

Reference Frames for Spacecraft Dynamics and Control

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Reference Frames

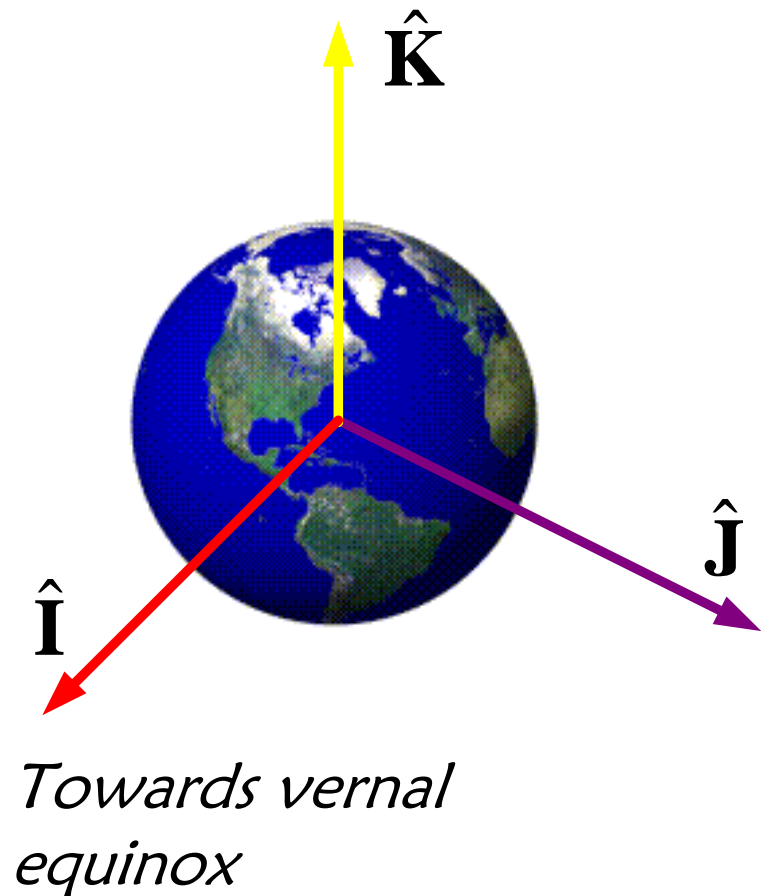
- A reference frame is a set of three mutually perpendicular (orthogonal) unit vectors
- Typical notations include

$$\hat{\mathbf{i}} \hat{\mathbf{j}} \hat{\mathbf{k}}, \quad \hat{\mathbf{I}} \hat{\mathbf{J}} \hat{\mathbf{K}}, \quad \hat{\mathbf{e}}_1 \hat{\mathbf{e}}_2 \hat{\mathbf{e}}_3, \quad \hat{\mathbf{b}}_1 \hat{\mathbf{b}}_2 \hat{\mathbf{b}}_3$$

- Typical reference frames of interest for ADCS include
 - ECI (Earth-centered inertial)
 - Perifocal (Earth-centered, orbit-based inertial)
 - ECEF (Earth-centered, Earth-fixed, rotating)
 - Orbital (Earth-centered, orbit-based, rotating)
 - Body (spacecraft-fixed, rotating)

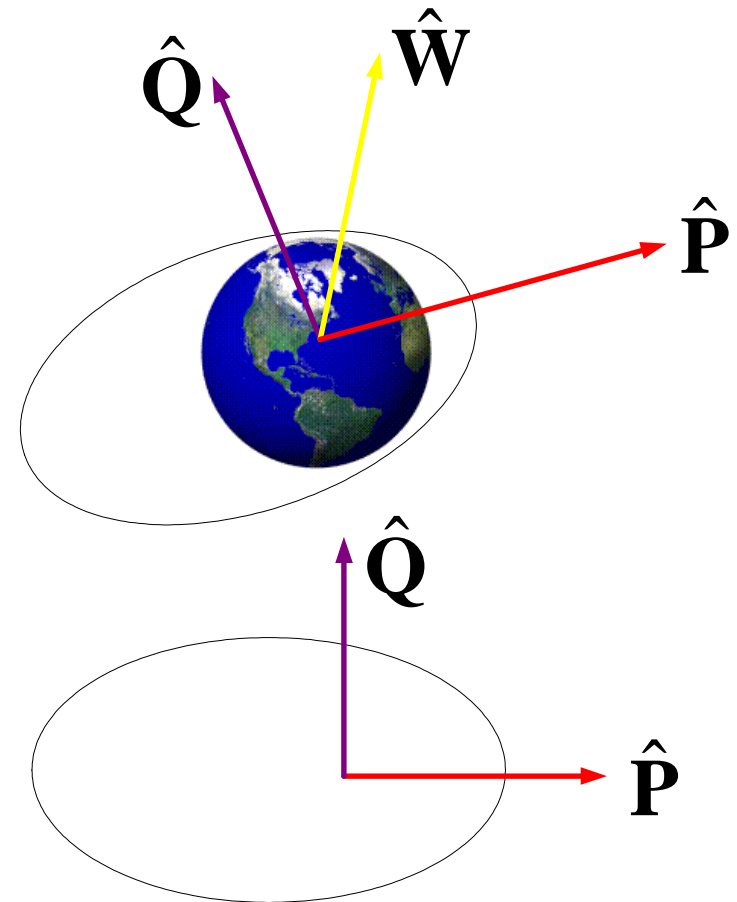
Earth-Centered Inertial (ECI)

- Also called “Celestial Coordinates”
- The **I-axis** is in vernal equinox direction
- The **K-axis** is Earth’s rotation axis, perpendicular to equatorial plane
- The **J-axis** is in the equatorial plane and finishes the “triad” of unit vectors



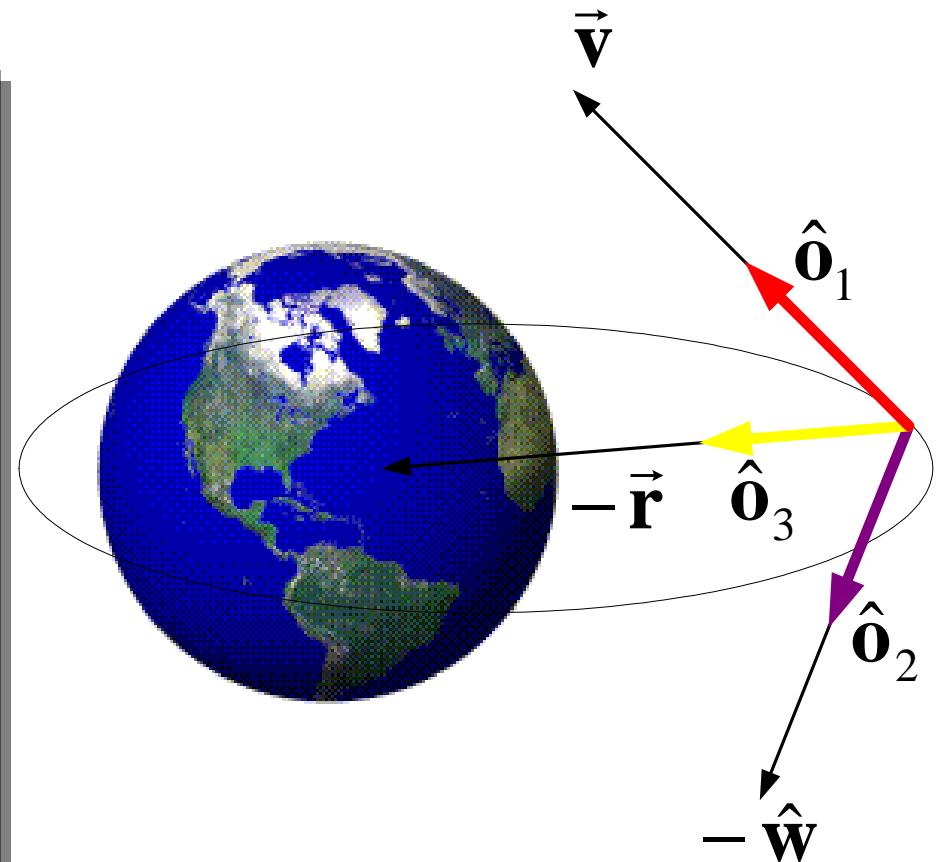
Perifocal Frame

- Earth-centered, orbit-based, *inertial*
- The **P-axis** is in periapsis direction
- The **W-axis** is perpendicular to orbital plane (direction of orbit angular momentum vector, $\vec{r} \times \vec{v}$)
- The **Q-axis** is in the orbital plane and finishes the “triad” of unit vectors



Orbital Frame

- Same as “roll-pitch-yaw” frame
- The \mathbf{o}_3 axis is in the nadir direction
- The \mathbf{o}_2 axis is in the negative orbit normal direction
- The \mathbf{o}_1 axis completes the triad, and is in the velocity vector direction for circular orbits



Body-Fixed Frame

- Typically denoted using “b” unit vectors
- The \mathbf{b}_3 axis is in the nadir direction
- The \mathbf{b}_2 axis is in the negative orbit normal direction
- The \mathbf{b}_1 axis completes the triad, and is in the velocity vector direction for circular orbits

