

- 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 $y_{3_VEL} = 4 \text{ cm/sec}$.
- 4) Numerically check the residuals of $\{\Phi\}$ using measurements from model hardware.
- 5) Symbolically write the corresponding Jacobian matrix $[\Phi_q]$.
- 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 $0 \leq t \leq 1 \text{ sec}$. 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.

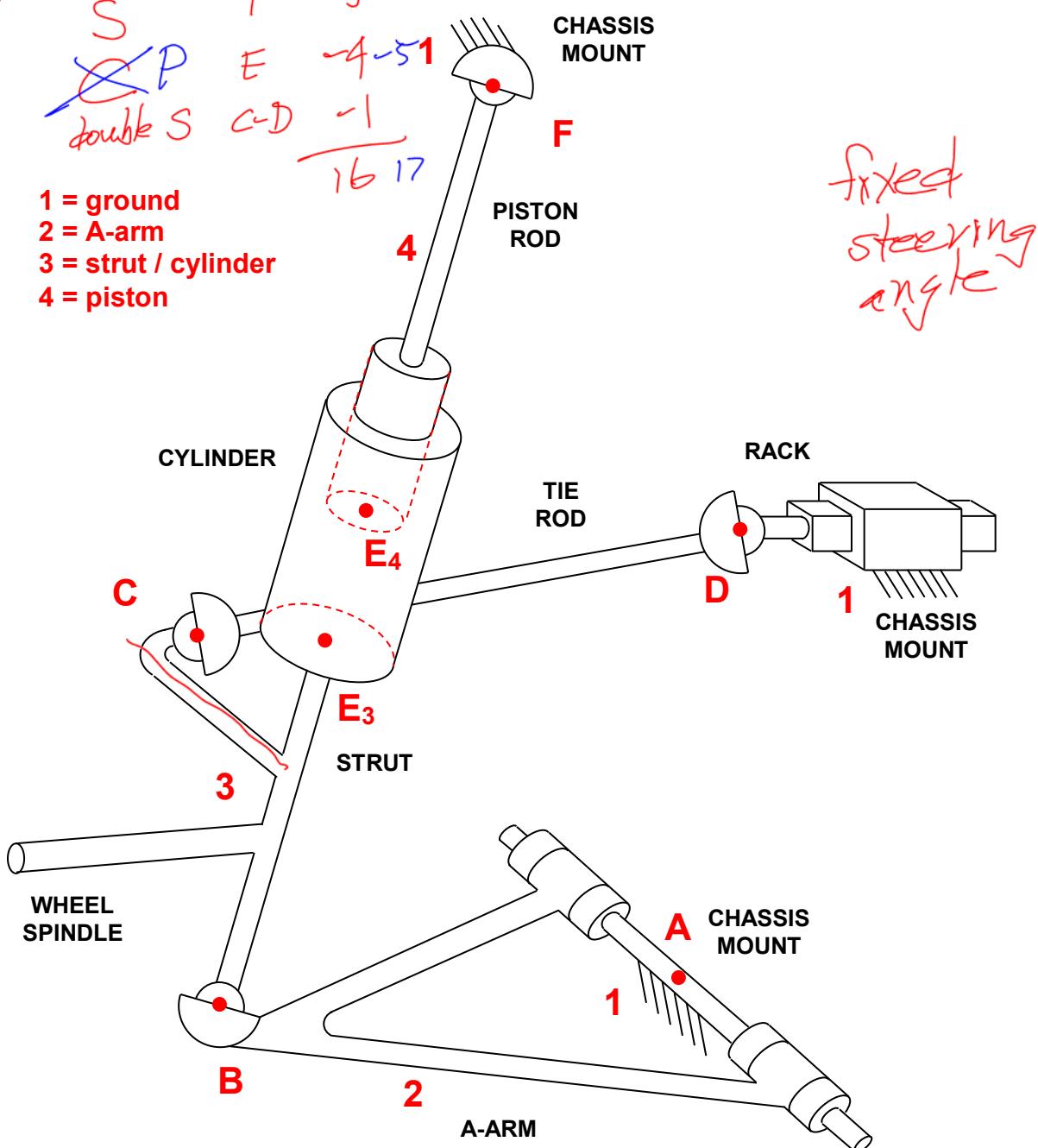
EXTRA CREDIT

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.

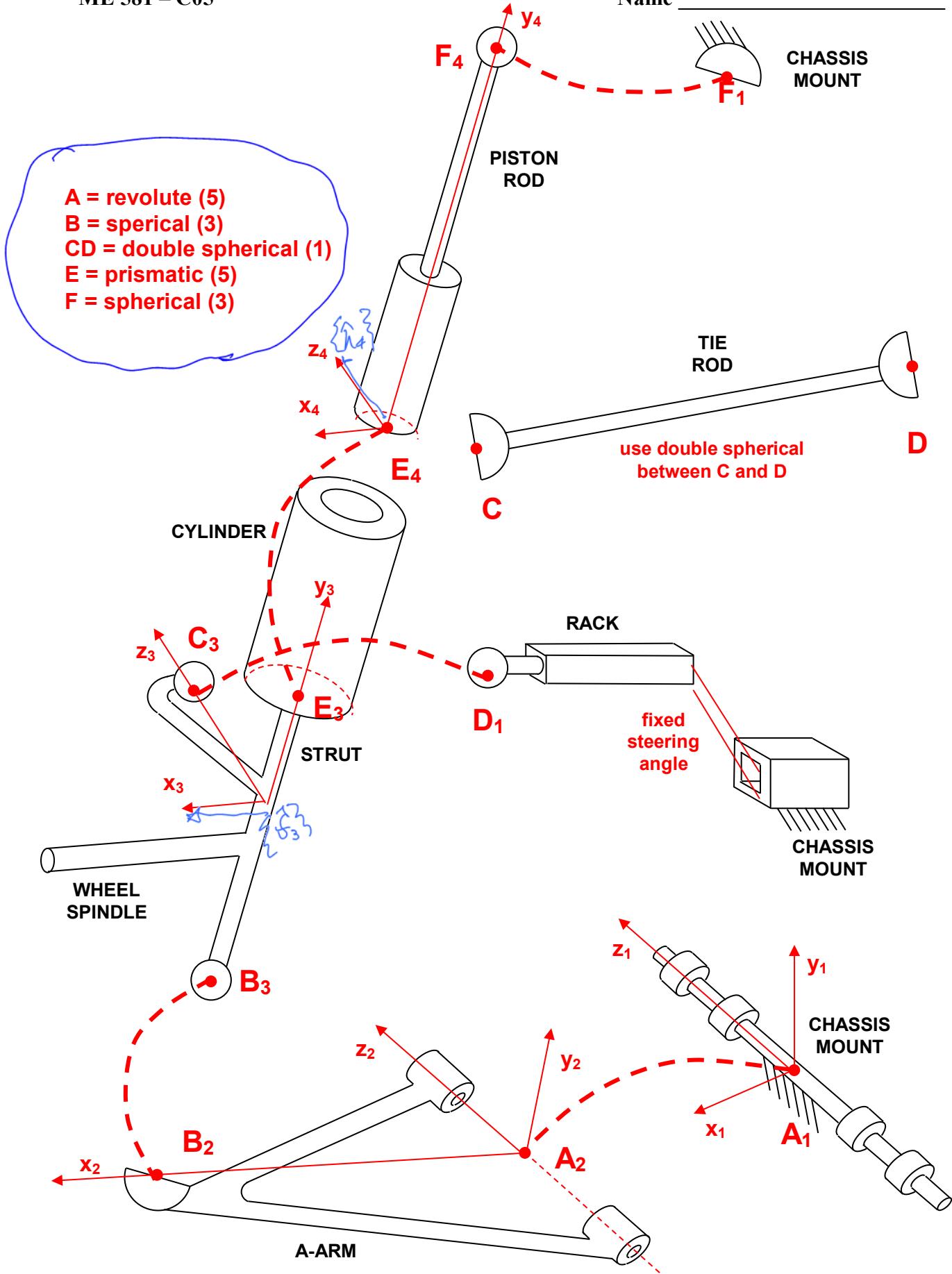
$nL = 4$
 $6(4-D)$
 18
~~X P~~
 double S

R	A -5
S	B -3
S	F -3
	E -4 -5 1
	C-D -1
	<u>16 17</u>

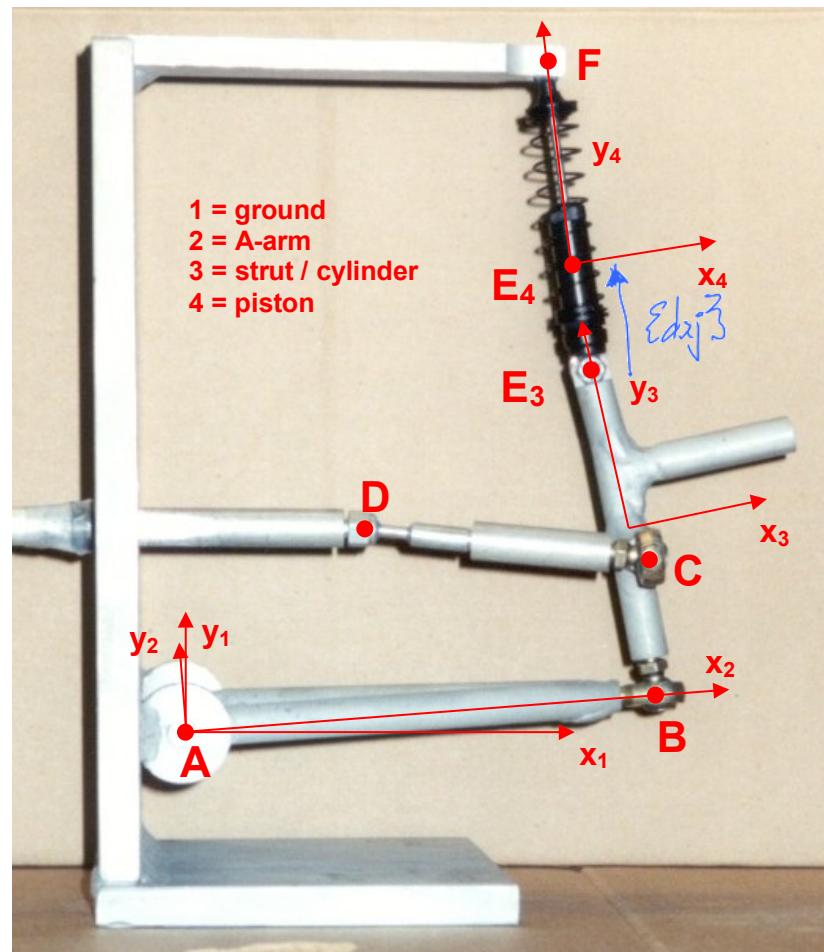
1 = ground
 2 = A-arm
 3 = strut / cylinder
 4 = piston



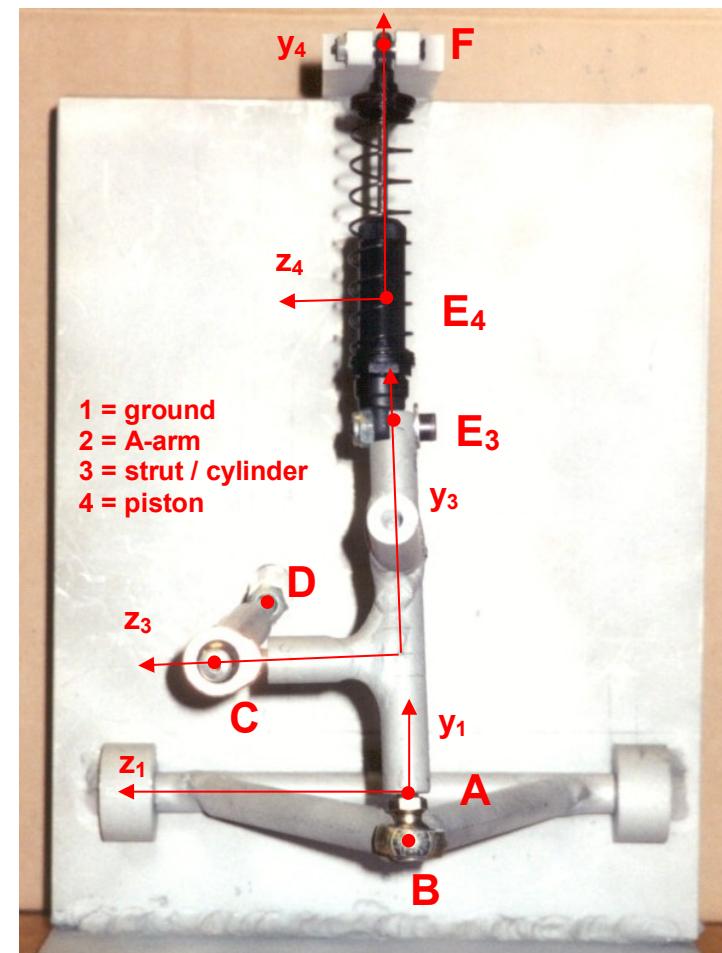
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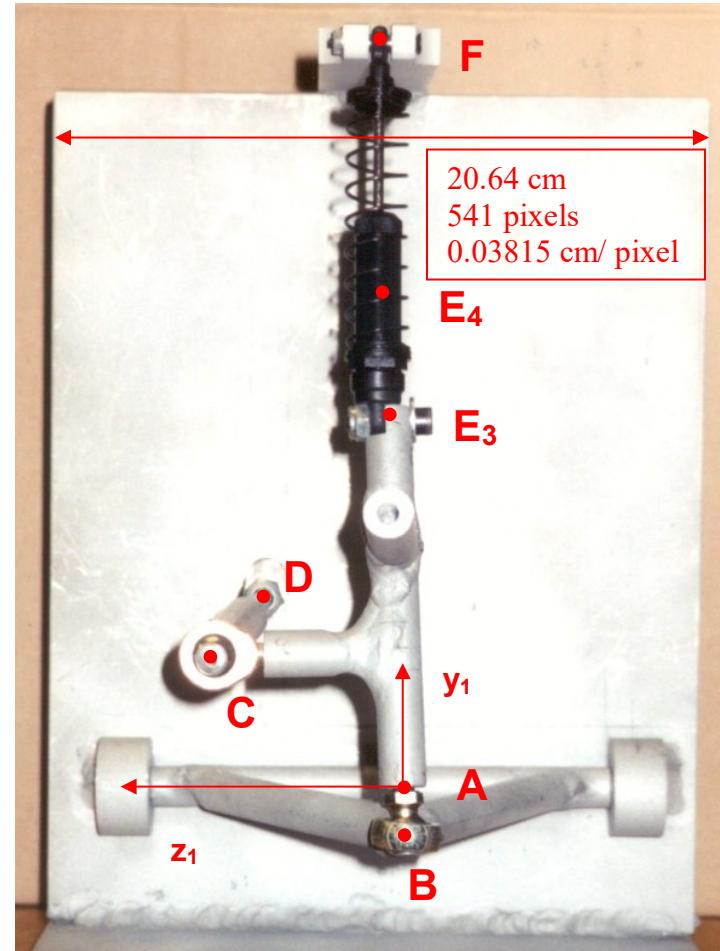
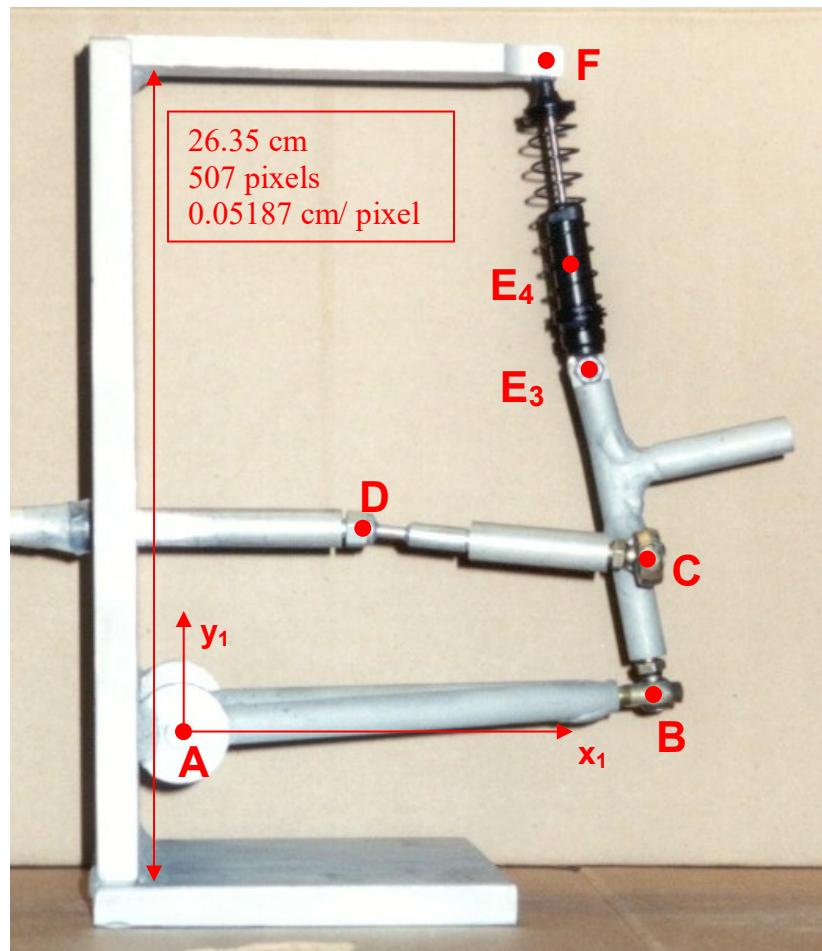


McPherson strut model - rear view



McPherson strut model - side view





scaled from photographs on class web page

cm	x ₁	y ₁	z ₁
A	0	0	0
B	15.70	1.40	0
C	15.49	5.87	5.77
D	6.03	6.81	4.60
E ₃	13.51	12.16	0
E ₄	13.03	15.56	0
F	12.06	22.35	0

Constraints

$\{q\} = \begin{bmatrix} \{r_2\} \\ \{p_2\} \\ \{r_3\} \\ \{p_3\} \\ \{r_4\} \\ \{p_4\} \end{bmatrix}_{21 \times 1}$	$\{\Phi\} = \begin{bmatrix} \{r_2\} \\ \{p_2\} \\ \{r_3\} \\ \{p_3\} \\ \{r_4\} \\ \{p_4\} \end{bmatrix}_{21 \times 1}$	$\{r_i\}^A - \{r_j\}^A$	revolute A	$\text{revA}, i = 2, j = 1$
		$\{\hat{f}_2\}^T \{\hat{h}_1\}$		$f_2 h_1, i = 2, j = 1$
		$\{\hat{g}_2\}^T \{\hat{h}_1\}$		$g_2 h_1, i = 2, j = 1$
		$\{r_2\}^B - \{r_3\}^B$	spherical B	$\text{sphB}, i = 3, j = 2$
		$\{d_{ij}\}^T \{d_{ij}\} - CD^2$		$\{d_{ij}\} = \{r_i\}^D - \{r_j\}^C \quad \text{1D-3C}, i = 3, j = 1$
		$\{\hat{f}_3\}^T \{\hat{g}_4\}$ $\{\hat{h}_3\}^T \{\hat{g}_4\}$ $\{\hat{f}_3\}^T \{d_{ij}\}$ $\{\hat{h}_3\}^T \{d_{ij}\}$ $\{\hat{f}_3\}^T \{\hat{h}_4\}$	prismatic E	$f_3 g_4, i = 3, j = 4$ $h_3 g_4, i = 3, j = 4$ $f_3, i = 3, j = 4$ $h_3, i = 3, j = 4$ $f_3 h_4, i = 3, j = 4$
		$\{r_i\}^F - \{r_j\}^F$	spherical F	$\text{sphF}, i = 4, j = 1$
		$\{p_2\}^T \{p_2\} - 1$ $\{p_3\}^T \{p_3\} - 1$ $\{p_4\}^T \{p_4\} - 1$	Euler parameters	p_2 p_3 p_4
		$y_3 - y_{3_START} - y_{3_VEL} t$	driver	driver
$JAC(21, q) =$				

Velocity

$$\{v\} = \begin{bmatrix} 0_{20 \times 1} \\ y_{3_VEL} \end{bmatrix}_{21 \times 1}$$