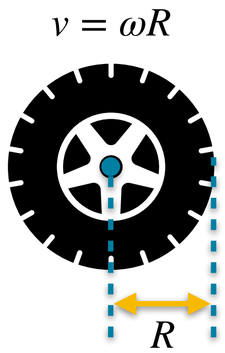
MODULE 5 LESSON 3

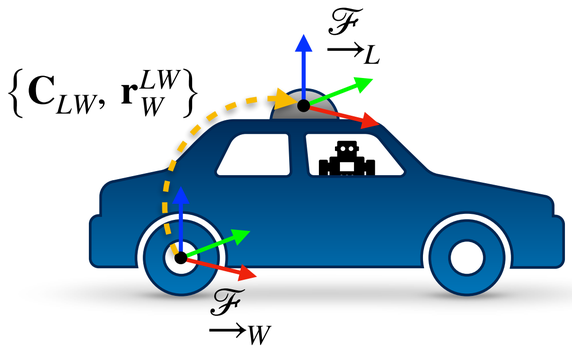
SENSOR CALIBRATION: A NECESSARY EVIL

Calibration: A Necessary Evil

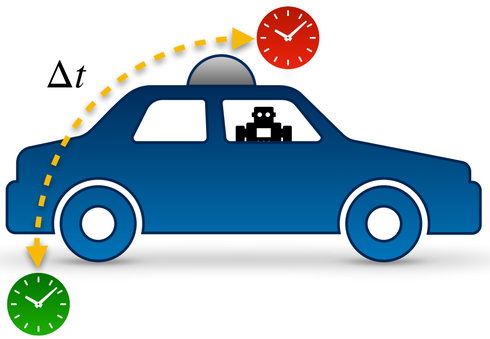
Intrinsic Calibration



Extrinsic Calibration



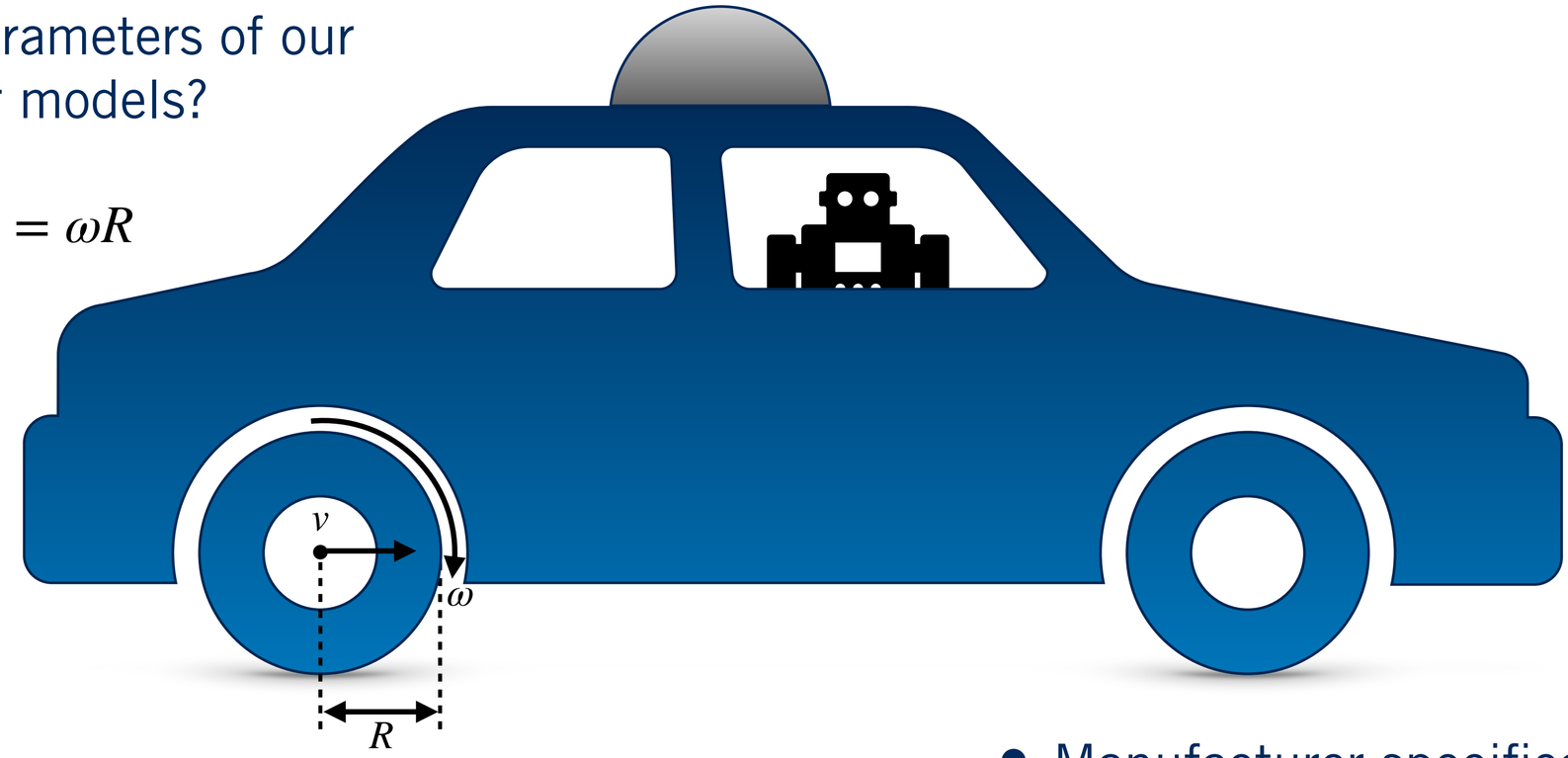
Temporal Calibration



Intrinsic Sensor Calibration

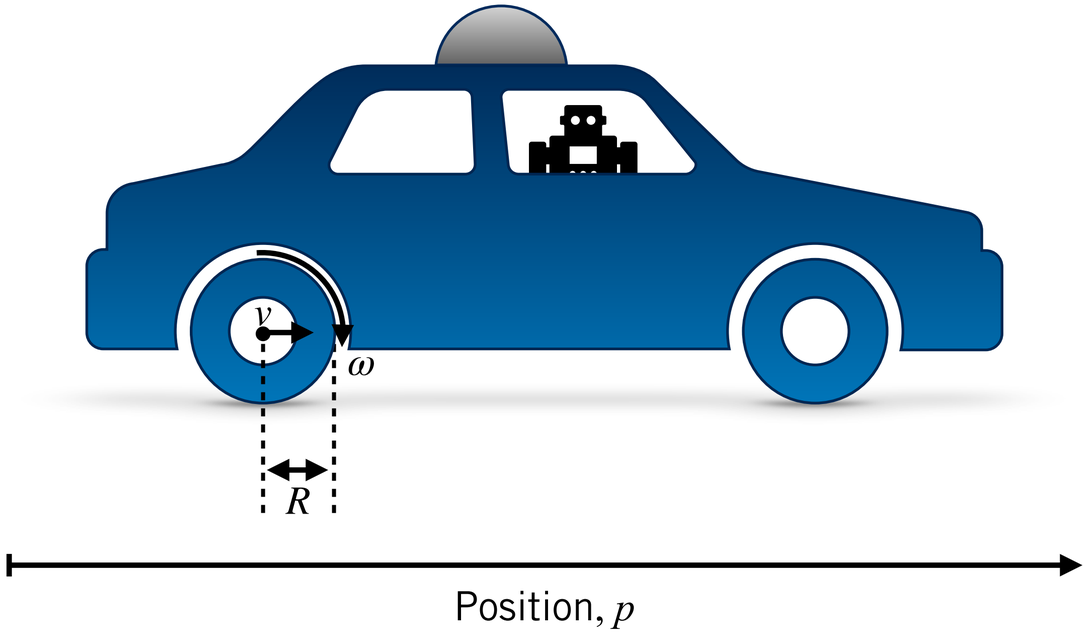
How can we determine the parameters of our sensor models?

$$v = \omega R$$



- Manufacturer specifications
- Measure by hand
- Estimate as part of the state

Calibration by Estimation



$$\mathbf{x} = \begin{bmatrix} p \\ \dot{p} \\ R \end{bmatrix} \qquad \mathbf{u} = \ddot{p}$$

$$\dot{p} = v = \omega R$$

Motion Model

$$\mathbf{x}_k = \begin{bmatrix} 1 & \Delta t & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \mathbf{x}_{k-1} + \begin{bmatrix} 0 \\ \Delta t \end{bmatrix} \mathbf{u}_{k-1} + \mathbf{w}_{k-1}$$

$$\mathbf{w}_k \sim \mathcal{N}(\mathbf{0}, \mathbf{Q}_k)$$

Position / Wheel Rate Observations

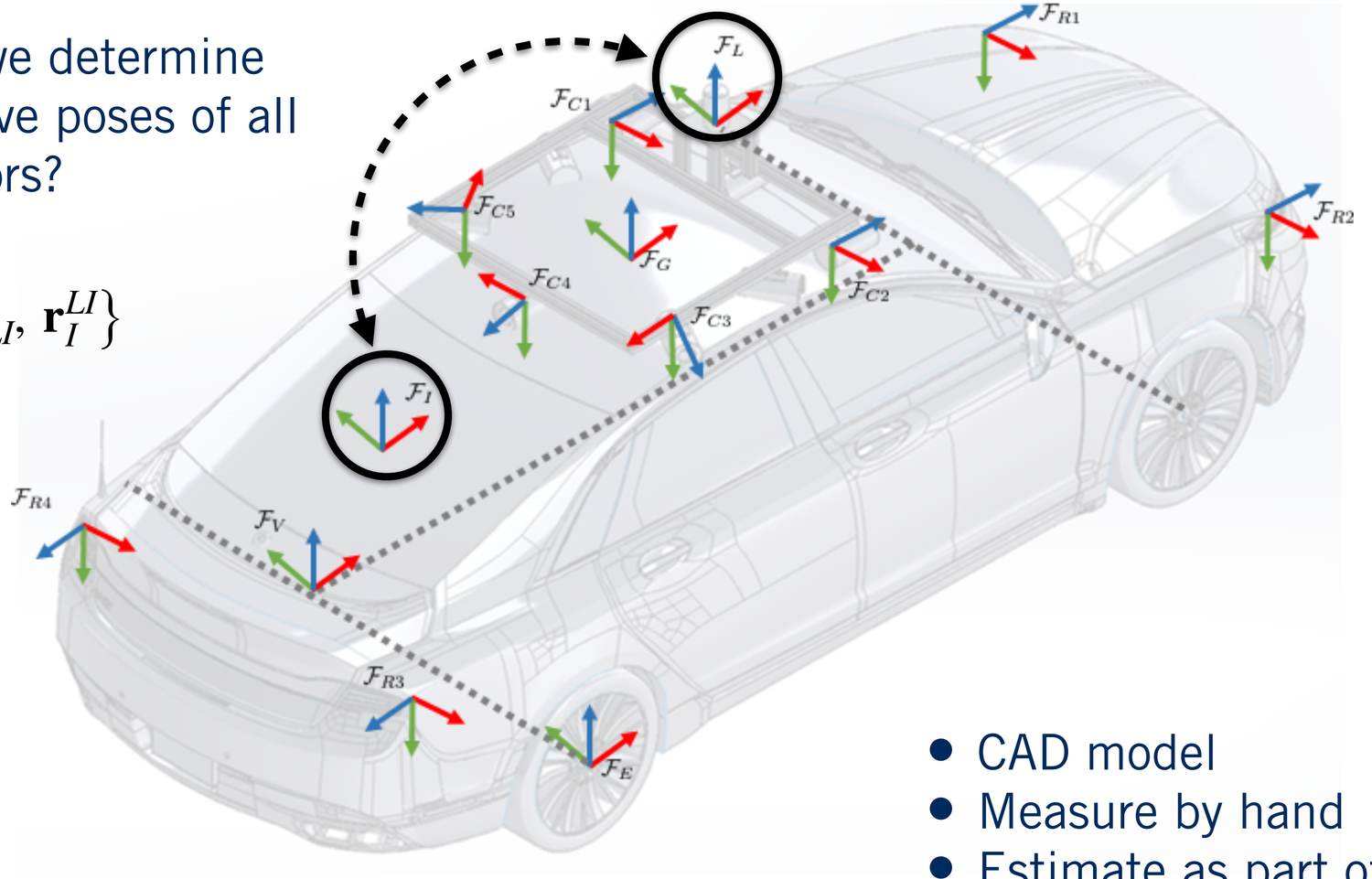
$$\mathbf{y}_k = \begin{bmatrix} p_k \\ \dot{p}_k \;/\; R_k \end{bmatrix} + \mathbf{v}_k$$

$$\mathbf{v}_k \sim \mathcal{N}(\mathbf{0}, \mathbf{R}_k)$$

Extrinsic Sensor Calibration

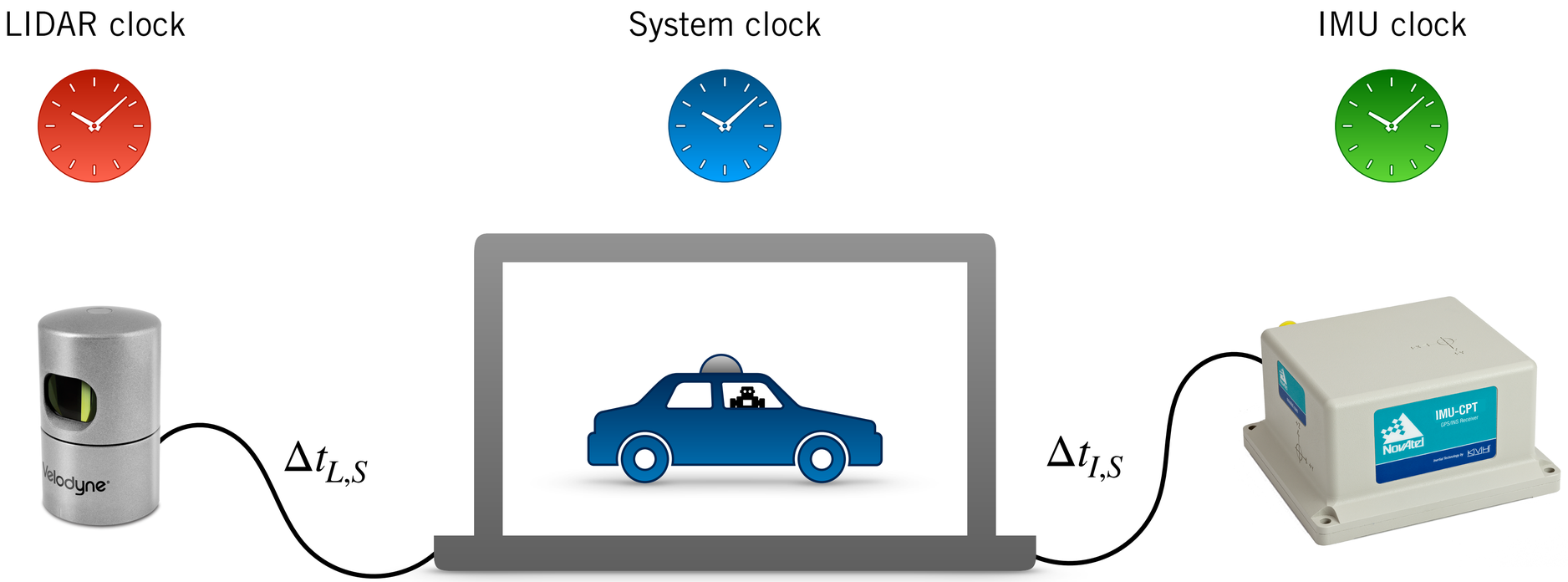
How do we determine the relative poses of all the sensors?

$$\{\mathbf{C}_{LI}, \mathbf{r}_I^{LI}\}$$



- CAD model
- Measure by hand
- Estimate as part of the state

Temporal Calibration



How do we determine the relative time delays of all the sensors?

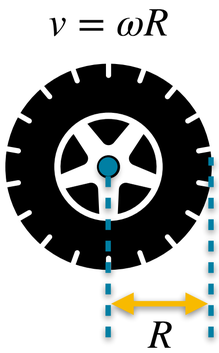
- Assume zero
- Hardware synchronization
- Estimate as part of the state

Bad Calibration vs Good Calibration

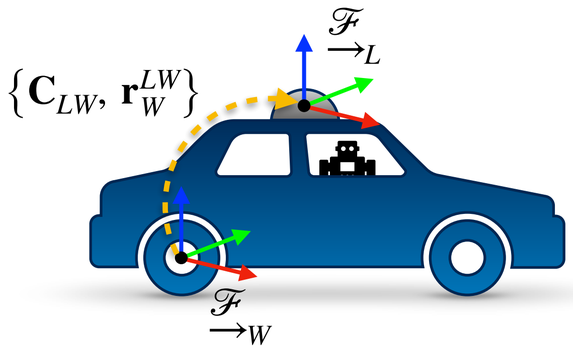
B-roll: Lidar map creation with good/bad calibration (from Autonomoose?)

Summary | Calibration

Intrinsic Calibration



Extrinsic Calibration



Temporal Calibration