Precise GNSS & V2X for Automated Vehicles

PNT Advisory Board
6 June 2019

Curtis Hay
Technical Fellow
GNSS, V2X & Maps
General Motors

OUR VISION

At General Motors, we envision a future with zero crashes, zero emissions and zero congestion:

Zero crashes to save lives

Each year close to 1.25 million people die in car crashes around the world, 40,000 in the United States alone. More than 2 million people are injured. Human error is a major contributing factor in 94 percent of these crashes.

Zero emissions to leave our children a healthier planet

Vehicles release almost 2 billion tons of carbon dioxide into the atmosphere every year.

Zero congestion to give our customers back their precious time

In the United States, commuters spend about a week of their lives in traffic each and every year. That's a week not spent with those we love, doing what we want to do and being where we want to be.

GM Super Cruise

Cadillac CT6 with Super Cruise

- Internal combustion engine
- Industry's first true hands-free driving technology for the freeway
- Retail Availability: Q4 2017
- Standard on CT6 Platinum,
  Optional Feature on CT6 Premium
- Becoming available on all Cadillac models, rollout starting 2020. Other GM brands to follow
- 0-85 mph on precisely mapped interstate highways
- Driver attention required!
- Precise map (+/- 10 cm 95%)
- Precise GNSS (median 90 cm)

Super Cruise Video

Precise GNSS Localization

Today:

- GPS L1 C/A, GLONASS G1
- Tightly coupled sensor fusion (MEMS yaw_rate gyro, differential wheel odometry)
- Low cost L1 antenna
- Real-time PPP/RTK corrections (Trimble RTX)
- 10-Hz update rate
- 1.8 meter horizontal accuracy (95%) on highways

Future:

- GPS L1/L5, Galileo e5a, GLONASS G1, Beidou
- Low cost multi-frequency, multi-constellation automotive antenna
- Improved Trimble RTX
- 100+ state Kalman Filter for camera feature points, IMU, GNSS, wheel odometry
- 20-Hz update rate
- 50-cm horizontal accuracy (95%) on all mapped roads

Why is Precise GNSS Required for Automated Vehicles?

Automated Vehicle Sensor Characteristics

	Sensor	*Pros*	*Cons*
Perception Vehicle Reference Frame	Radar	**Relatively Low Cost** **Good Ranging Accuracy**	**Cannot Detect Road Markings**
	Lidar	**Highly Accurate Ranging**	**Higher Cost** **Less Effective in Featureless Areas**
	Camera	**Lower Cost** **Good Object Detection**	**Less Effective in Featureless Areas** **Less Effective in Snow, Darkness**
Absolute Localization Global Reference Frame	HD Map	**Excellent Accuracy (< 10 cm 95%)**	**Requires Continuous Updates** **High Maintenance Costs**
	Motion Sensors (Gyro, Accel, Wheel Ticks)	**Lower Cost**	**High Drift Rate for MEMS Sensors**
	GNSS (GPS, GLONASS, Galileo, Beidou)	**Lower Cost** **Global Availability** **Common Reference Between Vehicles**	**Poor Performance in Urban Areas, Tunnels**

Precise GNSS (Sub-Meter) Provides these Benefits

- Same Reference Datum as HD Map– complimentary data
- Common Reference Datum between Adjacent Vehicles (V2V)
- Redundancy
    - Mitigate limitations with perception sensors
- Road Class Identification (referenced with map)
    - Interstate, state, county, pavement type, etc.
- Lane Identification
    - Especially important for lane change maneuvers, entering/exiting highway, turning at intersections, V2V
- Higher quality, lower cost HD map crowd-sourcing

GNSS cannot be used exclusively for localization!
Must be combined with perception, IMU, map!

Essential GNSS Technologies for Automated Vehicles

GNSS Corrections (Trimble RTX for Super Cruise)

- *Low rate (< 2 kbps)– minimize data costs*
- *Delivered through satellite L-band or mobile IP*
- *Clock, orbit, ionosphere, troposphere state corrections*
- *Required for confident lane identification and sensor redundancy*

Dual Frequency, Multi-Constellation

- *GPS L5 has better signal structure, fewer satellites*
- *Galileo E5a CDMA preferred over GLONASS FDMA*
- *Requires high volume, low cost antenna*
- *GNSS industry already far along with high accuracy, lower cost products*

Multi-Axis Gyro/Accelerometer IMU

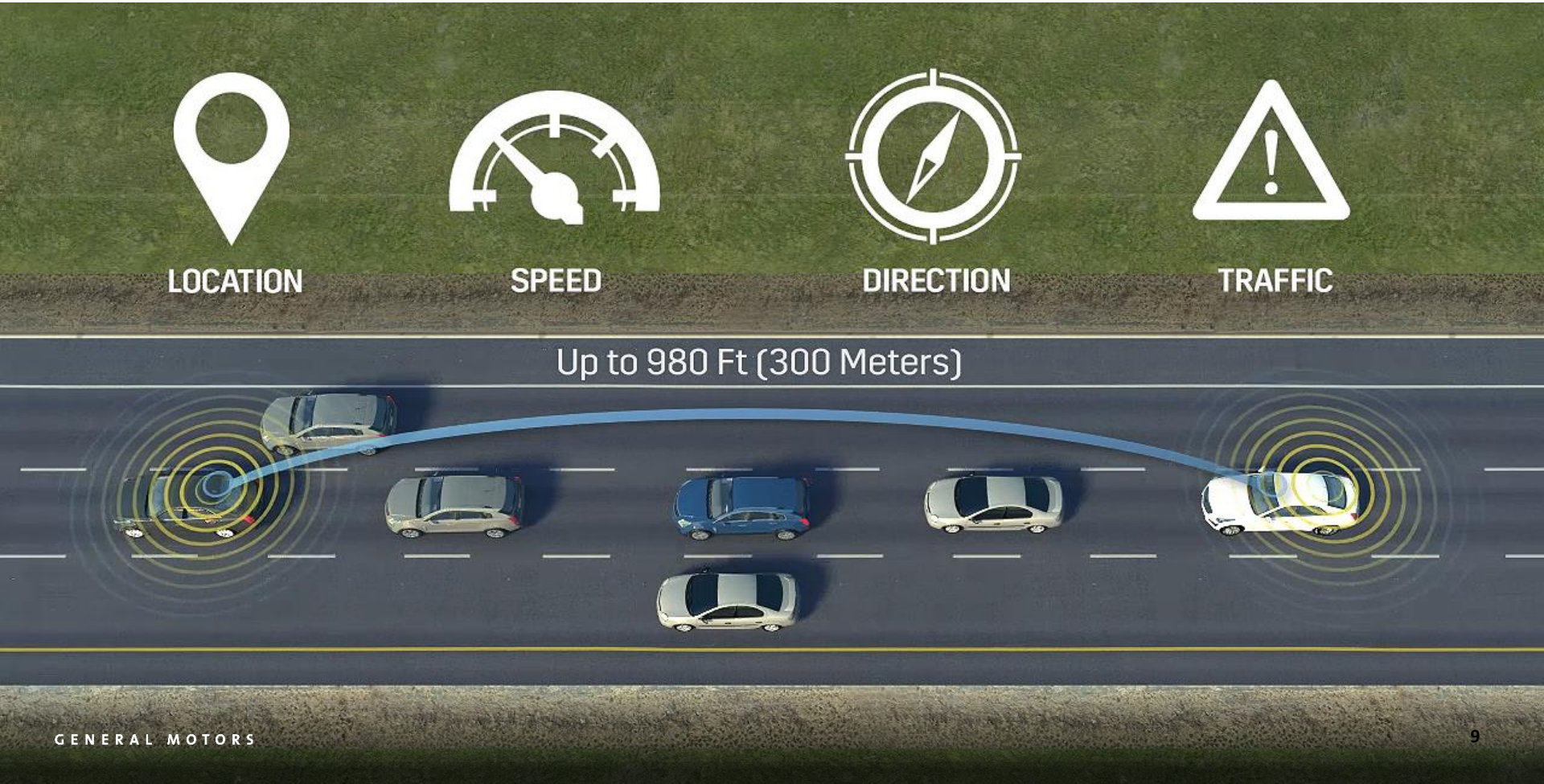
- *Low Bias Drift Rate, Low Angular Random Walk*
- *Yaw more important than Roll/Pitch!*

GNSS Integrity Monitoring is Critical

Also… Cellular Connectivity!

- *Precise Map Updates, GNSS Corrections & HD Map Crowd Sourcing*
- *Live advisor services (OnStar)*
- *Remote diagnostics*

V2X COMMUNICATIONS



Summary

No Perfect Sensor for Automated Vehicles– All have limitations

- *Relative perception (Lidar, Camera, Radar) must be complemented by Absolute (GNSS, IMU, Map)*

Sub-Meter GNSS Supports many AV Use Cases!

- *Lane Identification*
- *Road Classification*
- *HD Map Development and Maintenance*
- *V2X*

GNSS Integrity Monitoring is Critical

******

Despite uncertainty with radio technology and lack of federal mandate–

V2X continues to offer great potential for automotive safety and automated vehicles