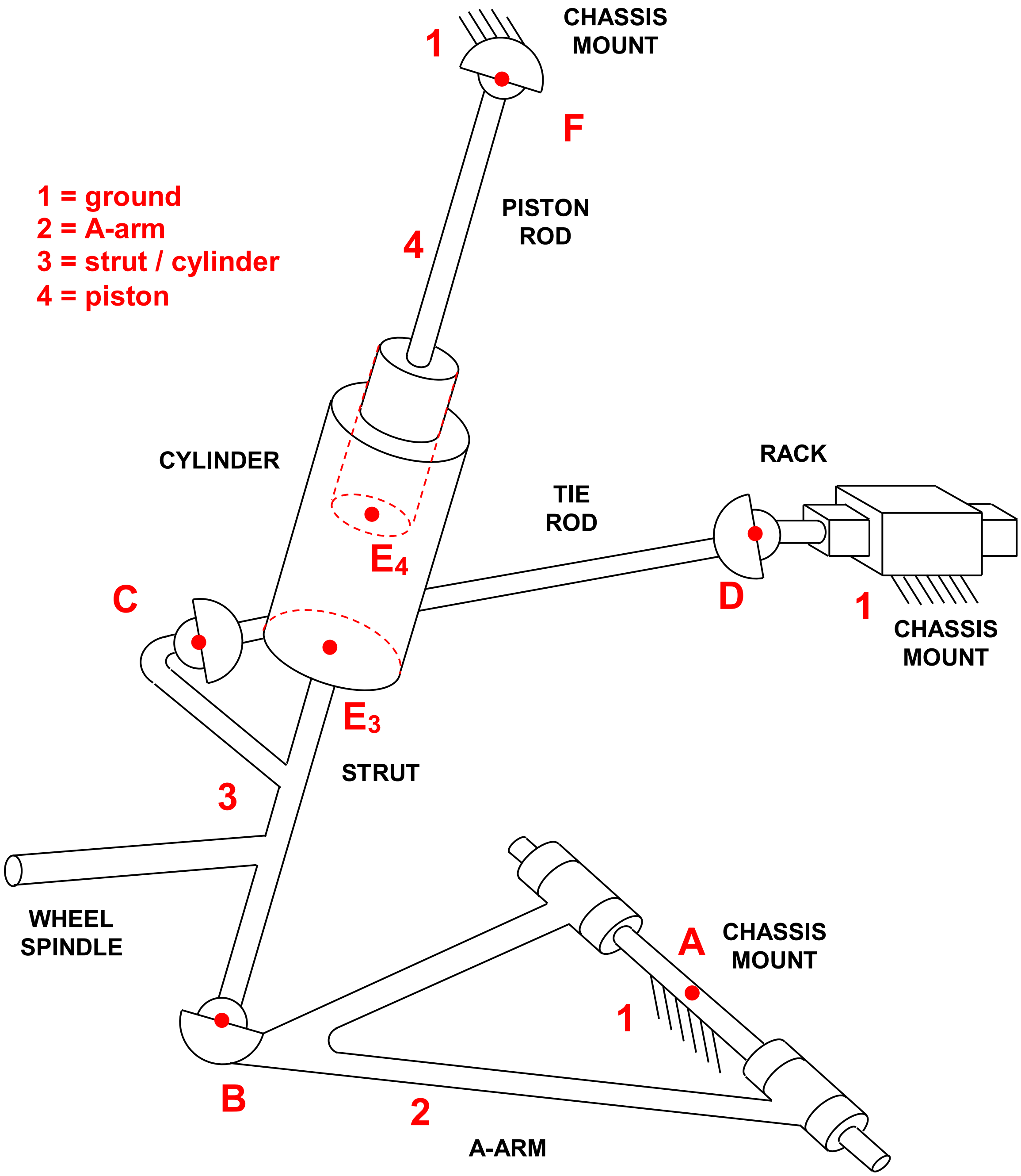

1 = ground
2 = A-arm
3 = strut / cylinder
4 = piston

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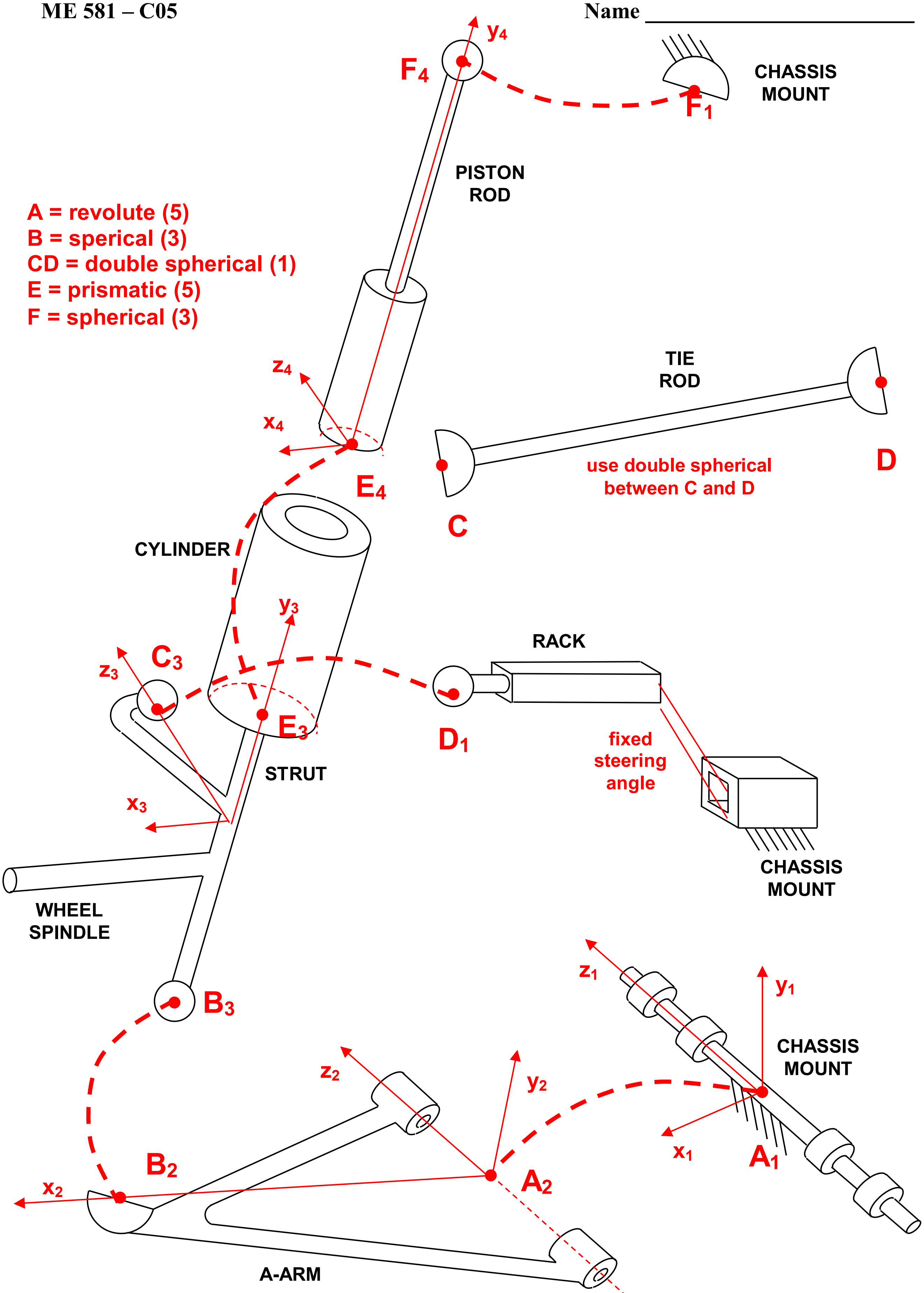

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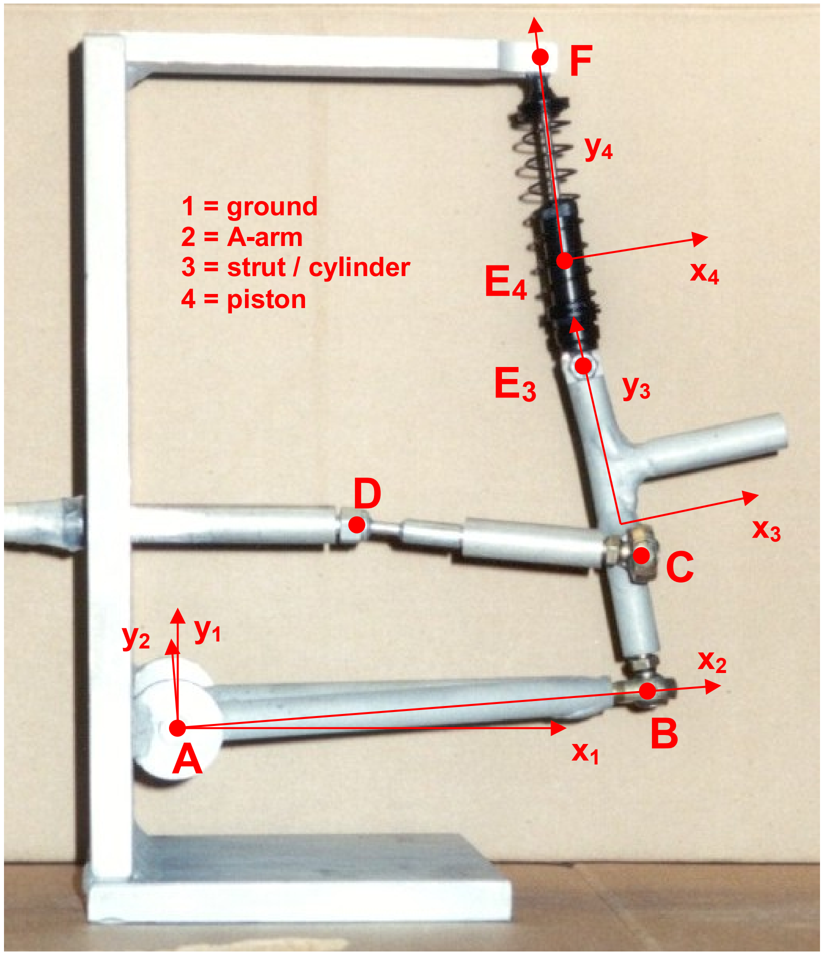
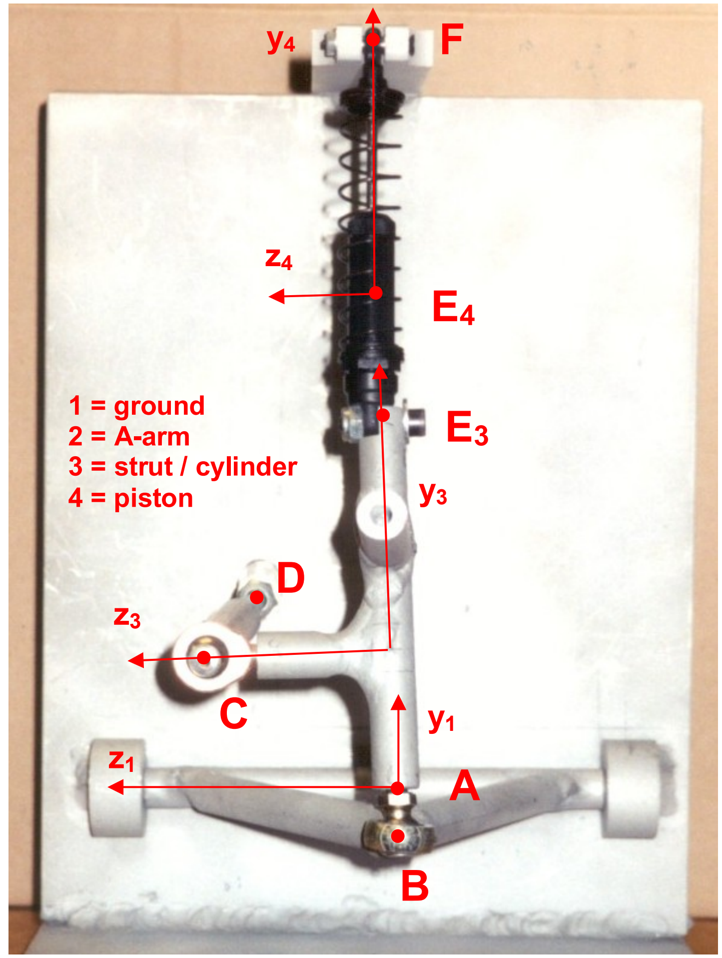
McPherson strut model - rear view



McPherson strut model - side view



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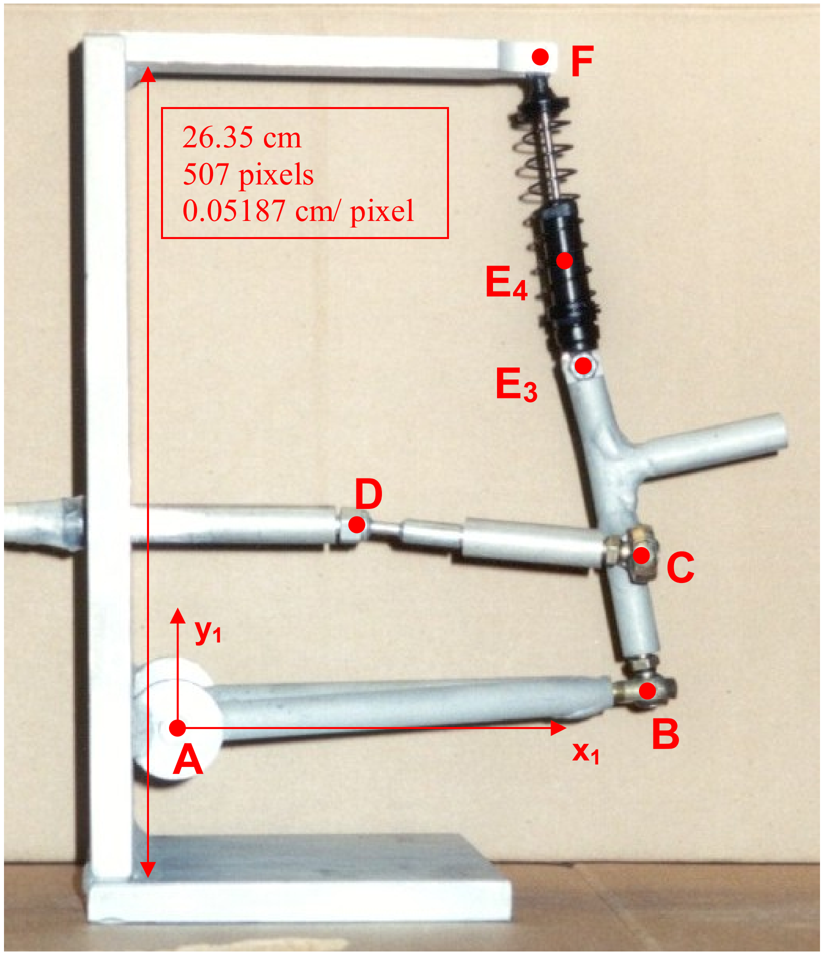

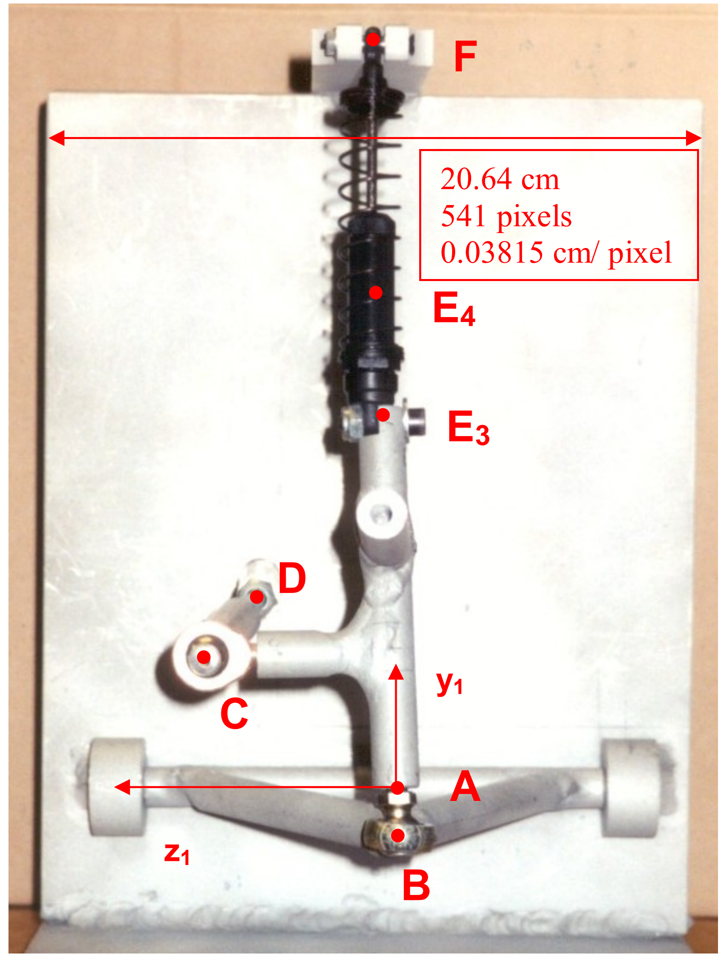

scaled from photographs on class web page

cm	x1	y1	z1
A	0	0	0
B	15.70	1.40	0
C	15.49	5.87	5.77
D	6.03	6.81	4.60
E3	13.51	12.16	0
E4	13.03	15.56	0
F	12.06	22.35	0

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Constraints

$$\underset{21x1}{\{q\}} = \begin{Bmatrix} \{r_2\} \\ \{p_2\} \\ \{r_3\} \\ \{p_3\} \\ \{r_4\} \\ \{p_4\} \end{Bmatrix} \qquad \underset{21x1}{\{\Phi\}} = \begin{Bmatrix} \{r_1\}^A - \{r_2\}^A \\ \{\hat{f}_2\}^T\{\hat{h}_1\} \\ \{\hat{g}_2\}^T\{\hat{h}_1\} \\ \{r_2\}^B - \{r_3\}^B \\ \{d_{ij}\}^T\{d_{ij}\} - CD^2 \\ \{\hat{f}_3\}^T\{\hat{g}_4\} \\ \{\hat{h}_3\}^T\{\hat{g}_4\} \\ \{\hat{f}_3\}^T\{d_{ij}\} \\ \{\hat{h}_3\}^T\{d_{ij}\} \\ \{\hat{f}_3\}^T\{\hat{h}_4\} \\ \{r_1\}^F - \{r_4\}^F \\ \{p_2\}^T\{p_2\} - 1 \\ \{p_3\}^T\{p_3\} - 1 \\ \{p_4\}^T\{p_4\} - 1 \\ y_3 - y_{3\_START} - y_{3\_VEL}\ t \end{Bmatrix}$$

revolute A	revA, i = 2, j = 1 f_2h_1, i = 2, j = 1 g_2h_1, i = 2, j = 1
spherical B	sphB, i = 3, j = 2
$\{d_{ij}\} = \{r_1\}^D - \{r_3\}^C$	1D – 3C, i = 3, j = 1
prismatic E $\{d_{ij}\} = \{r_4\}^E - \{r_3\}^E$	f_3g_4, i = 3, j = 4 h_3g_4, i = 3, j = 4 f_3, i = 3, j = 4 h_3, i = 3, j = 4 f_3h_4, i = 3, j = 4
spherical F	sphF, i = 4, j = 1
Euler parameters	p2 p3 p4
driver	driver

Velocity

$$\underset{21x1}{\{\nu\}} = \begin{Bmatrix} 0_{20x1} \\ y_{3\_VEL} \end{Bmatrix}$$