

EE 570: Location and Navigation:

Assignment #4 – Due Thursday 28th Feb 2013 (in class)

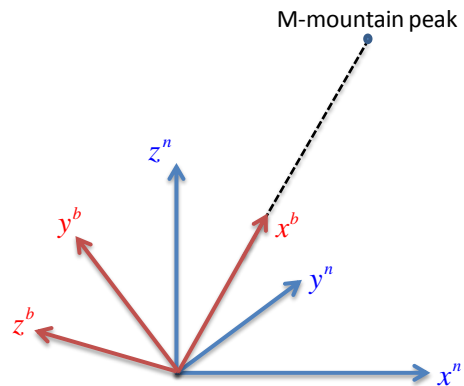
Question # 1. The NMT UAV club located at the Workman center at a latitude = 34.066147° , longitude = -106.907562° , and elevation = 1414m (geodetic height).

- What are the x/y/z coordinates of the NMT UAV club in the ECEF frame (SI units please)?
- In preparation for its inaugural flight the new UAV sits on its launch pad pointing directly towards the peak of M-mountain (latitude = 34.071684° , longitude = -106.962968° , and elevation = 2201m).

- What is the orientation of the Nav frame (on the launch pad) wrt the ECEF frame (i.e. C_n^e)?
- What are the x/y/z coordinates of the peak of M-mountain in the ECEF frame?
- Using the info from b) ii. and a) (or otherwise) what is the vector from the origin of the Body/Nav frame to the peak of M-mountain resolved in the Nav frame (i.e. \vec{r}_{nM}^n)? **HINT:**

Compute the vector resolved in the ECEF frame first.

- In order to point to the peak, assume that the body frame is initially aligned with the nave frame, then yaw by ψ , pitch by θ , and finally roll by $\phi=0$ (i.e. *NO roll*). What is the orientation of the Body frame (on the launch pad) wrt the Nav frame (i.e. C_b^n) and what are the required yaw and pitch angles in deg? **HINT:** The normalized version of the vector you computed in iii. must be the “x-axis” of your C_b^n rotation matrix!!



Question # 2. Our quadcopter UAV has been successfully launched and is now flying. Using the NMT radar tracking system which is also located at the Workman center we can determine the position vector from the Workman center to the UAV (*i.e.* to the origin of the body frame $\vec{r}_{tb}^t(t)$) resolved in the frame of the tracking system (*t*-frame). The orientation of the *t*-frame is the same as that of original nav frame (*i.e.* when we were on the launchpad).

Given the position vector of the quadcopter by the radar to be

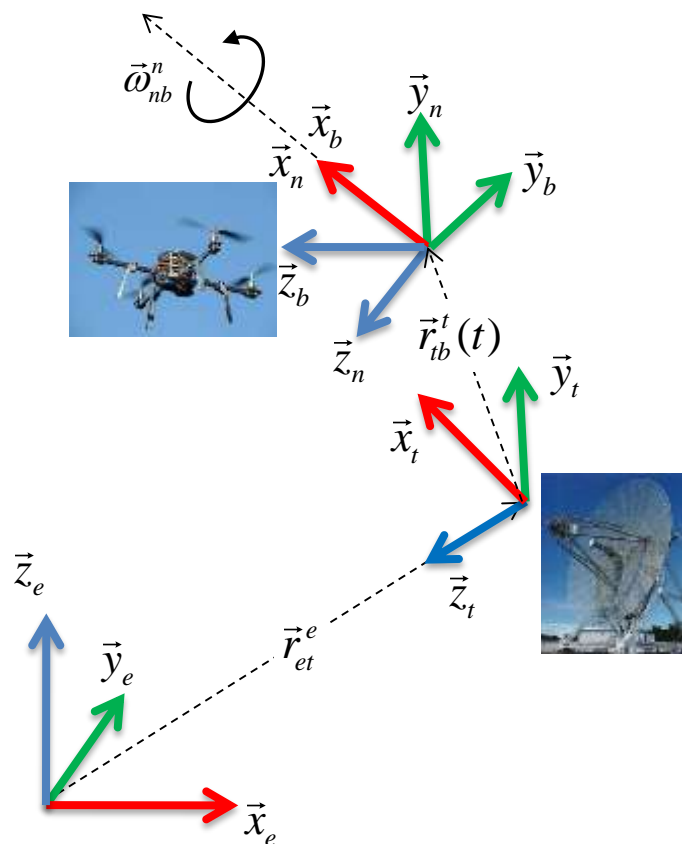
$$\vec{r}_{tb}^t = \vec{r}_m^t = \begin{bmatrix} 5t^2 + 250t - 3000 \\ 2000 \\ -4000 \end{bmatrix} \quad (\text{meters})$$

and knowing that the UAV is performing rolls about the x_b -axis (*i.e.* about x_b), at a rate of one every two seconds (*i.e.* roll angle $\phi = \pi t$ rad), hence,

$$C_b^n = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\phi) & -\sin(\phi) \\ 0 & \sin(\phi) & \cos(\phi) \end{bmatrix}$$

Determine analytic expressions for the following quantities and compute numeric values for the times $t = 0, 5,$ and 10 seconds:

- \vec{r}_{eb}^e
- $\vec{v}_{eb}^e = \dot{\vec{r}}_{eb}^e$
- $\vec{a}_{eb}^e = \ddot{\vec{r}}_{eb}^e$
- $[L_b \quad \lambda_b \quad h_b]$.
 - Also, plot the Lat (in $^\circ$), Lon (in $^\circ$), and height (in m) as a function of time for $t=0:0.1:10$ seconds
- $[\dot{L}_b \quad \dot{\lambda}_b \quad \dot{h}_b]$. **HINT:** You may want to numerically differentiate lat, lon, and height?
 - Also, plot the Lat (in $^\circ$), Lon (in $^\circ$), and height (in m) rates as a function of time for $t=0:0.1:10$ seconds



f) $\vec{\omega}_{en}^e$ (in $\mu\text{rad/s}$)

g) C_n^e

h) $\vec{\omega}_{nb}^n$ (in $\mu\text{rad/s}$)

i) $\vec{\omega}_{eb}^e$ (in $\mu\text{rad/s}$)

j) C_b^e

k) $\vec{\omega}_{nb}^n$ (in rad/s)

l) $\vec{\omega}_{eb}^e$ (in rad/s)