Alternative Positioning Technologies – Know where you are without GPS.

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Exploratory Advanced Research

- Generally: Addresses the need to conduct research on longer term and higher risk breakthrough research with the potential for transformational improvements.
- FHWA recognized that GPS doesn't work everywhere and alternatives would be useful
- Goal: Examine alternative vehicle positioning technologies that will satisfy requirements while maintaining low on-vehicle and highway infrastructure costs
- Work completed by the University of California, Riverside
  - Phase I - Assess the viability, benefits, limitations, and obstacles for different approach's
  - Phase II – Describe and examine technologies from Phase I and then provide further details on integration strategies and performance for vehicle applications.

Key Technical Evaluation Metrics

- Sensor Orientation
  - Sensor monitoring orientation relative to the direction of travel;
- Aiding Rate
  - Frequency of correction signal being acquired, processed, and integrated within the vehicle state determination;
- Processing Latency
  - Time from signal being acquired to aided position determination;
- Demonstrated Positional Accuracy
  - Accuracy of vehicle position utilizing only the specified aiding technique when GPS signal is interrupted.
- Vehicle state being aided
  - Positional correction along and/or perpendicular to the signal propagation path, and;
- Measured feature or signal
  - Monitored signal frequency or objects serving as landmarks.

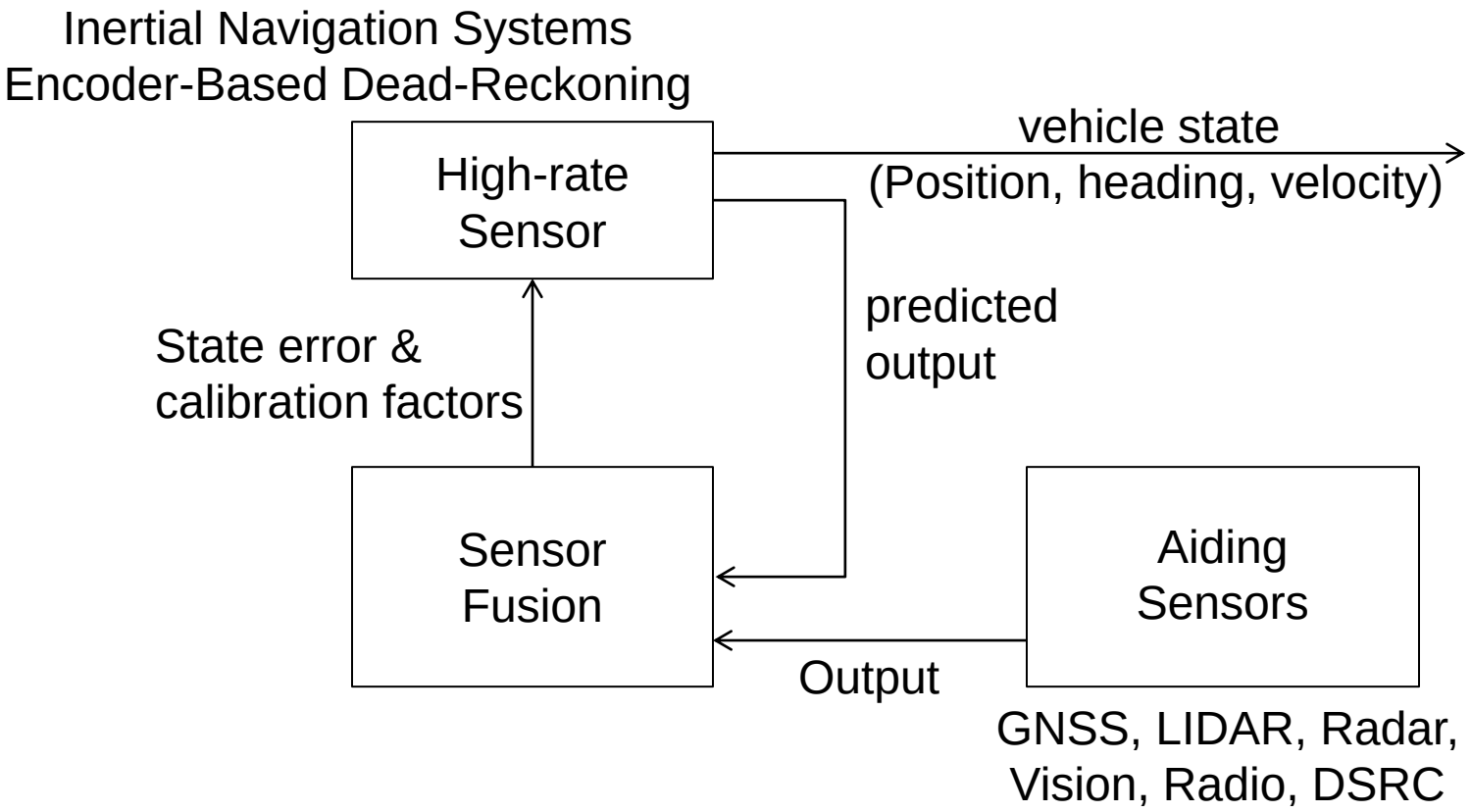
Aiding Technologies, Performance, and Implementation Characteristics

Aiding Sensor	Mounting Orientation	Aiding Rate	Processing Latency	Positional Accuracy in Demonstration	State Components Corrects	Measured feature or Signal
LIDAR	Side	1 Hz	<10ms	<1cm	Position perpendicular to wall, yaw	Wall
Radar	Forward	1 Hz	50ms	<.5m	Full horizontal position, Yaw	Pole, Sign, reflector
Vision	Forward	1 Hz	200ms	Using a single feature, lateral error is less than 1 meter	Position perpendicular to camera-to-feature LOS	Signs, Signals
Radio	Omnidirectional	1 Hz	500ms	30m	Positional along signal path	AM
DSRC	Omnidirectional	1 Hz	500ms	12m	Positional along signal path	RSU

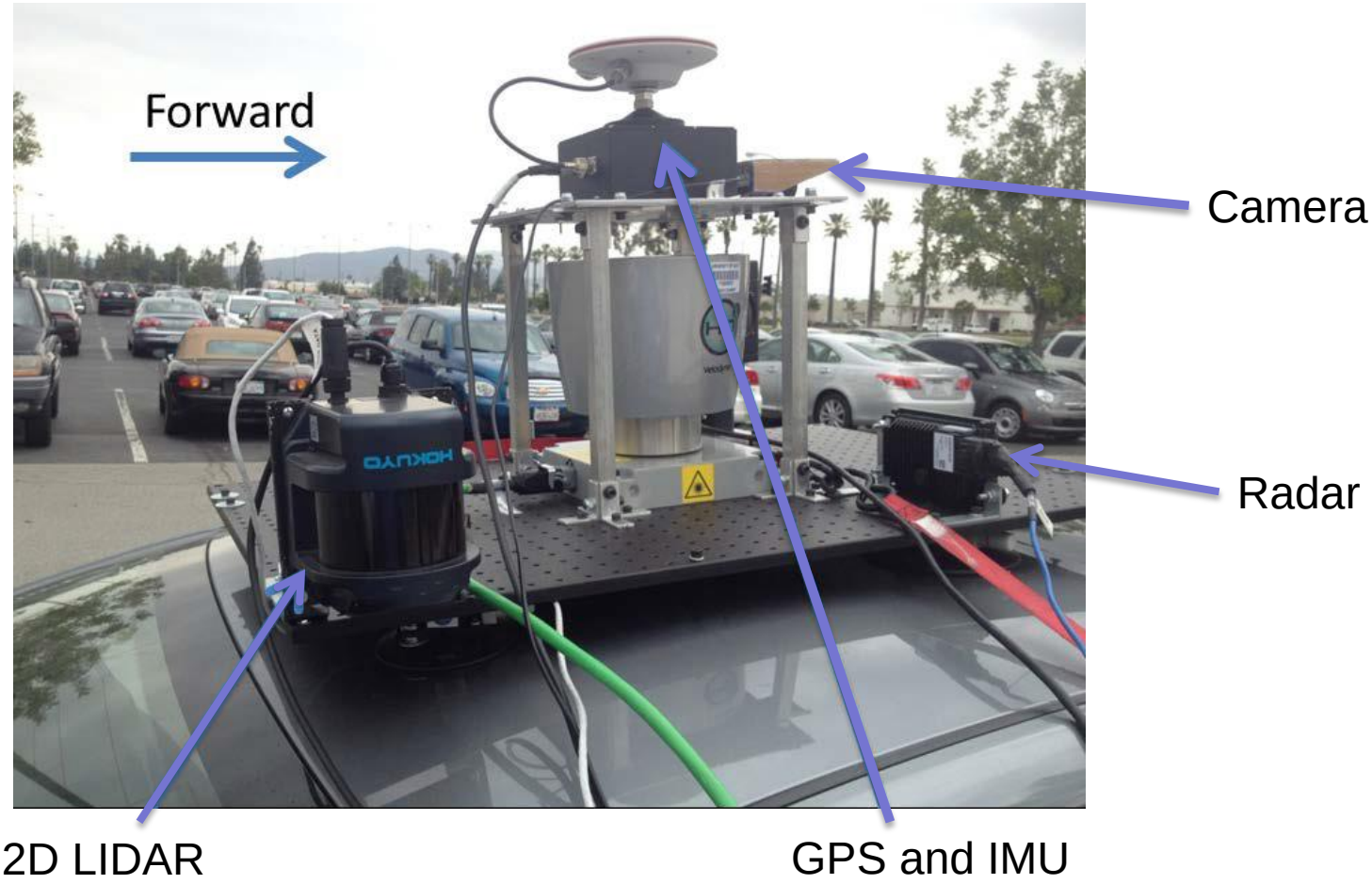
Limitations

- No single sensor technology satisfies all the requirements in terms of positioning accuracy, availability, and continuity in diverse driving environments.
  - LIDAR – a relative positioning technique
    - Infrastructure reference data is not always available
    - Requires accurate mapping – expensive to create and maintain
  - Radar – a relative positioning technique
    - Infrastructure reference data is not always available
    - Requires accurate mapping – expensive to create and maintain
  - Vision – a relative positioning technique
    - Infrastructure reference data is not always available
    - Requires accurate mapping – expensive to create and maintain
  - Radio
    - Accuracy insufficient for lane level positioning
  - DSRC
    - Limited infrastructure

Integration is the Key!



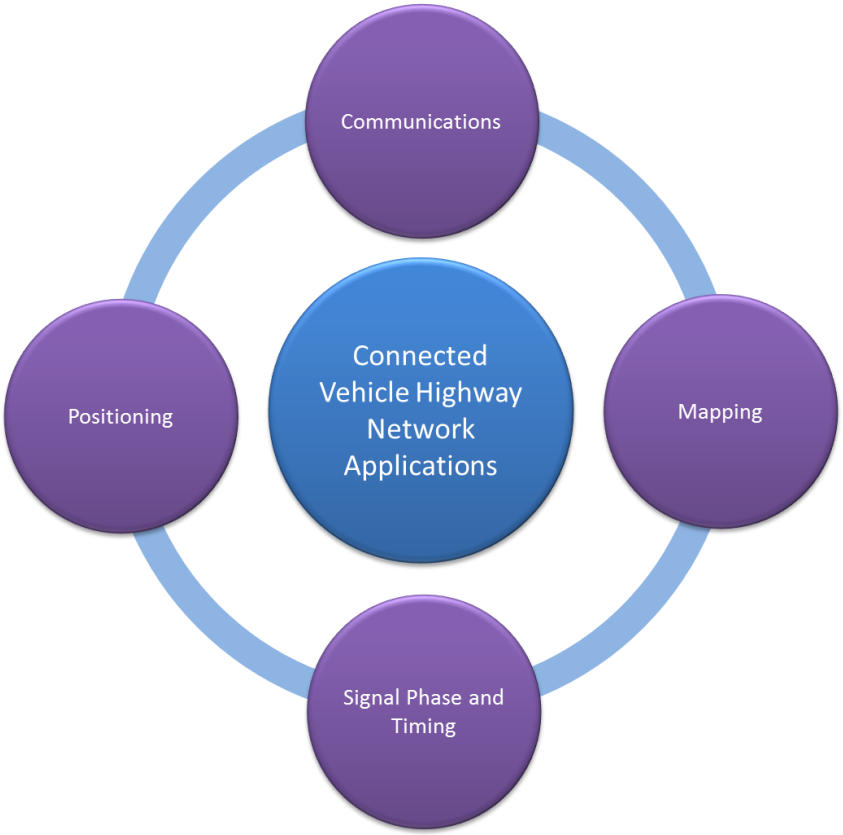
Experimental Configuration



Phase III – Mapping

Using What we Learned – Signal Phase and Timing (SPaT)

- Connected vehicle applications will utilize **mapping**, **positioning**, **communications** including interaction with roadside equipment as well as **Signal Phase and Timing (SPaT)** technology to provide information on the location of vehicles in relation to the roadway, other vehicles, and pedestrians.
- Mapping can refine the position of each connected vehicle and provide a context for the interaction between the connected vehicles and the roadway environment especially for SPaT applications.
- USDOT is working to identify the positioning, communication, and mapping requirements relevant to connected vehicle applications as well as the specific technologies for addressing these needs.



Example – Lane Departure Warning

Reports:

- EAR Web Page:
  - https://www.fhwa.dot.gov/advancedresearch/
- Topic Overview/Research Conference:
  - Vehicle Positioning, Navigation, and Timing: Leveraging Results From EAR Program-Sponsored Research
  - http://www.fhwa.dot.gov/advancedresearch/pubs/13052/index.cfm
- Final report
  - Innovative Approaches for Next Generation Vehicle Positioning
  - Not Yet Published

Summary

- No single independent sensor technology is capable of simultaneously attaining accuracy, integrity, and availability specifications required for lane level positioning in the expected diversity of vehicle environments.
- Differential GNSS can provide good performance in open areas where satellite signals are available but has degraded performance in dense urban areas
- Inertial Navigation Systems and Encoder Navigation Systems can provide solutions in all environments but their accuracy deteriorates over time.
- Feature-based navigation can be successful only if there are sufficient mapped features
- DSRC and ground based radio communication systems offer useful information for determination of vehicle position and can be influenced by the engineering community interested in roadway applications.