## UAV Kinematics

Position of the UAV will be given in reference frame {n} using NED. This gives the states:

$$\boldsymbol{p}^n_{b/n} = \begin{bmatrix} N \\ E \\ D \end{bmatrix} = \begin{bmatrix} x_n \\ y_n \\ z_n \end{bmatrix} \tag{1}$$

Attitude will be given as Euler-angles:

$$\boldsymbol{\Theta}_{nb} = \begin{bmatrix} \phi \\ \theta \\ \psi \end{bmatrix} \tag{2}$$

Together these make up the position and orientation vector $\boldsymbol{\eta}$:

$$\boldsymbol{\eta} = \begin{bmatrix} \boldsymbol{p}^n_{b/n} \\ \boldsymbol{\Theta}_{nb} \end{bmatrix} \tag{3}$$

### Wind

Wind will introduce what is called crab angle $\chi_c$ in the horizontal plane and the angle of attack $\gamma_a$ in the vertical plane. This will change the UAVs actual heading $\psi$ and pitch $\theta$ to:

$$\chi = \psi + \chi_c \tag{4a}$$

$$\gamma = \theta + \gamma_a \tag{4b}$$

where $\chi$ is called the course and $\gamma$ is maybe called something????

## Camera position

When assuming flat earth, the centre point of the camera on the ground can be expressed in the body frame {b} using the attitude $\boldsymbol{\Theta}_{nb}$ of the UAV and the height $z_n$:

$$\boldsymbol{c}^b_b = \begin{bmatrix} c^b_{x/b} \\ c^b_{y/b} \end{bmatrix} = \begin{bmatrix} z_n sin(\theta) \\ z_n sin(\phi) \end{bmatrix} \tag{5}$$

The distance from the UAV to the camera centre point can be expressed in {n} by using the rotational matrix $\boldsymbol{R}_{z,\psi}$:

$$\boldsymbol{c}^n_b = \begin{bmatrix} c^n_{x/b} \\ c^n_{y/b} \end{bmatrix} = \boldsymbol{R}_{z,\psi}\boldsymbol{c}^b_b \tag{6}$$

In order to translate this to position in NED, it needs to be added to the UAV's NED position:

$$\boldsymbol{c}^n = \begin{bmatrix} x_n + c^n_{x/b} \\ y_n + c^n_{y/b} \end{bmatrix} \tag{7}$$

*ADD TRANSLATIONAL MATRIX FOR POSITION OF CAMERA*
*DECIDE ON HAVING ONE CENTER POINT, OR TWO EXTREMITIES*