



# FMCW AS THE END STATE:

Exploring The Perception Advantages Of Per-Point Instant Velocity Data

# James Reuther

Vice President of Technology, Aeva



PASSENGER VEHICLES



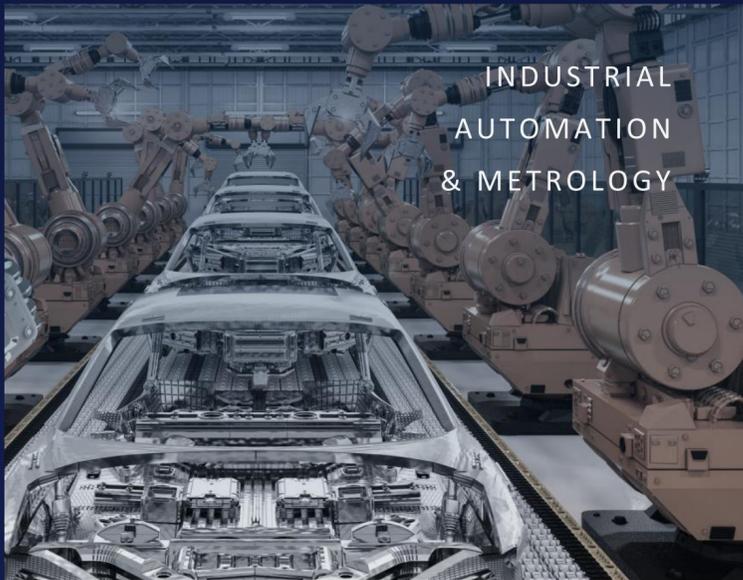
TRUCKING



MOBILITY



INDUSTRIAL  
AUTOMATION  
& METROLOGY



CONSUMER  
TECHNOLOGY



CONSUMER  
HEALTH



SMART  
INFRASTRUCTURE



# Our Mission: Perception For Everything



# Incorporates All Key LiDAR Elements Into a Compact Fiberless Module

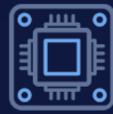
- Integrated Range Finder Module
- Hermetically Sealed For High Reliability
- High-Precision Automated Assembly
- Built on Silicon Photonics Technology



# The Next Generation of Sensing and Perception



AUTOMOTIVE  
GRADE



LIDAR ON CHIP



INSTANT VELOCITY  
DETECTION



COMPACT  
DESIGN



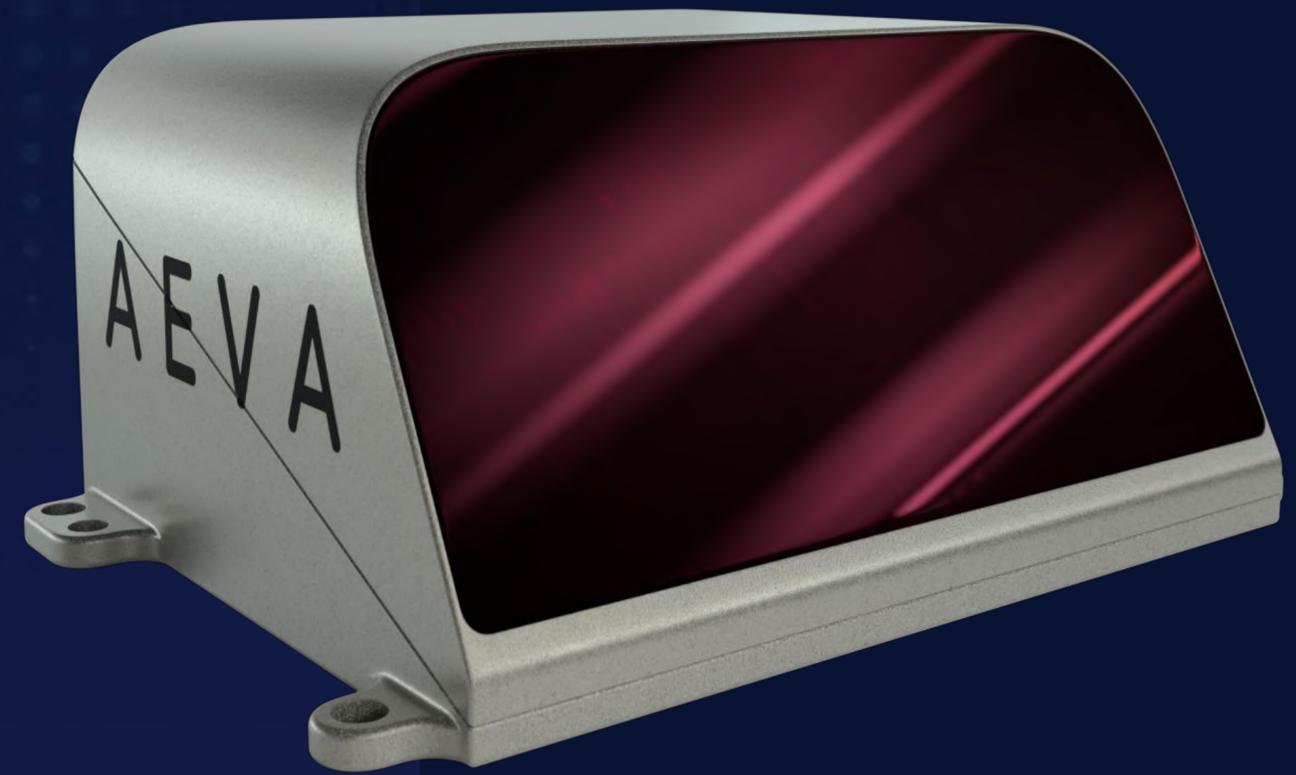
MULTIPLE  
FOVS



FREE FROM ALL  
INTERFERENCE



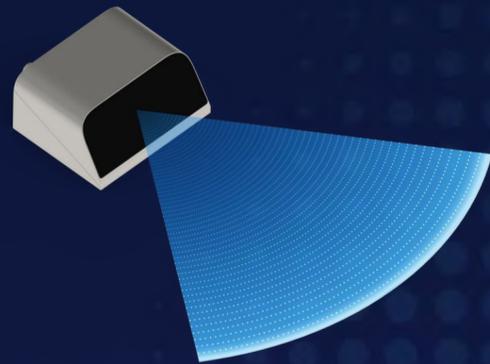
ULTRA LONG  
RANGE



# Unique Benefits of FMCW Technology

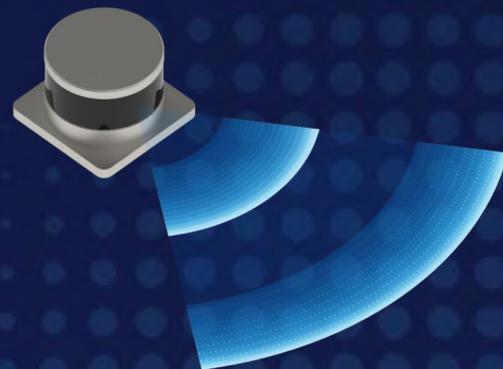
## Aeva 4D LiDAR

Frequency Modulated  
Continuous Wave



## Legacy 3D LiDAR

Time of Flight



## Superior Perception Capabilities

### Interference Immunity

- Immune to sunlight
- Immune to all other LiDAR sensors

### Clear Vision

- No retroreflective blooming or ghosting
- Greater visibility in fog, rain, snow and dust

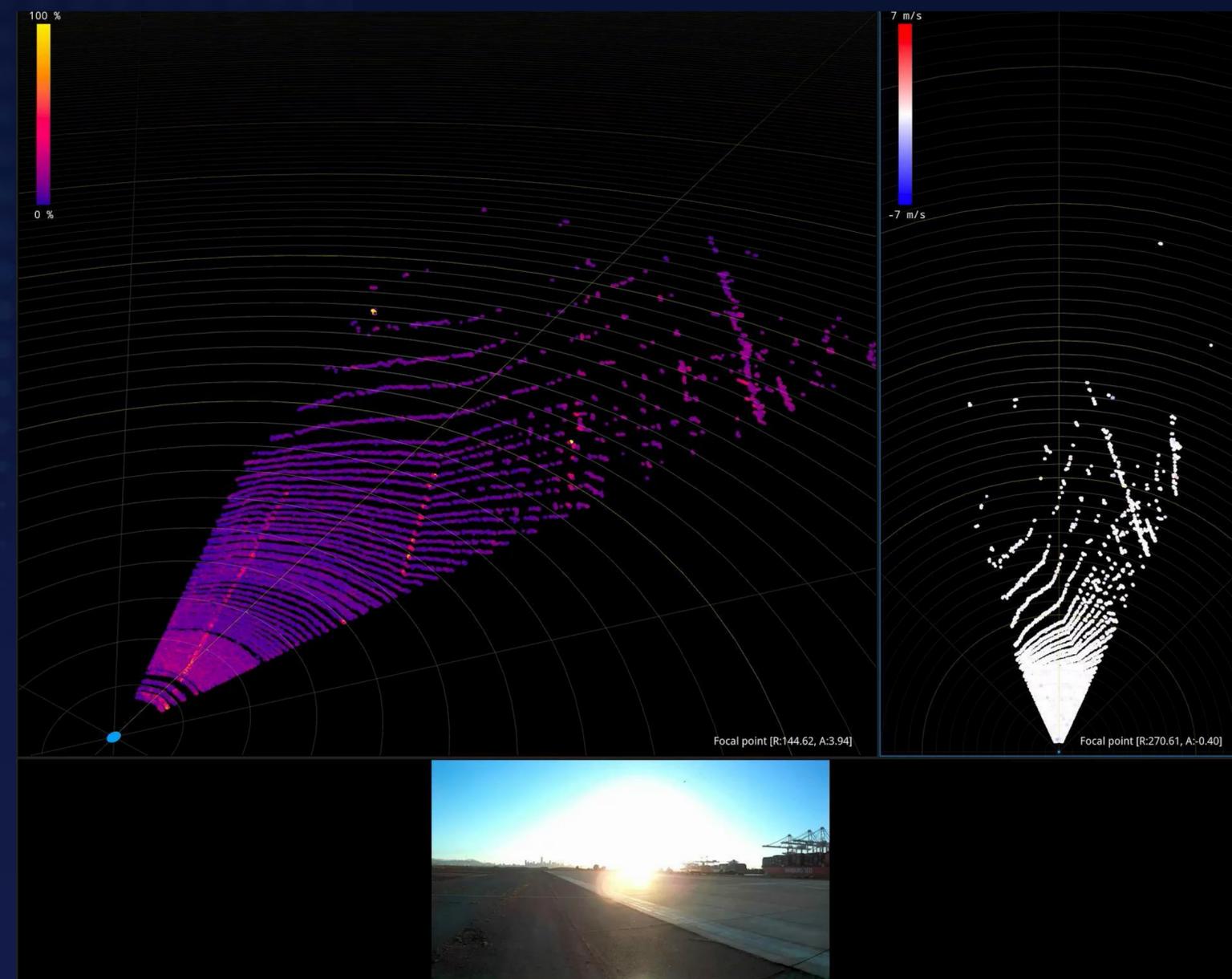
### Simultaneous Range and Velocity

- Instant velocity detection plus 3D position and reflectivity

# Immunity from Direct Sun Interference

FMCW Coherent Detection Provides Complete Interference Immunity from Direct Sunlight

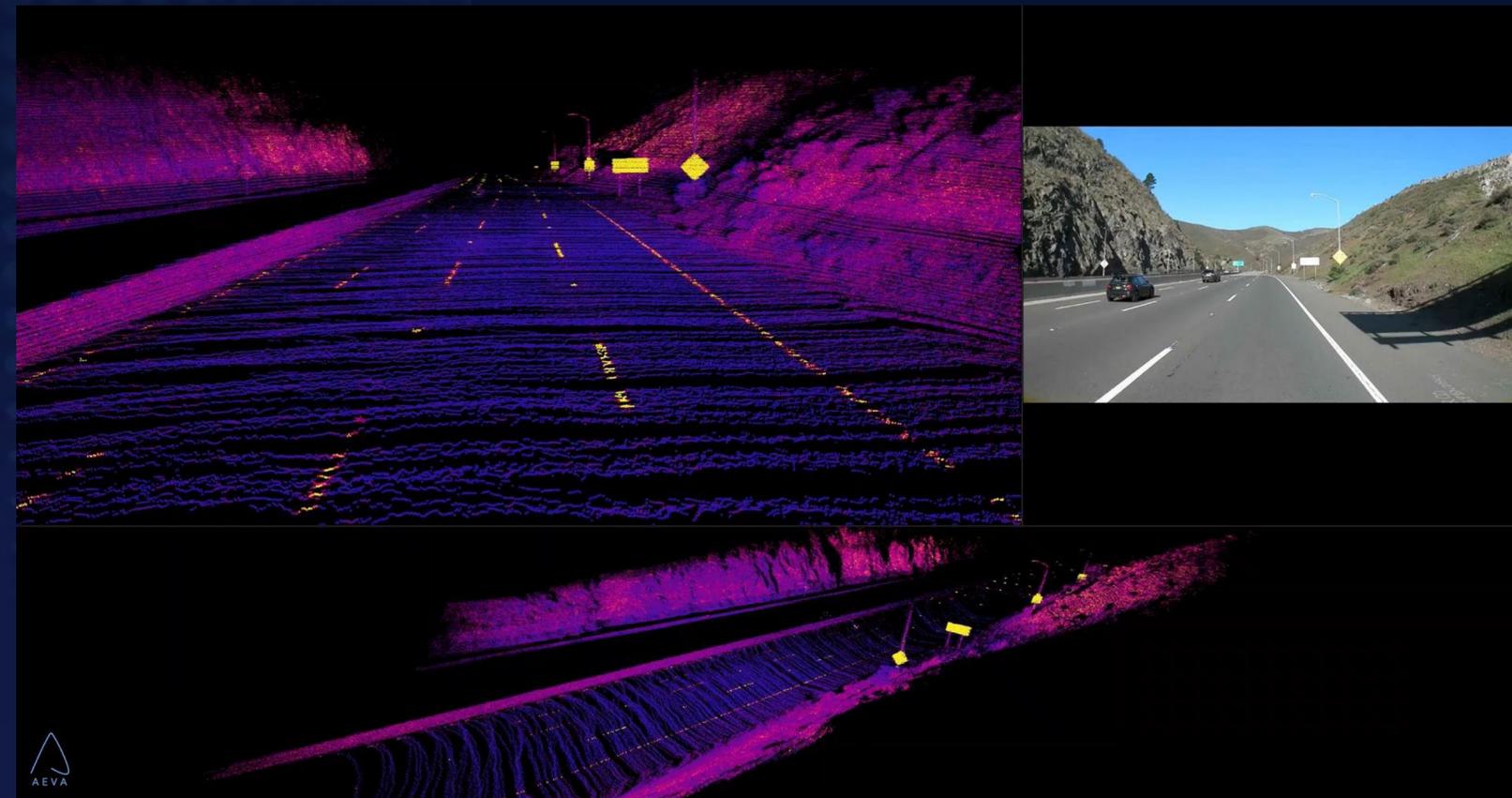
- FMCW LiDARs are inherently immune to ambient light, even direct sunlight
- No degradation in detection or tracking performance and no artifacts due to the sun



# No Blooming or Ghosting on Retros

FMCW LiDAR with High Dynamic Range & Low Cross Talk

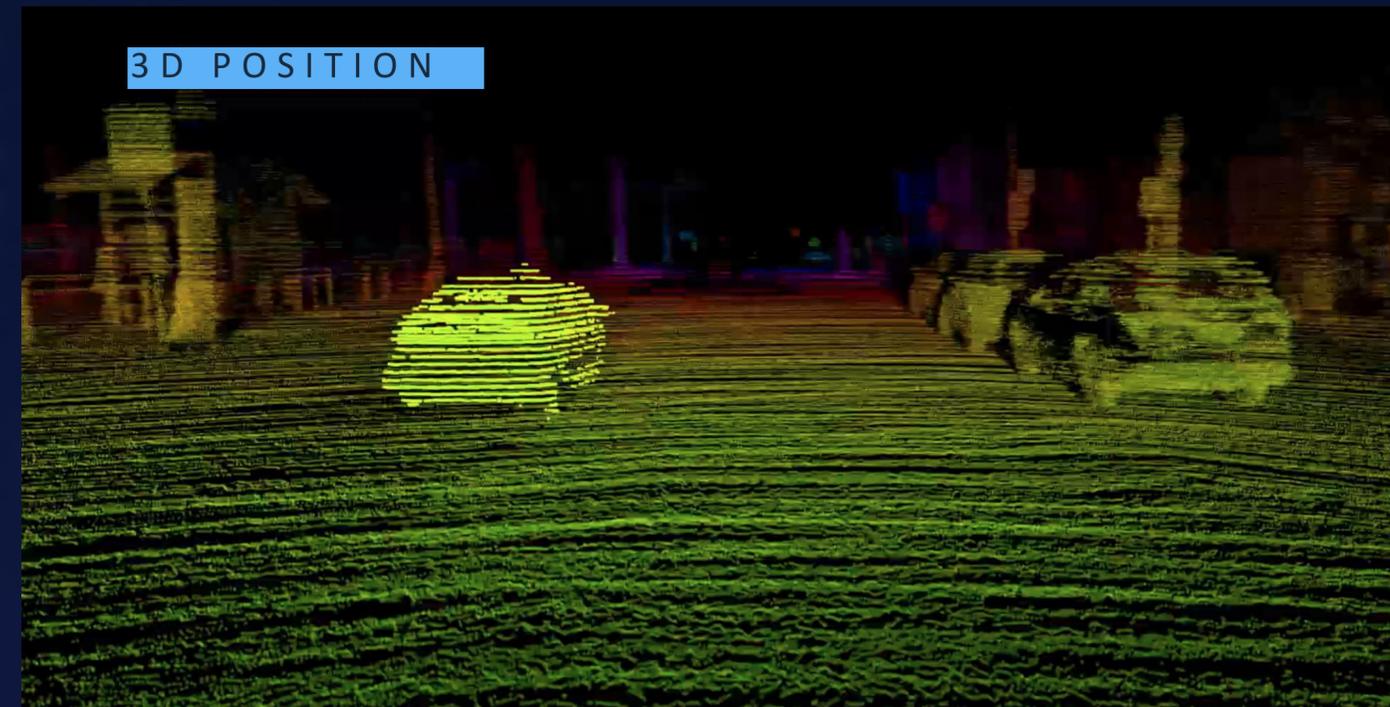
- FMCW LiDARs have high dynamic range and low cross talk between channels
- No blooming or ghosting; Crisp clean edges

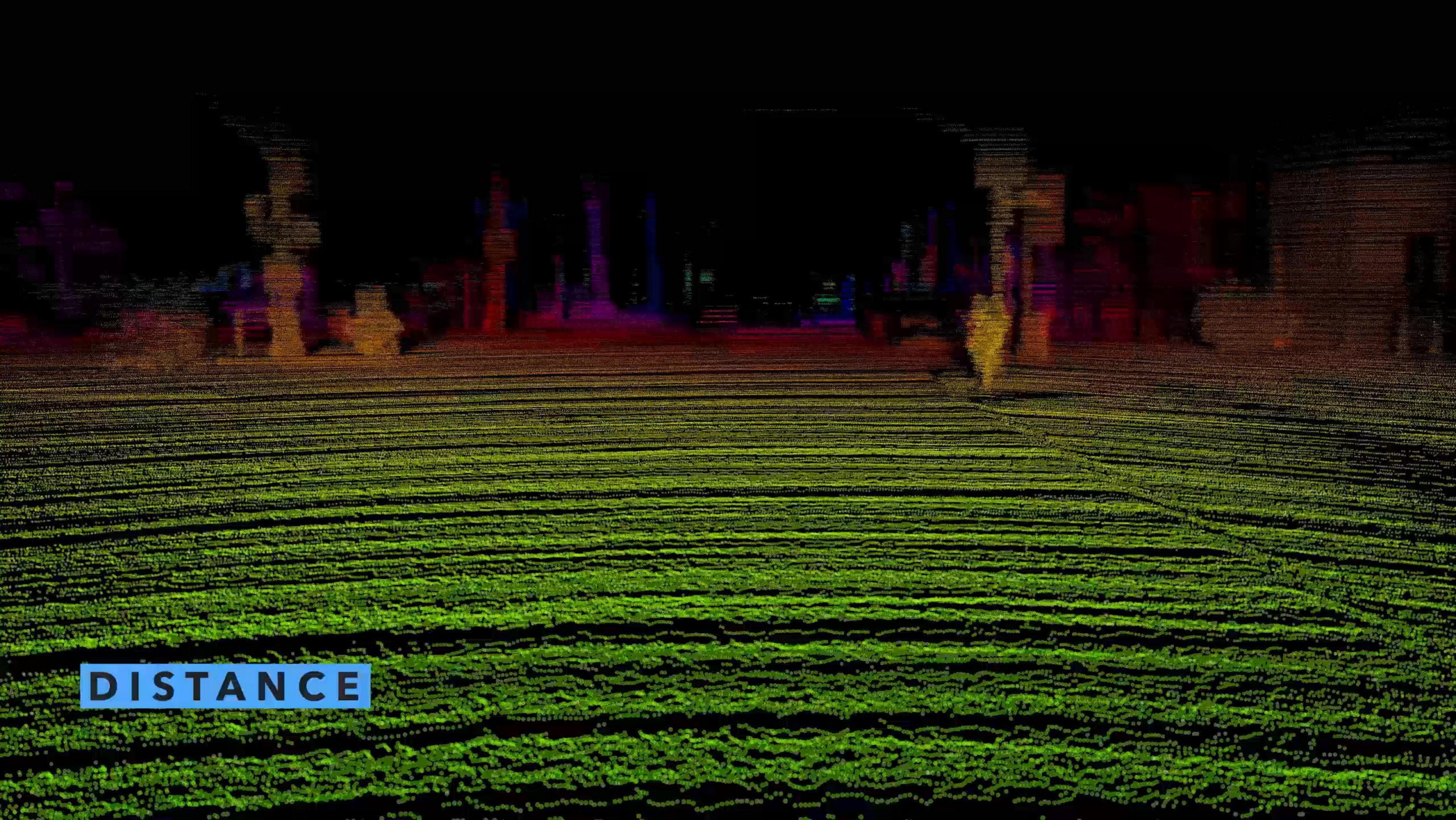


# Direct Velocity Detection

## FMCW LiDAR Adds a Fourth Dimension of Velocity

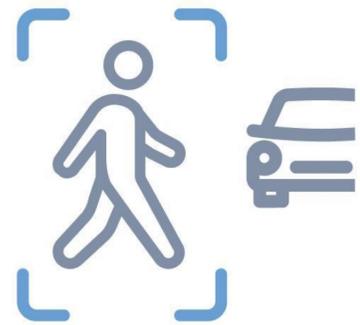
- Doppler Effect provides high-precision velocity data for every point, in addition to 3D position
- Measures velocity directly versus inferring it over time



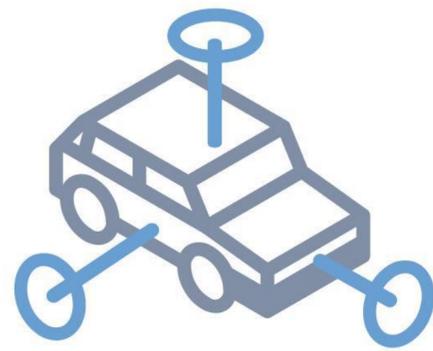


**DISTANCE**

# Perception Advantages Enabled By Per Point Instantaneous Velocity



Long-Range Object  
Detection and Tracking

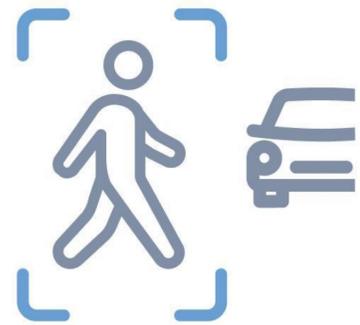


4D Localization

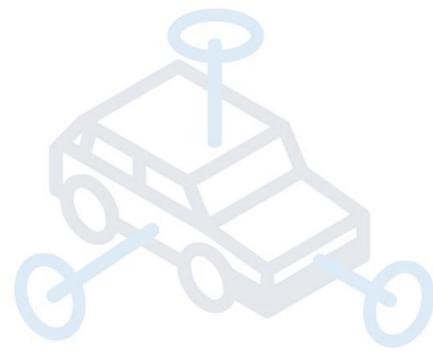


Ultra Resolution Perception

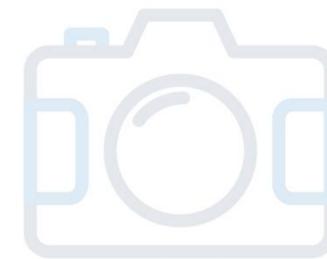
# Perception Advantages Enabled By Per Point Instantaneous Velocity



Long-Range Object  
Detection and Tracking

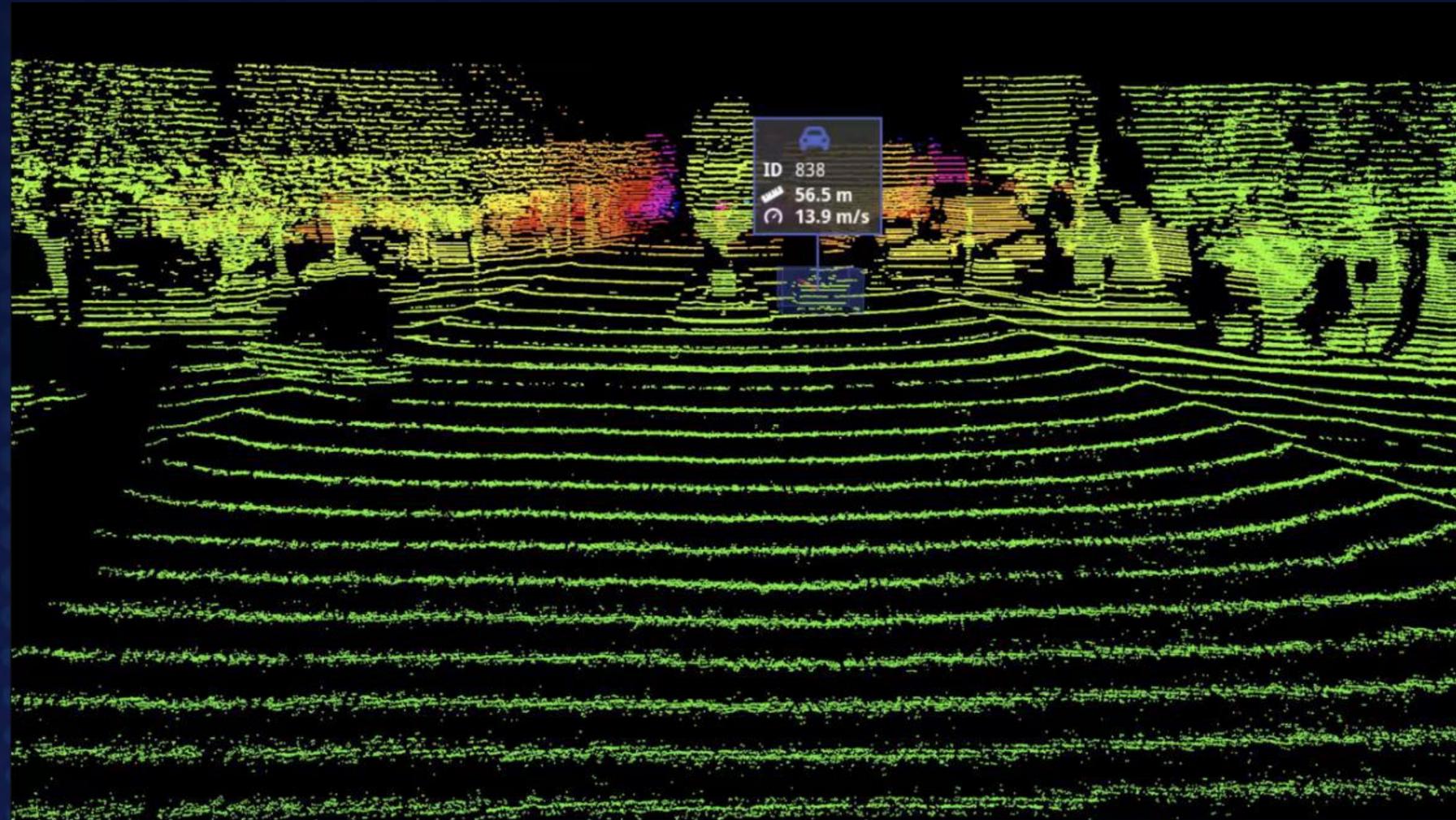


4D Localization



Ultra Resolution Perception

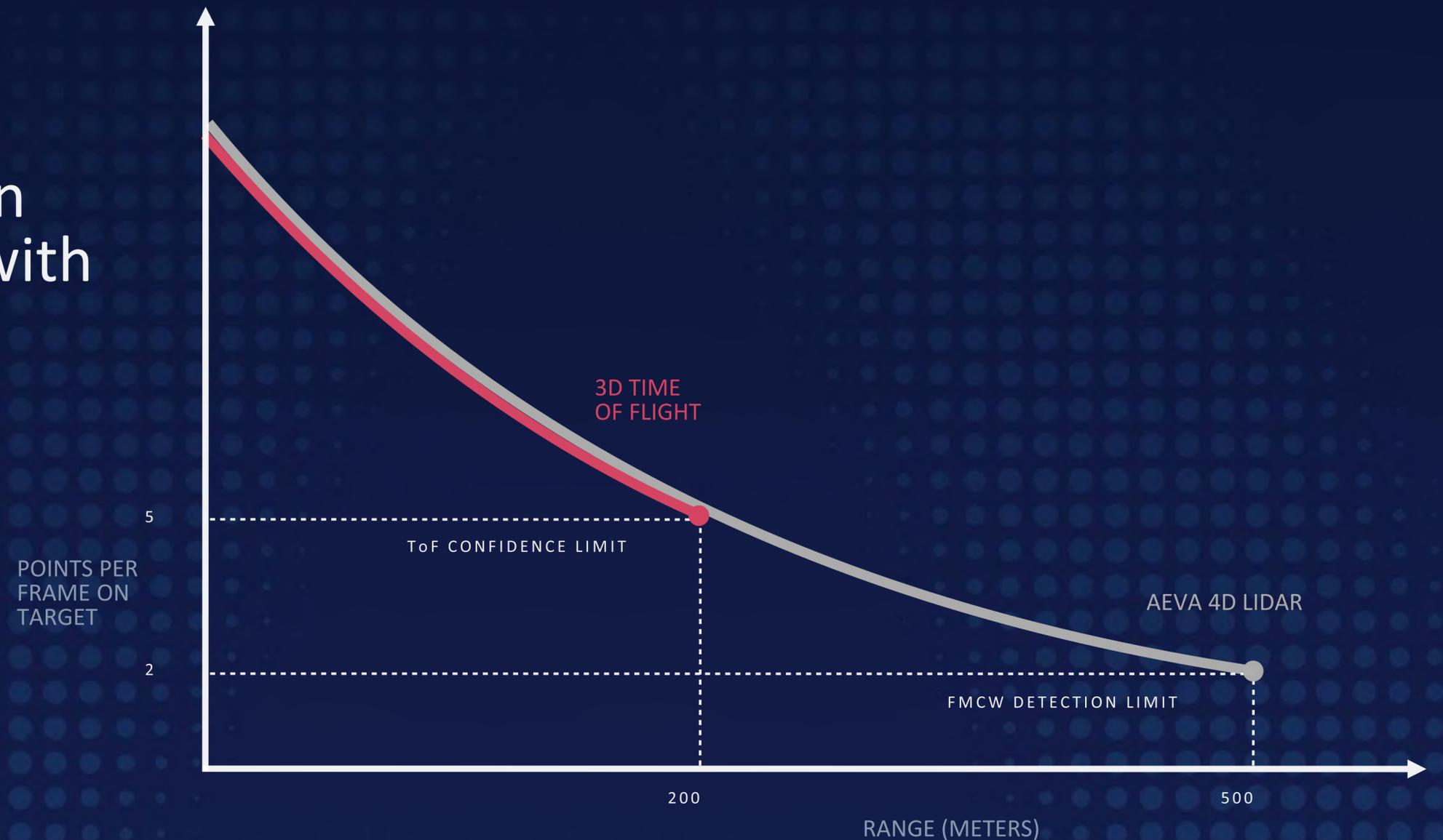
# Detect, Classify and Track Dynamic Objects Up to 500 Meters Away

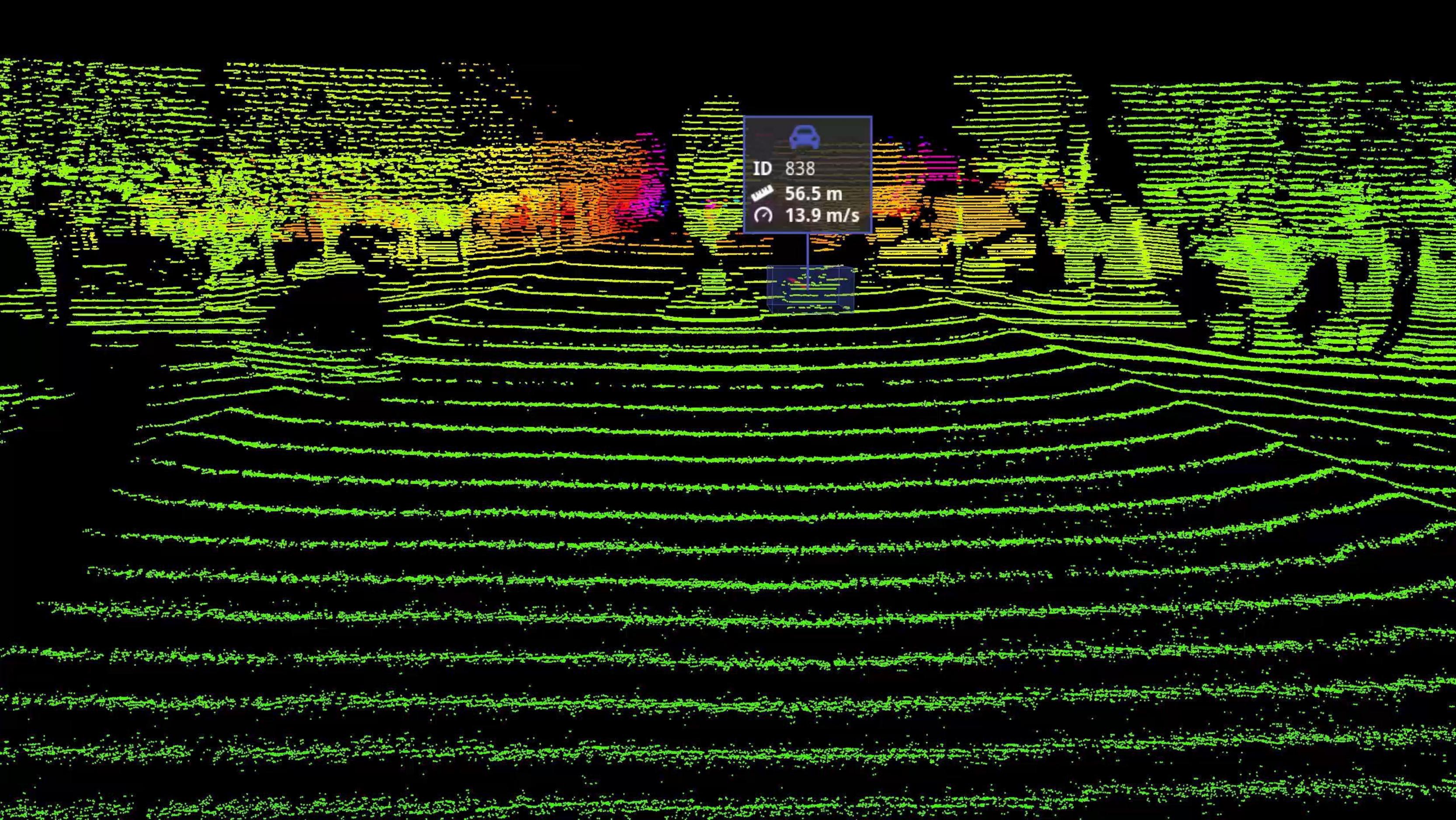


# Long Range Object Detection and Tracking

FMCW offers greater detection distance for dynamic objects with less resolution

- Over 2x detection range
- 2 points needed for FMCW
- 5 points needed for ToF

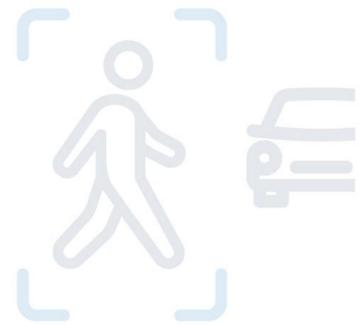




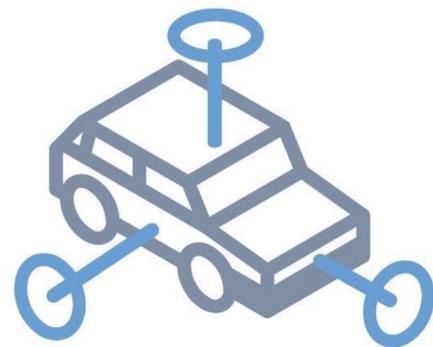
  
ID 838  
 56.5 m  
 13.9 m/s



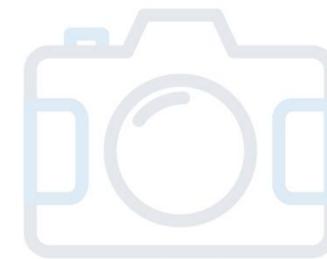
# Perception Advantages Enabled By Per Point Instantaneous Velocity



Long-Range Object  
Detection and Tracking

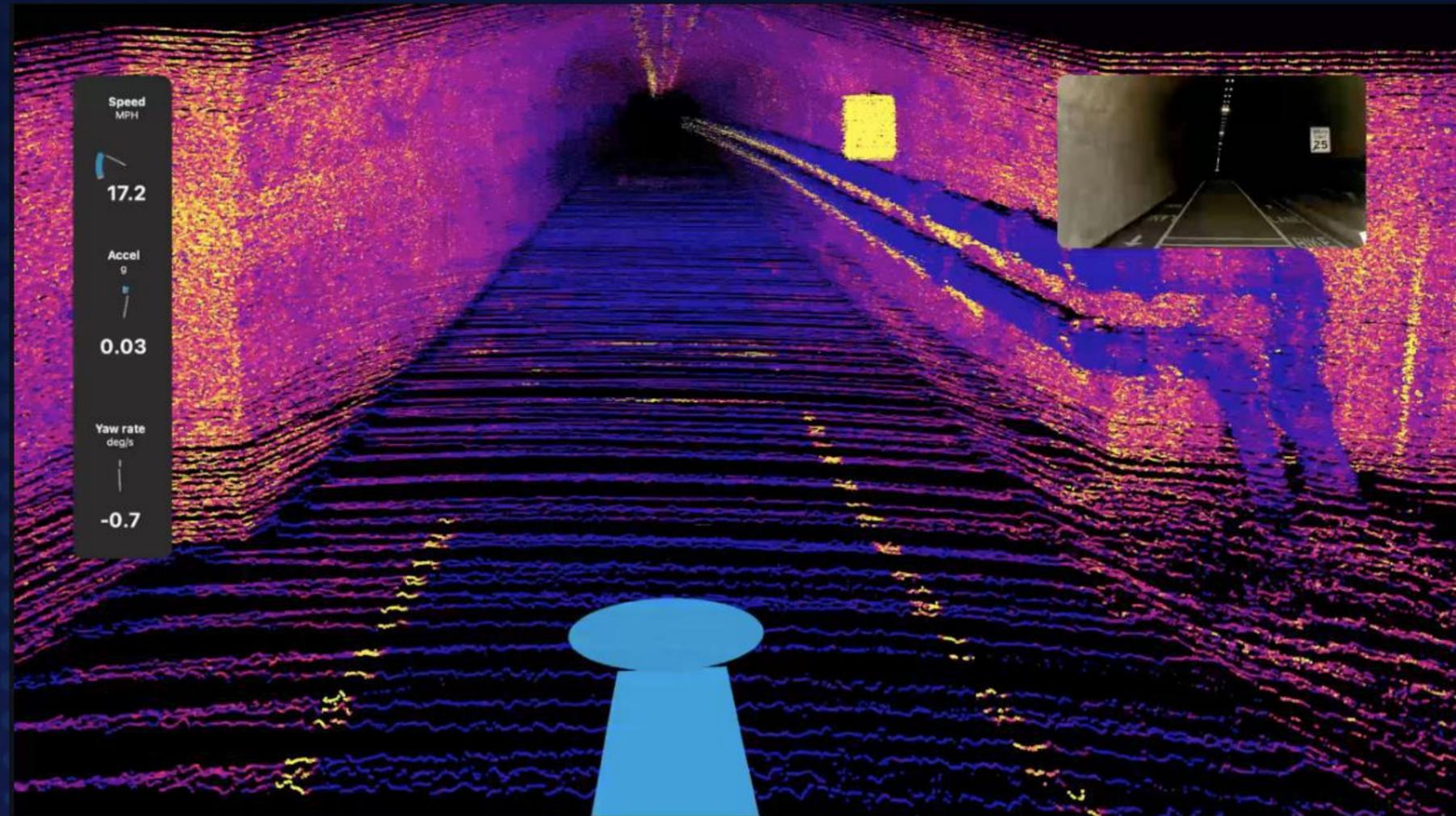


4D Localization



Ultra Resolution Perception

# Real-time Vehicle State Estimation With 6 DoF And Motion Compensation



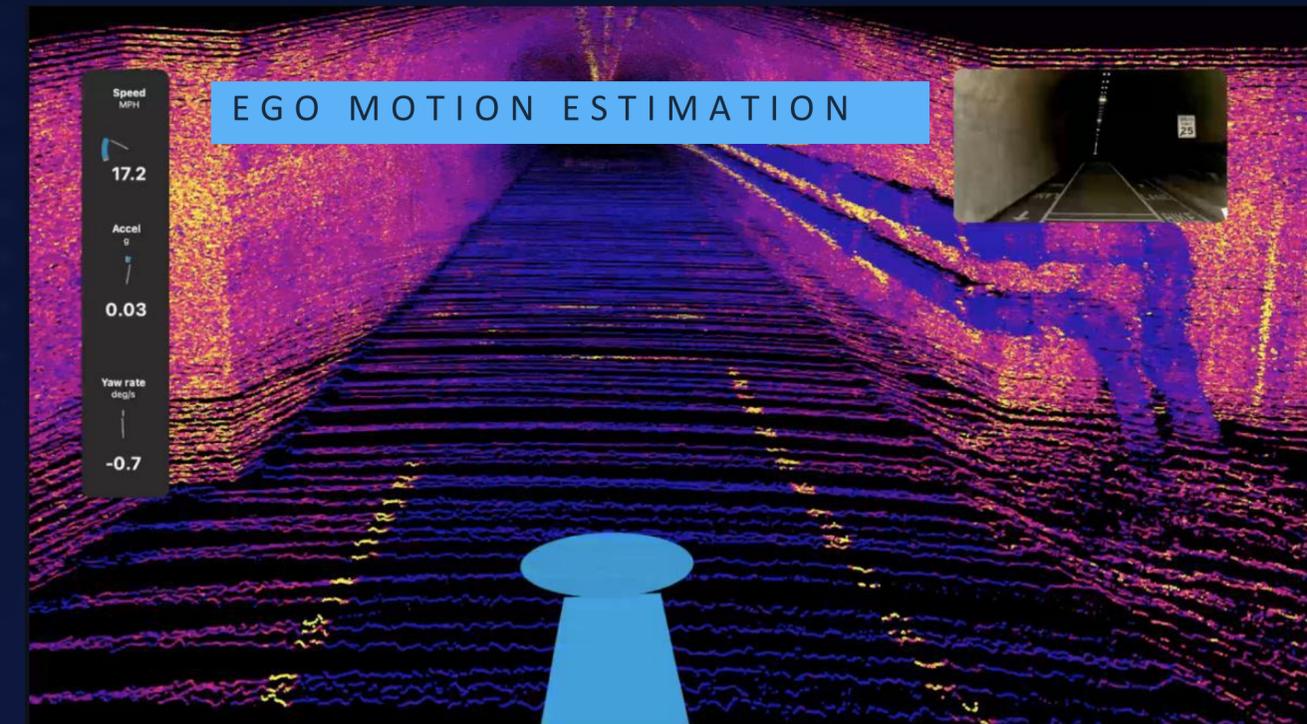
# Allows autonomous navigation in GPS-denied and featureless environments like tunnels

### Ego-motion Estimation

- Enhanced ego-motion estimation with six degrees of freedom (w/o external sensor inputs)
- Accurate vehicle positioning and navigation without the need for additional sensors, like IMU or GPS

### Motion Tracking & Motion Compensation

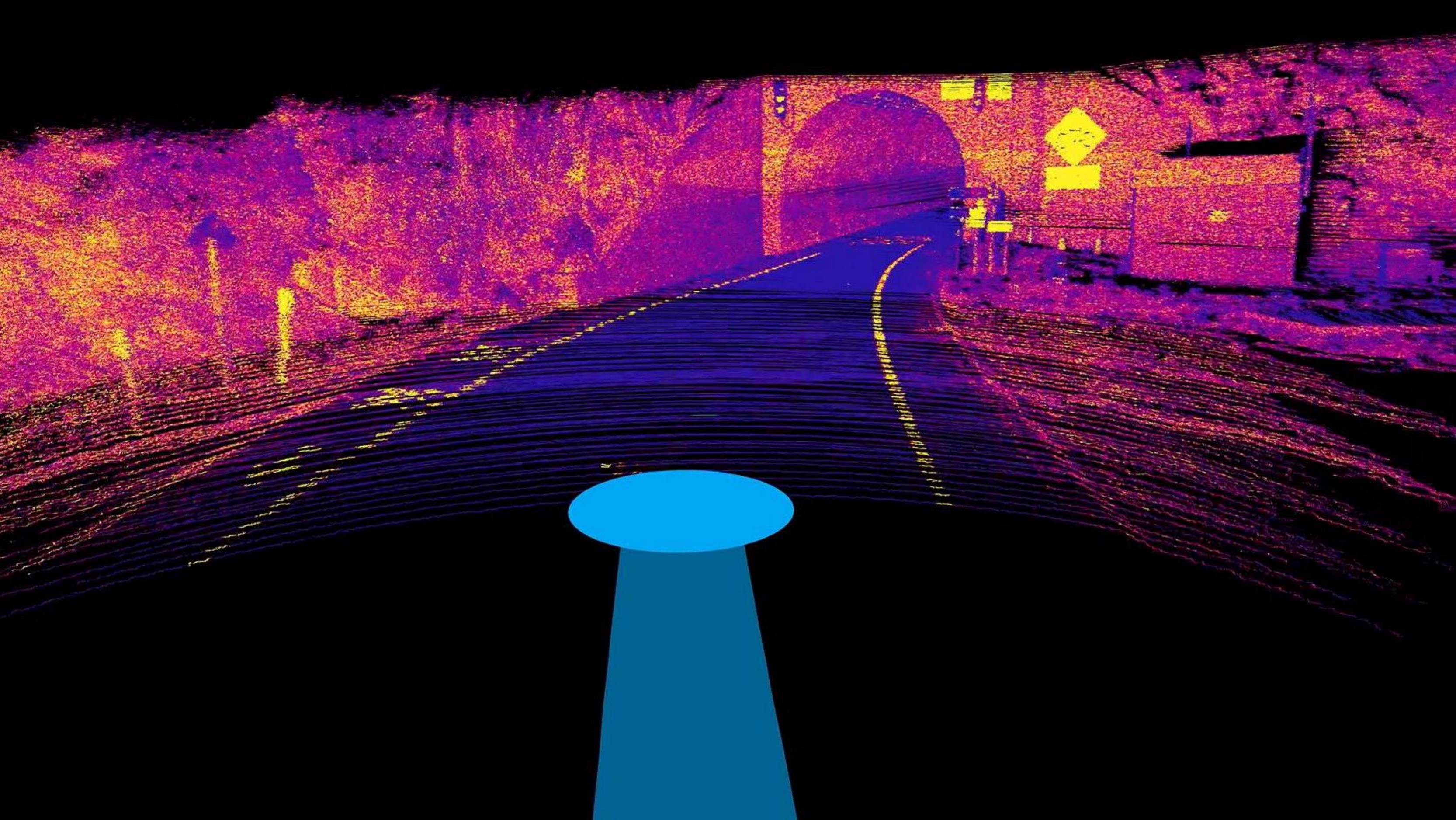
- Odometry, position and pose over time
- Motion compensation within frame (eg. rolling-shutter effect)
- Enables automatic sensor extrinsic calibration



# Rolling Shutter Artifact Compensation

- Progressive scanning through the scene, aka “Rolling shutter” causes dynamic objects to deform or “tear”
- Using velocity based ego motion estimation, rolling shutter is fully compensated





# FMCW for Mapping and Navigation on the Moon

Space Tech

Apr 20, 2022



## NASA, Partners Develop 'Lunar Backpack' Technology to Aid New Moon Explorers

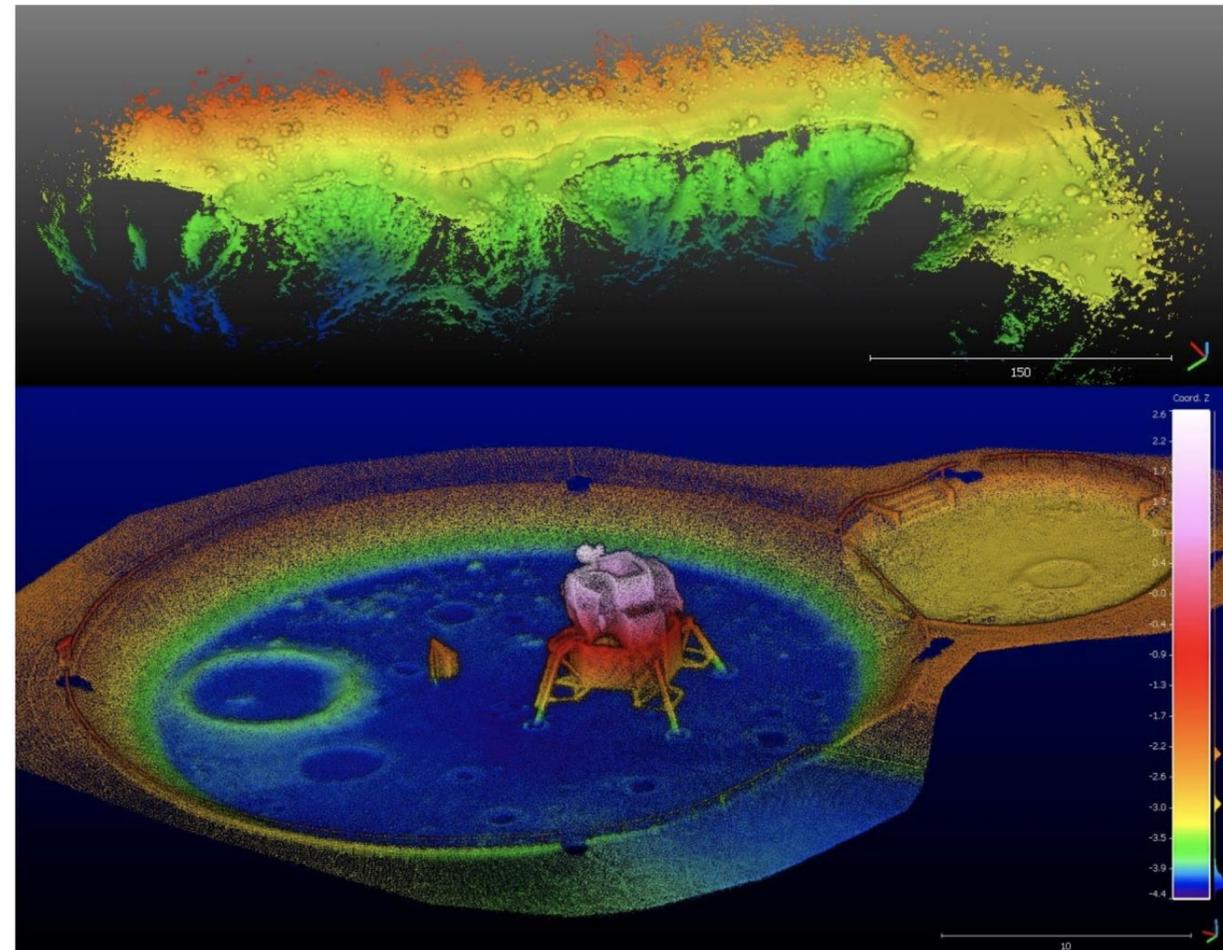
Imagine a mountaineering expedition in a wholly uncharted environment, where the hikers had the ability to generate a real-time 3D map of the terrain. NASA researchers and their industry partners have developed a remote-sensing mapping system set to aid explorers in the most isolated wilderness imaginable: the airless wastes at the South Pole of the Moon.

The Kinematic Navigation and Cartography Knapsack (KNaCK) is a mobile lidar scanner – a remote sensing method that uses light detection and ranging laser light to measure range. Donned like a hiker's backpack, it makes use of an innovative type of lidar called frequency modulated continuous wave (FMCW) lidar in order to provide Doppler velocity and range for millions of measurement points per second. These measurement points instantly create a real-time navigation system, delivering to the explorer a 3D "point cloud" or high-resolution map of the surrounding terrain.

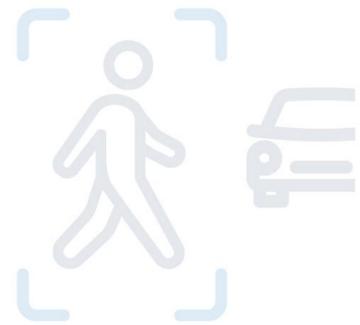


## Aeva and NASA want to map the moon with lidar-powered KNaCK pack

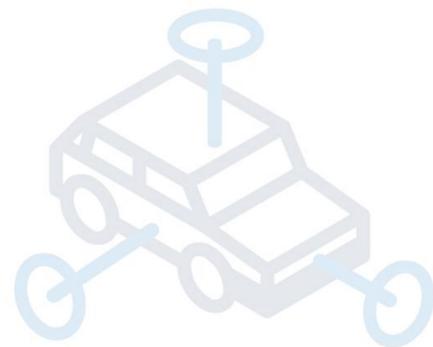
Devin Coldewey @techcrunch / 4:02 AM PDT • April 21, 2022



# Perception Advantages Enabled By Per Point Instantaneous Velocity



Long-Range Object  
Detection and Tracking

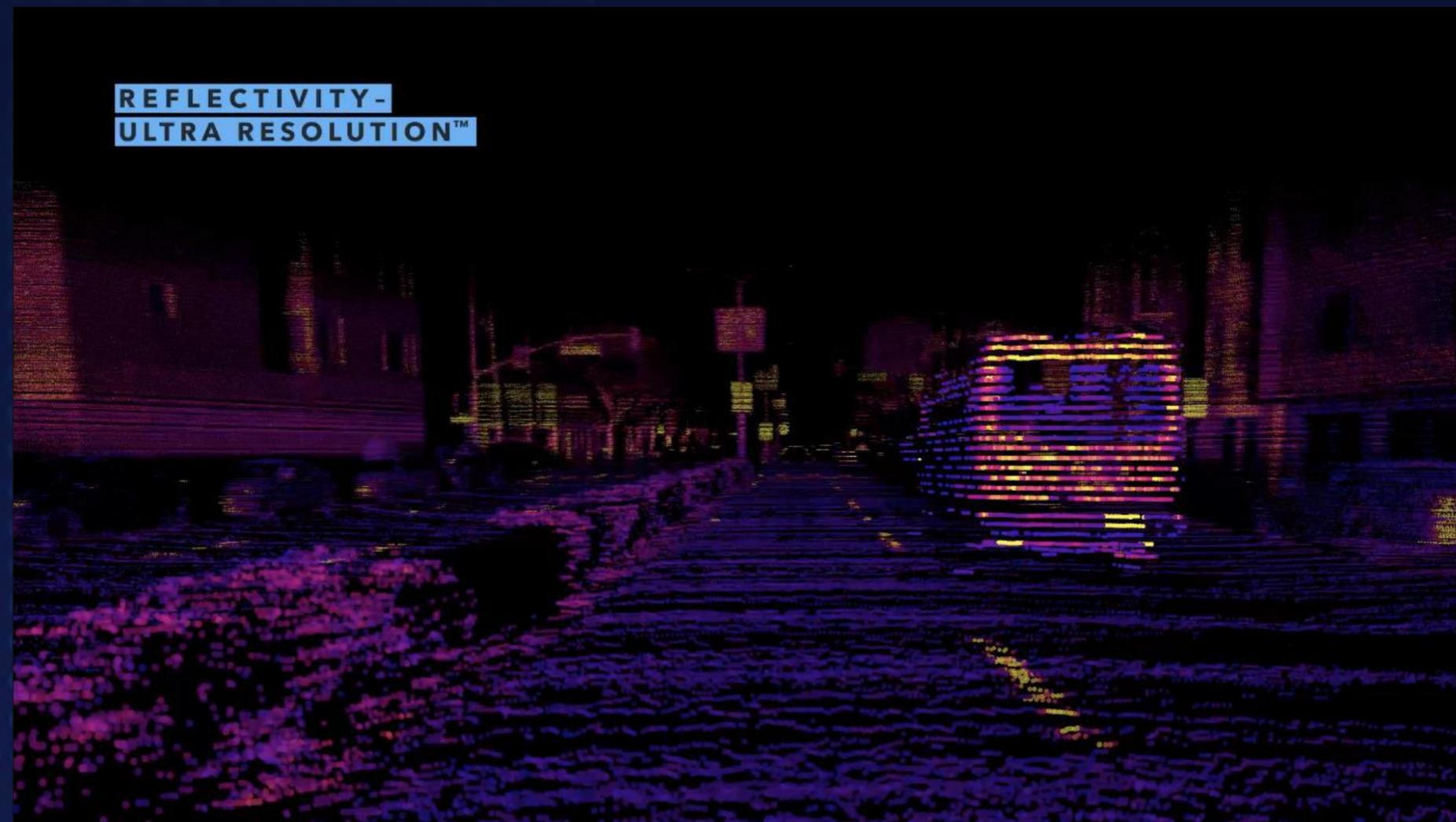


4D Localization



Ultra Resolution Perception

# Real-time Camera-level Resolution



## Camera-level resolution with up to 20x performance increase \*

### Ultra Resolution

- Velocity channel allows clean separation of static and dynamic points
- Leverages ego-motion estimation to build high resolution image of static world

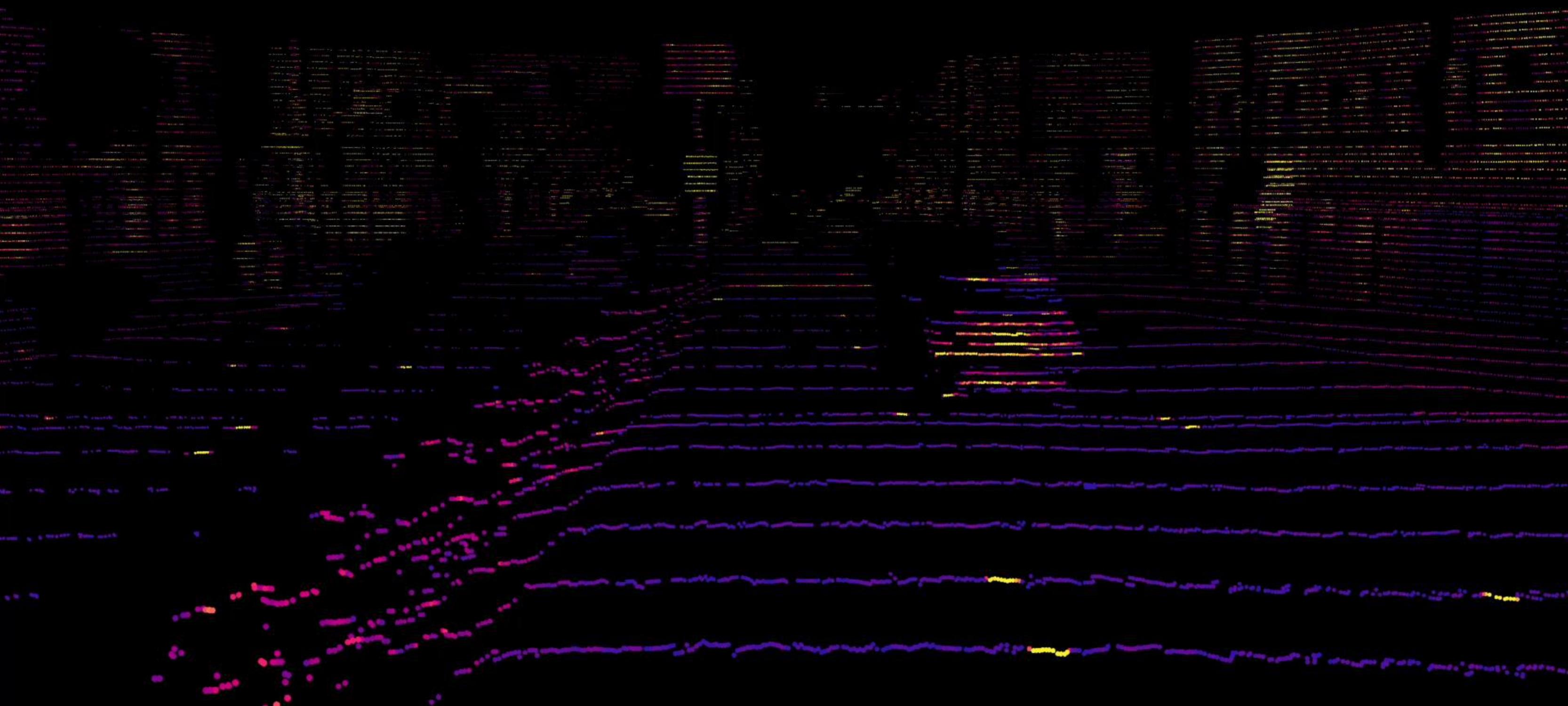
### Road Hazard Detection

- Small object detection at 50% greater range\*

\* Relative to native sensor resolution

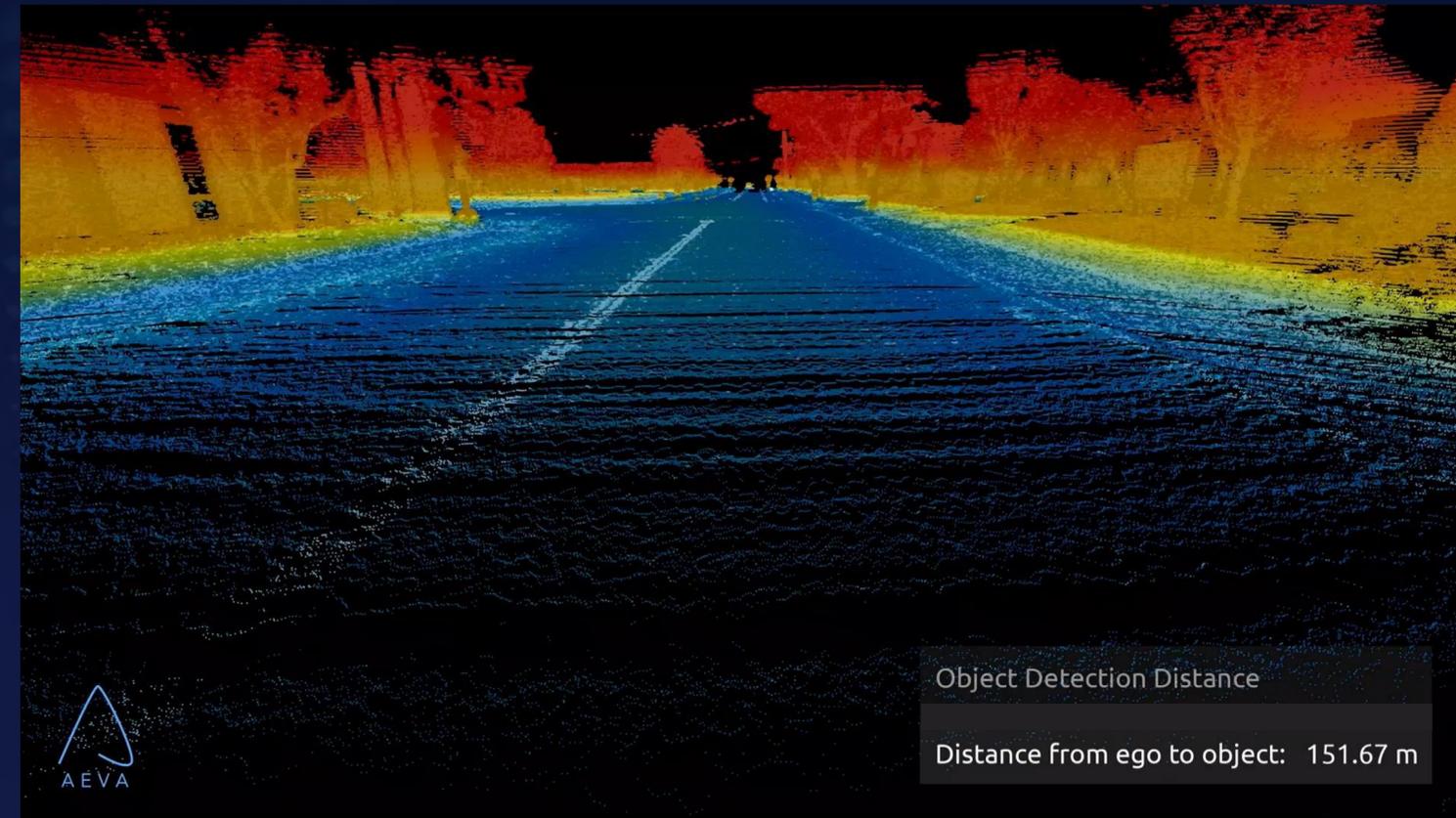


# REFLECTIVITY - STANDARD RESOLUTION



# Ultra Resolution Applied To Small Static Object Detection

- FMCW LiDARs directly discriminate between static and dynamic targets
- Ultra Resolution provides a large number of points on target
- Enables detection of small objects at 50% greater range\*



\* Relative to native sensor resolution

# Summary

## FMCW Technology Advantages



Interference Immunity



Clear Vision

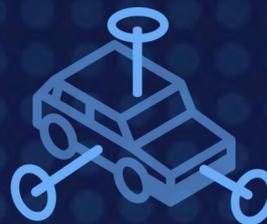


Simultaneous Range and Velocity

## FMCW Perception Advantages



Long Range Object Detection & Tracking



4D Localization



Ultra Resolution Perception

