Simultaneous Local and Global State Estimation for Robotic Navigation

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Joint work with
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Talk Outline

- Define problem of state estimation
- Discuss two traditional coordinate frames:
  - Globally-referenced coordinate system
  - Body-centered coordinate system
- Propose new representation: “Local Frame”
- Show simulations and collected data

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State Estimation in Mobile Robotics

- Two general classes of measured state information:
  - **Globally referenced**
    - GPS Position
    - Map constructed using SLAM
  - **Body-referenced**
    - Sensor data (LIDAR, cameras, radar, etc.)
    - Inertial measurement (gyro, accelerometer)
    - Kinematics (odometry, joint position, etc.)

How do we reconcile this state data?

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Reconciling Global and Body State

One solution:

Transform all state into the global frame before storing it or reasoning with it

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What happened?

- Alice lost GPS under some power lines.
- Signal returned, but new state estimate had a bias.
- Obstacle map was still registered against previous localization.
- Alice obeyed previous obstacle map and drove into barriers.
- Conclusion: Don't store persistent data in the global frame.

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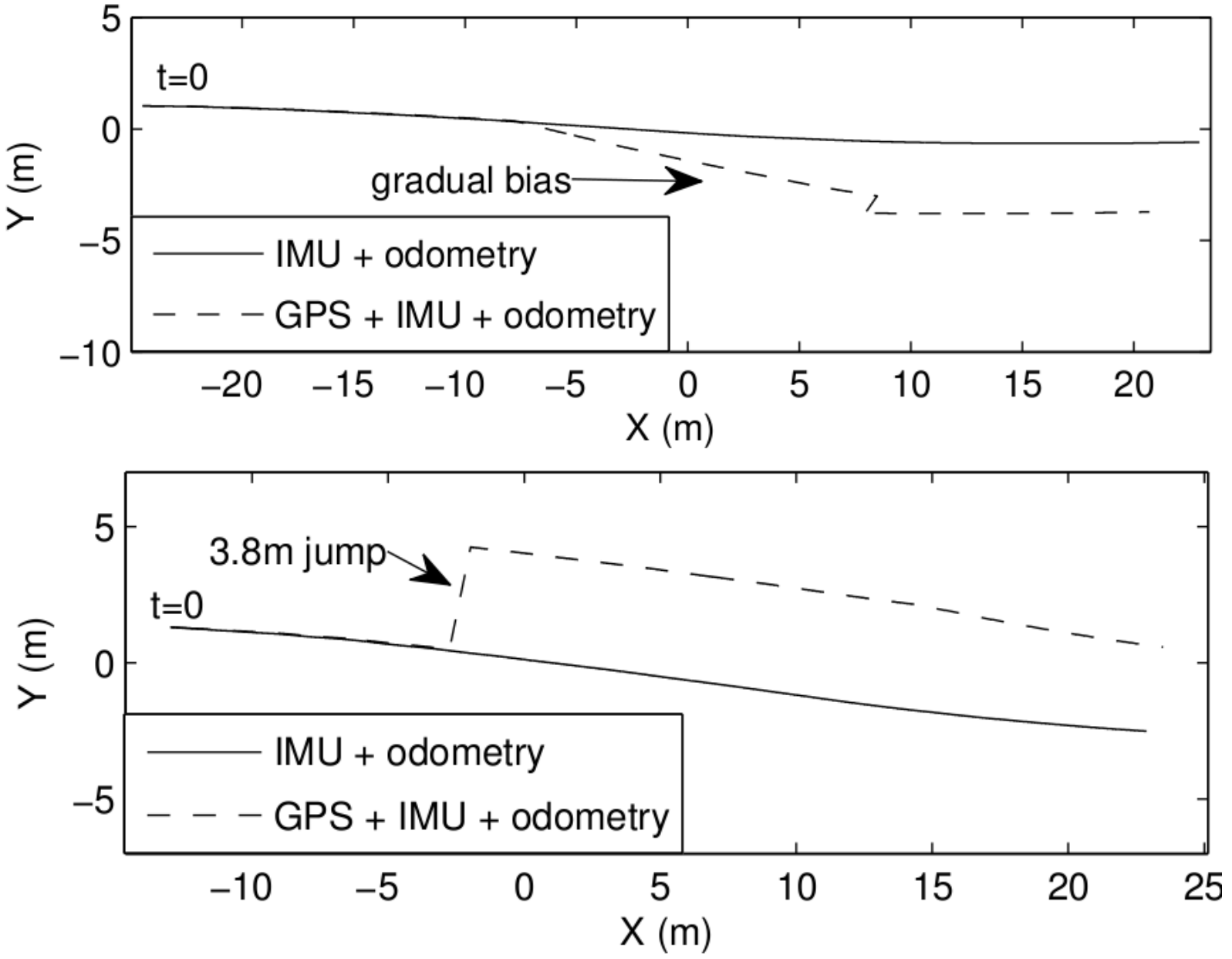
GPS Discontinuities



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Body Frame

- Vehicle position defined as (0,0,0)
- Sensor data:
  - Project into body frame per sensor
  - Corrupted by intrinsic sensor and projection error
- Globally-registered data:
  - Project into body frame using localization fix
  - Corrupted by noise from localization system
- Primary disadvantage:

Must propagate stored map data
at every time step

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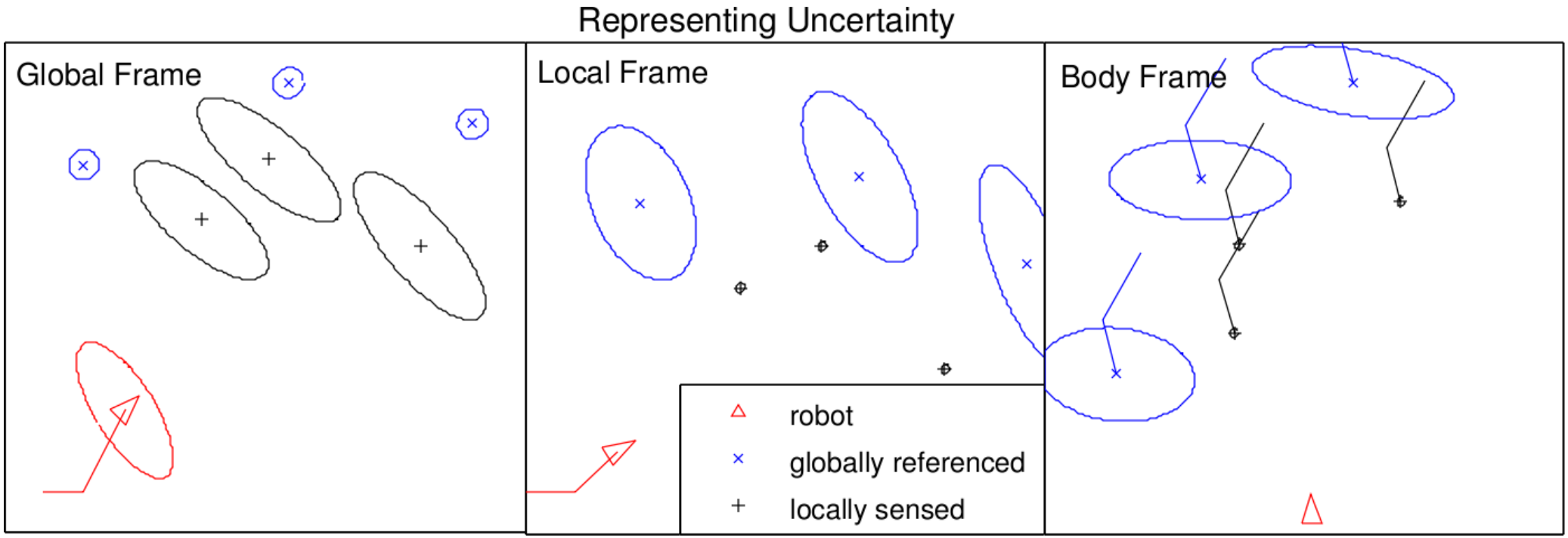
Three Possible Frames



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The Local Frame Defined

- Traditional position update in same frame L_t:

$$\boldsymbol{x}_{t+1}^{L_t} = F\left(\boldsymbol{x}_t^{L_t}, \boldsymbol{u}_t\right) + \boldsymbol{w}_t^{L_t}$$

vehicle position — inertial measurement — noise

- Local frame update:
  - Position update into new frame L_{t+1} without noise:

$$\boldsymbol{x}_{t+1}^{L_{t+1}} = F\left(\boldsymbol{x}_t^{L_t}, \boldsymbol{u}_t\right)$$

  - Must also migrate map data into L_{t+1} with noise
- Key feature: Maximum Likelihood Estimate of map data is the same in L_t and L_{t+1}

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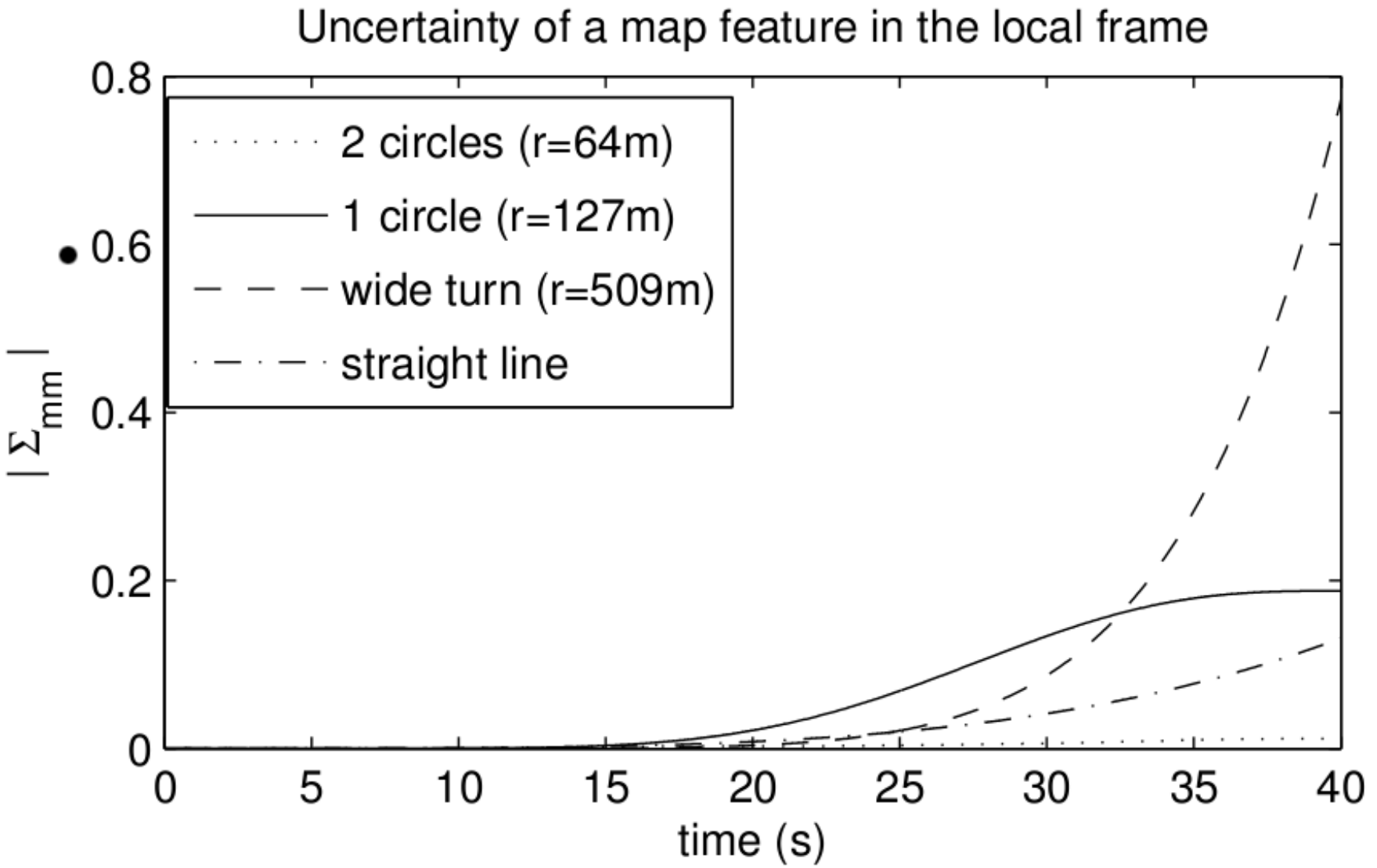
Local Frame Simulation



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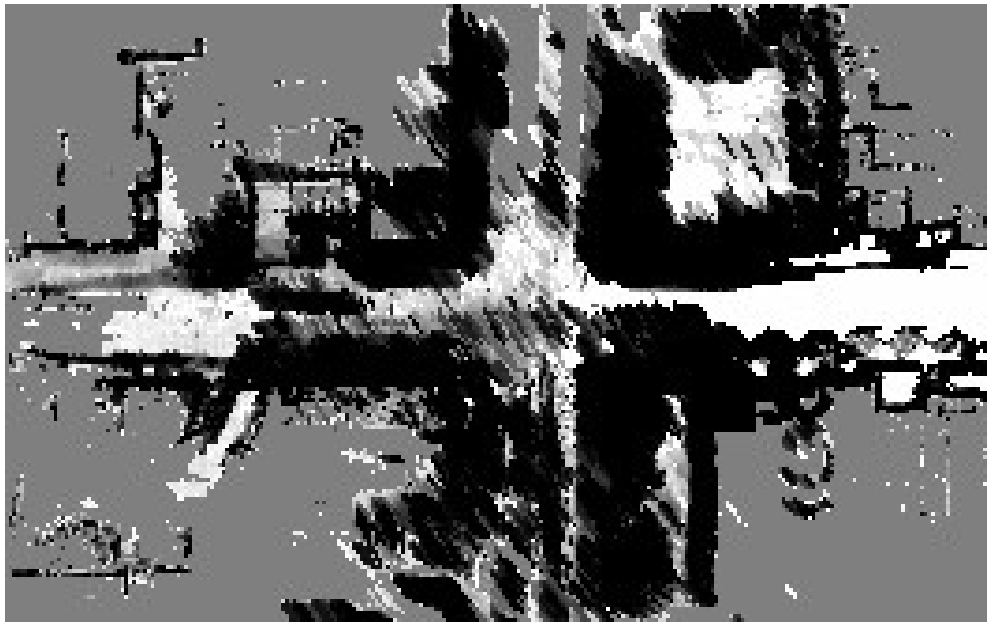
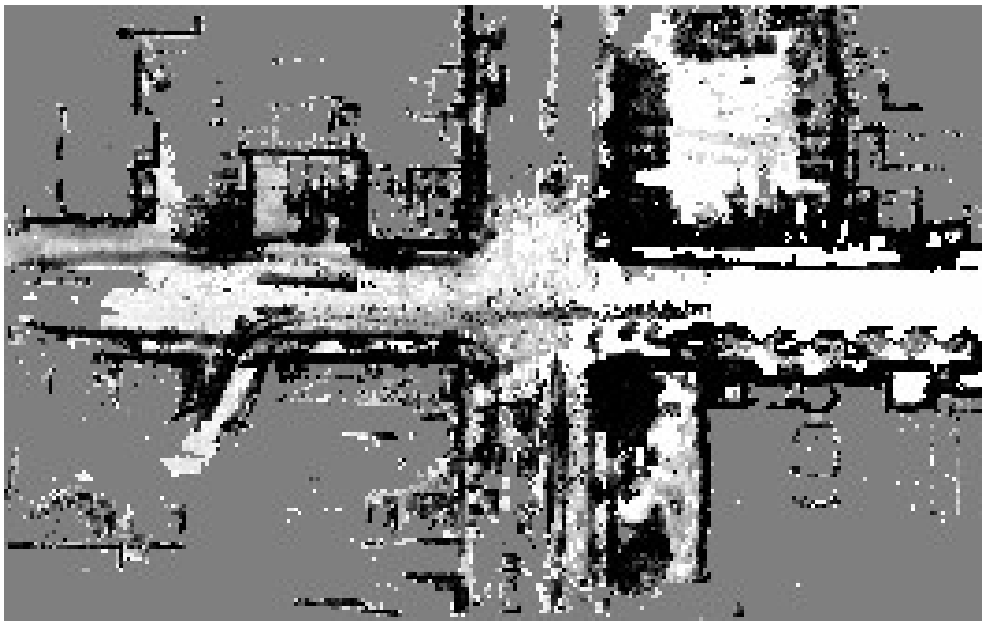
Global vs. Local in the Real World

Global Frame



Local Frame



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Conclusions

- Global frame is not recommended for storing measured sensor data.
- Body frame is suitable, but can be expensive to do time updates.
- The local frame is a good alternative.
- Request for manufacturers of high-end Inertial Navigation Systems (INS):

  Please provide a purely inertial position/attitude estimate *in addition* to traditional GPS-fused position estimate

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Questions?