IMU
- → Accelerometer
- → Gyroscope.

Equation for IMU sensor model:

$$a_{meas} = a_{true} + bias_{acc} + noise_{acc}$$

$$\boxed{a_{meas} = a_{true} + b_a + n_a(t)}$$

Equation for a gyroscope:

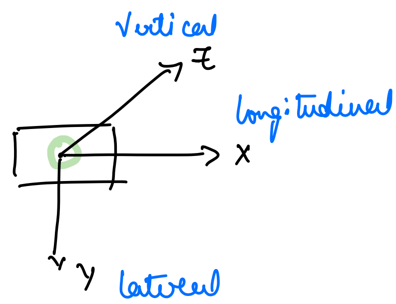
$$\omega_{meas} = \omega_{true} + bias_{gyro} + noise_{gyro}$$

$$\boxed{\omega_{meas} = \omega_{true} + b_g + n_g(t)}$$

Use Case:

lets use the above equations for our Rover, which acceleration along longitudinal but zero acceleration along lateral direction.

Accelerometer measures the linear acceleration (x, y and z) directions




$$\text{acceleration}_{true} \; (a_{true}) = \begin{bmatrix} a_{long} \\ a_{later} \\ a_{vertical} \end{bmatrix}$$

$$= \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}$$

## Accelerometer bias ( $b_{accel}$ ) :

This is a Constant offset along x, y and z directions

$$b_{accel} = \begin{bmatrix} b_x \\ b_y \\ b_z \end{bmatrix} \quad \text{aka} \quad \begin{bmatrix} b_{ax} \\ b_{ay} \\ b_{az} \end{bmatrix}$$

## Accelerometer noise ( $n_{accel}$ ):

Similar to the bias, noise is affected along each direction

$$n_{accel} = \begin{bmatrix} n_{ax} \\ n_{ay} \\ n_{az} \end{bmatrix}$$

Accelerometer sensor model is given by

$$a_{measured} = \left.\begin{bmatrix} a_x + b_{ax} + n_{ax} \\ a_y + b_{ay} + n_{ay} \\ a_z + b_{az} + n_{az} \end{bmatrix}\right\} \text{along Rover's body frame.}$$

$\rightarrow$ 1

## Gyroscope sensor model:

Gyroscope measures the angular velocity for our rover/car

$$\omega_{true} = \begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix}$$

$$bias_{gyro} = \begin{bmatrix} b_{gx} \\ b_{gy} \\ b_{gz} \end{bmatrix}$$

$$noise_{gyro} = \begin{bmatrix} n_{gx} \\ n_{gy} \\ n_{gz} \end{bmatrix}$$

Similar to accelerometer, gyroscope equations are given by:

$$\omega_{meas} = \omega_{true} + bias_{gyro} + noise_{gyro}$$

$$\omega_{meas} = \begin{bmatrix} \omega_x + b_{gx} + n_{gx} \\ \omega_y + b_{gy} + n_{gy} \\ \omega_z + b_{gz} + n_{gz} \end{bmatrix} \longrightarrow (2)$$

Combining (1) and (2), sensor model for IMU is given by:

$$IMU_{meas} = IMU_{true} + bias + noise$$

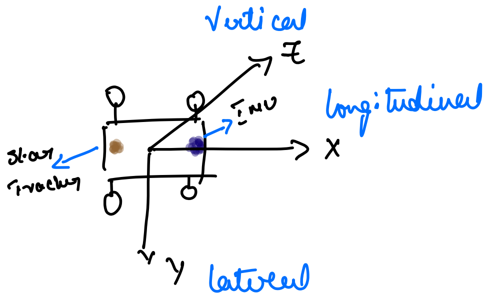
$$= \begin{bmatrix} a_x + b_{ax} + n_{ax} \\ a_y + b_{ay} + n_{ay} \\ a_z + b_{az} + n_{az} \\ \omega_x + b_{gx} + n_{gx} \\ \omega_y + b_{gy} + n_{gy} \\ \omega_z + b_{gz} + n_{gz} \end{bmatrix}$$

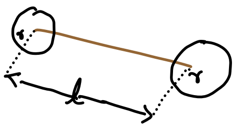
$\longrightarrow$ Ignoring $a_y$ and $a_z$, as we are considering acceleration along x and making it zero in y (lateral) direction

## Star Tracker Sensor Model :

We assume that, the star tracker is placed along the rear wheel axis axle.

Rover wheel and axle :




$r \rightarrow$ radius of the wheel of our rover

$l \rightarrow$ length of the axle of our rover

$d \rightarrow$ center of the rear axle to the star tracker.

We assume that the rover moves along longitudinal direction without any slip.

absolute orientation

$$(\theta) = \theta_{true} + b_{st} + n_{st}.$$

absolute orientation provides the Euler angles roll, pitch and yaw i.e $(\alpha, \beta, \gamma)$

Position of star tracker is given by :

$$x_{st} = d\cos\theta$$

$$y_{st} = l/2$$

$$z_{st} = r(1-\cos(\theta)) + d\sin\theta$$

$\theta \rightarrow$ wheel angle.