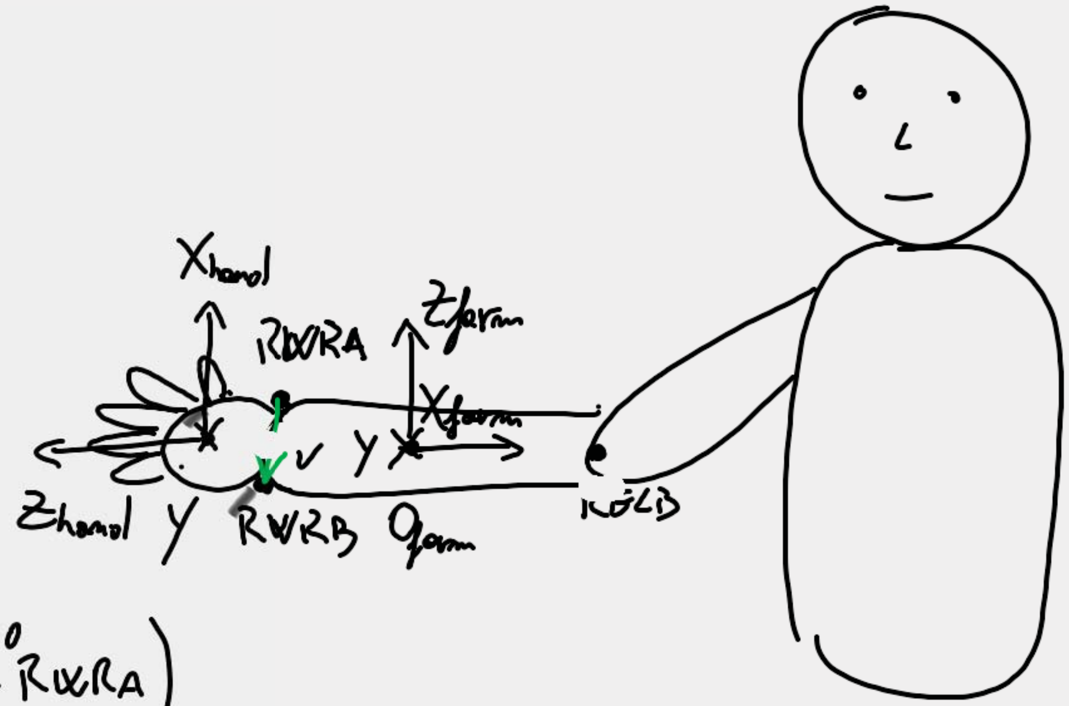
1a)

$$^{0}O_{farm} = \frac{^{0}RWRA + {^{0}RWRB} + {^{0}RELB}}{3}$$

$$^{0}X_{farm} = vers\left(^{0}RELB - {^{0}O_{farm}}\right)$$

$$^{0}Y_{farm} = vers\left(^{0}X_{farm} \times \left(^{0}RWRB - {^{0}RWRA}\right)\right)$$

$$^{0}Z_{farm} = {^{0}X_{farm}} \times {^{0}Y_{farm}}$$

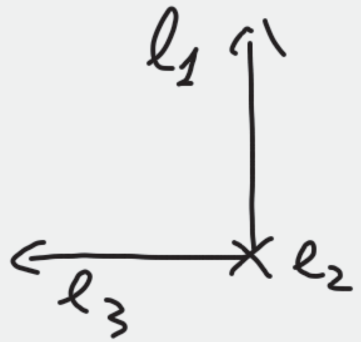


$$^{0}T_{farm} = \begin{bmatrix} ^{0}X_{farm} & ^{0}Y_{farm} & ^{0}Z_{farm} & ^{0}O_{farm} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

1 b) l_1 : Fl / Ex

l_2 : Dev ULN/Rad

l_3 : PR / SUP



$l_1 \parallel Z_{farm}$

$l_3 \parallel Z_{hand}$

$l_2 \perp l_1, l_3$

$Z \; Y' \; Z''$

$\varphi \; \theta \; \psi$

l_1 : FLEX ⊕

l_2 : DEV ULN ⊕

l_3 : SUPIN ⊕

1c) $H \rightarrow {}^{farm}\omega^{farm}_{hand} = H(\alpha)\,\dot{\alpha} \qquad \dot{\alpha} = \begin{bmatrix} \dot{\varphi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$

$z \; y' \; z''$

$\downarrow \; \downarrow \; \downarrow$

$\varphi \; \theta \; \psi$

$$\omega_\psi = R_z(\varphi)\, R_y(\theta) \begin{bmatrix} 0 \\ 0 \\ \dot{\psi} \end{bmatrix}$$

$$\omega = \omega_\varphi + \omega_\theta + \omega_\psi$$

$$\omega_\varphi = \begin{bmatrix} 0 \\ 0 \\ \dot{\varphi} \end{bmatrix}$$

$$\omega_\theta = R_z(\varphi) \cdot \begin{bmatrix} 0 \\ \dot{\theta} \\ 0 \end{bmatrix} = \begin{bmatrix} c\varphi & -s\varphi & 0 \\ s\varphi & c\varphi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ \dot{\theta} \\ 0 \end{bmatrix} = \begin{bmatrix} -s\varphi\,\dot{\theta} \\ c\varphi\,\dot{\theta} \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} c\varphi & -s\varphi & 0 \\ s\varphi & c\varphi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} c\theta & 0 & s\theta \\ 0 & 1 & 0 \\ -s\theta & 0 & c\theta \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ \dot{\psi} \end{bmatrix} = \omega_\psi$$

$$= \begin{bmatrix} c\varphi & -s\varphi & 0 \\ s\varphi & c\varphi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} s\theta\dot{\psi} \\ 0 \\ c\theta\dot{\psi} \end{bmatrix} = \begin{bmatrix} c\varphi\, s\theta\, \dot{\psi} \\ s\varphi\, s\theta\, \dot{\psi} \\ c\theta\, \dot{\psi} \end{bmatrix}$$

$$\omega = \begin{bmatrix} 0 \\ 0 \\ \dot{\varphi} \end{bmatrix} + \begin{bmatrix} -s\varphi\dot{\theta} \\ c\varphi\dot{\theta} \\ 0 \end{bmatrix} + \begin{bmatrix} c\varphi s\theta\dot{\psi} \\ s\varphi s\theta\dot{\psi} \\ c\theta\dot{\psi} \end{bmatrix} = \begin{bmatrix} -s\varphi\dot{\theta} + c\varphi s\theta\dot{\psi} \\ c\varphi\dot{\theta} + s\varphi s\theta\dot{\psi} \\ \dot{\varphi} + c\theta\dot{\psi} \end{bmatrix} = H \begin{bmatrix} \dot{\varphi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$$

$$= \begin{bmatrix} 0 & -s\varphi & c\varphi s\theta \\ 0 & c\varphi & s\varphi s\theta \\ 1 & 0 & c\theta \end{bmatrix} \begin{bmatrix} \dot{\varphi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$$

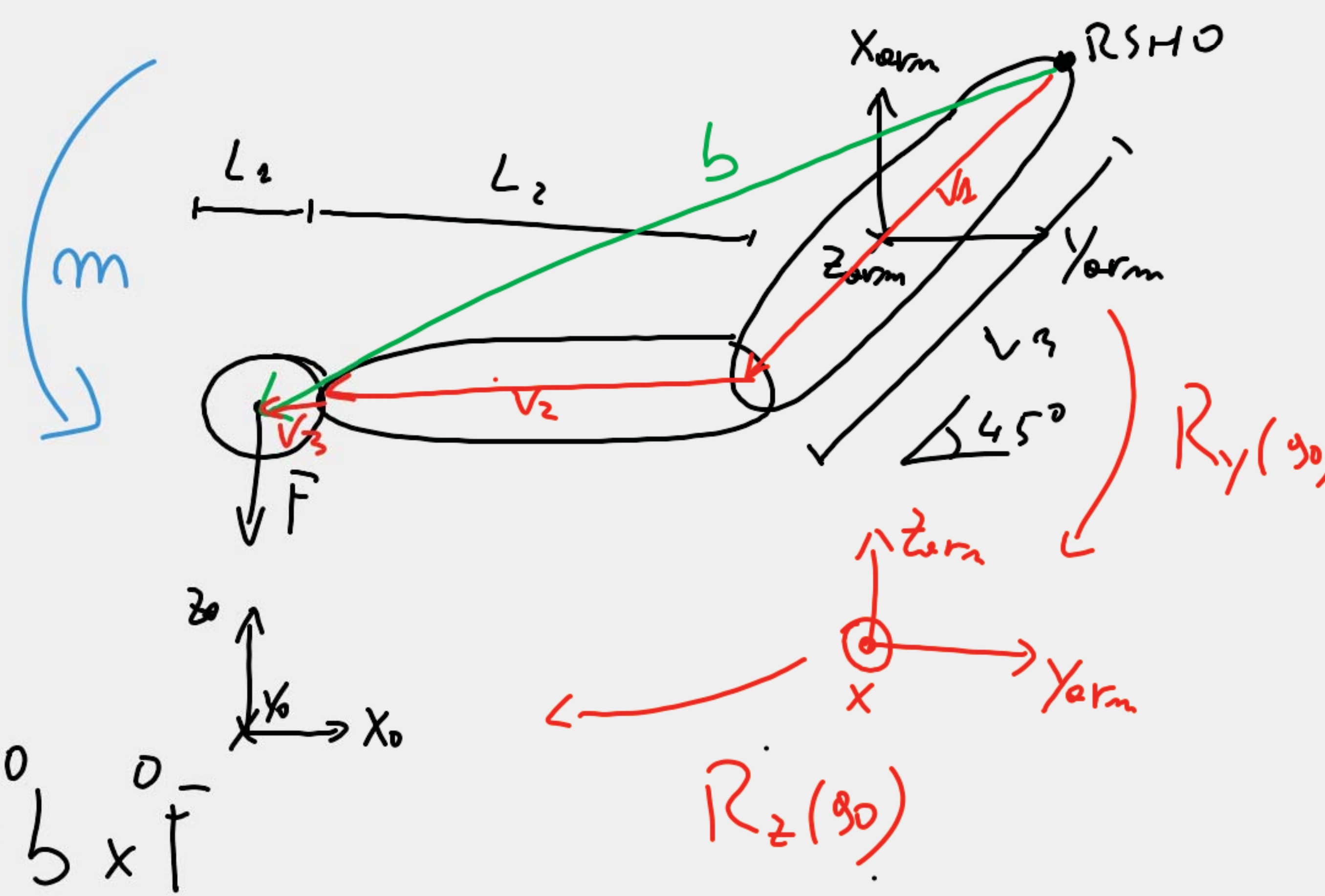
$$\parallel$$

$$H(\alpha)$$

1 d) $^{arm}m = ?$

$$\vec{m} = \vec{b} \times \vec{F}$$

$$^{0}F = \begin{bmatrix} 0 \\ 0 \\ -50 \end{bmatrix} N$$



1) $^{arm}m = {}^{arm}R_0 \, {}^{0}m \; ; \; {}^{0}m = {}^{0}b \times {}^{0}\vec{F}$

$$^{arm}R_0 = \begin{pmatrix} | & | & | \\ ^{arm}X_0 & ^{arm}Y_0 & ^{arm}Z_0 \\ | & | & | \end{pmatrix} = \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}$$

$$^{arm}R_0 = R_y(90) \, R_z(90)$$

$$\vec{b} = \vec{V_1} + \vec{V_2} + \vec{V_3}$$

$$^0V_2 = \begin{bmatrix} -L_2 \\ 0 \\ 0 \end{bmatrix}$$

$$^0V_3 = \begin{bmatrix} -\frac{L_1}{2} \\ 0 \\ 0 \end{bmatrix}$$

$$^0V_1 = \begin{bmatrix} -\frac{\sqrt{2}}{2} L_3 \\ 0 \\ -\frac{\sqrt{2}}{2} L_3 \end{bmatrix}$$

$$^0b = \begin{bmatrix} -\frac{\sqrt{2}}{2} L_3 \\ 0 \\ -\frac{\sqrt{2}}{2} L_3 \end{bmatrix} + \begin{bmatrix} -L_2 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} -\frac{L_1}{2} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} b_x \\ 0 \\ b_z \end{bmatrix} mm$$

$$^{0}m = \begin{vmatrix} i & j & k & i & j \\ b_x & b_y & b_z & b_x & b_y \\ F_x & F_y & F_z & F_x & F_y \end{vmatrix} = \begin{bmatrix} 0 \\ -27.5 \\ 0 \end{bmatrix} \text{Nm}$$

$$^{arm}m = {}^{arm}R_0 \, {}^{0}m$$

2) $$^{arm}m = {}^{arm}b \times {}^{arm}F$$