



Key Milestones of Autonomous Vehicles



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Outline

- › Introduction to Metawave
- › Ground and Aerial Mobility dynamics
- › From consumer driver-assist to full autonomy
- › Aerial mobility
- › ADAS/Safety: Radar essential role
- › Perception at the edge
- › Innovations: Protecting Metawave disruptive technologies
- › Evolution of automotive value and supply chain

Metawave is Solving Mission Critical Mobility and Connectivity Challenges



Poor Visibility



Radar technology for automotive and aerial applications – Advancing ADAS and autonomy

Poor Connectivity



Improving 5G connectivity, speed and bandwidth through low-cost, infrastructure-light solutions

Modular and scalable platforms for multi-mode and multi-functional applications

Enabling Smart Cities and Infrastructure – Convergence of Technology

Metawave's mmWave Technologies



ADAS
AV Applications
Aerial / eVTOL

Smart Cities
Smart Infrastructure

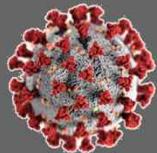
5G Infrastructure
Access and Backhaul Connectivity

Metawave is leveraging decades of team experience in telecom and sensing design to become a leader for all beamforming and steering millimeter-Wave front-end radio-frequency integrated circuits (RFICs), modules and sub-systems



Impact of Global Warming

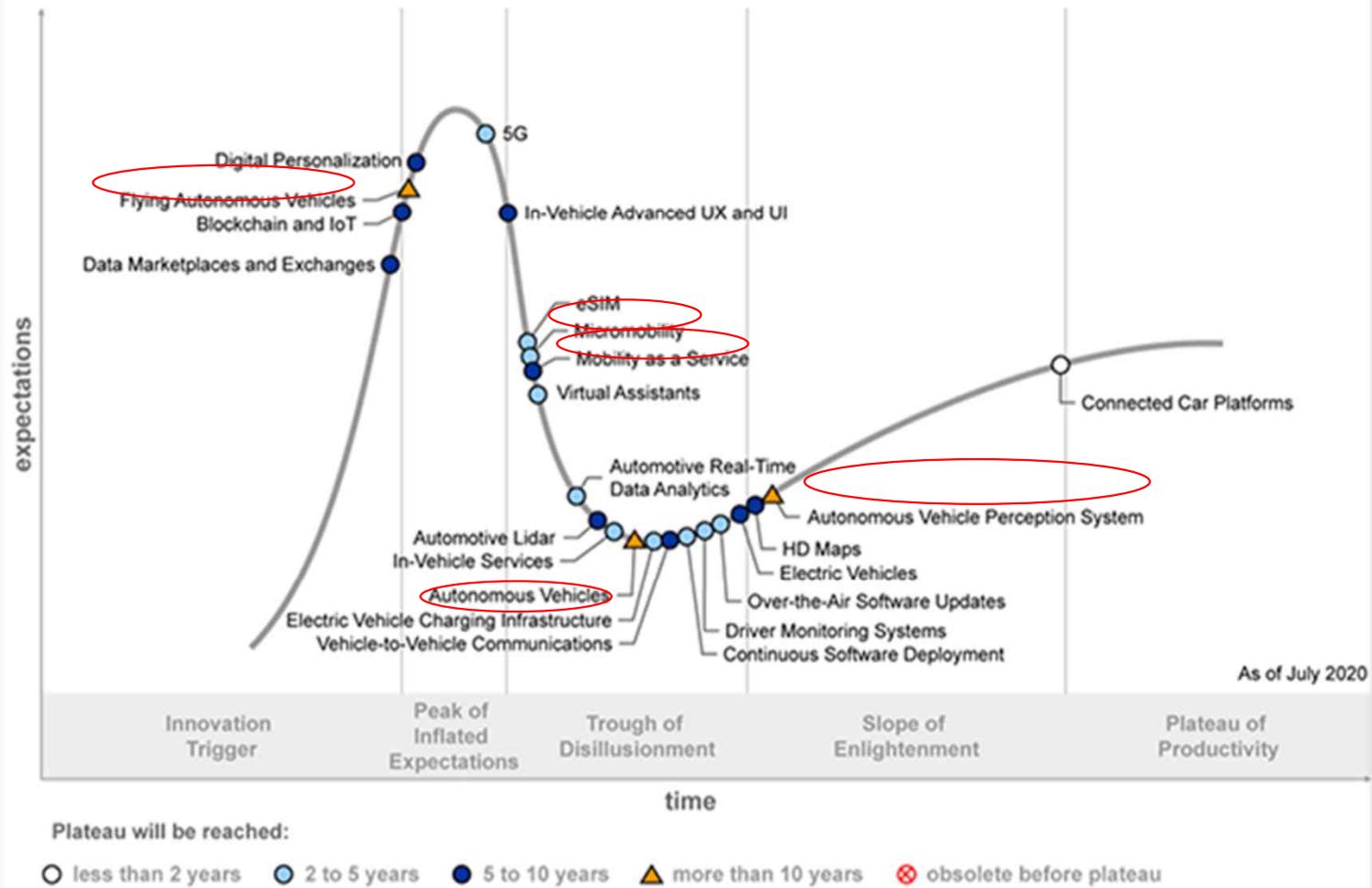
- Electrification
- Energy storage capacity, delivery, efficiency, and charging
- Long-haul delivery of goods
- SMART Infrastructure and Cities



Impact of Coronavirus (COVID-19)

- 40% increase in data load
- Micro-mobility
- Long-haul delivery of goods
- Last mile delivery robots
- Shared and mass transportation

Hype Cycle for Connected Vehicles and Smart Mobility, 2020



Source: Gartner

As of July 2020

Crossroad between e-Mobility and Connectivity



- Unlimited 5G capacity
- Secure, reliable, and low-latency connections
- Novel edge-services
- Mobility as a Service
- Delivery of Goods
- Autonomous Vehicles (AV)
- Ground and Air
- Consumer Experience
- Safety ratings



- Convenience and Productivity
- Trust and Safety
- Ultimate convergence

Urban Air Mobility (UAM)

- > Emerging mobility industry to transport people and goods in dense urban areas
- > New automated or autonomous e-Vehicles with vertical take-off and landing (eVTOL).
- > Urban operation includes airspace allocation and consumer demands
- > Public policy, city planning, and regulations are in progress

> Value proposition:

- High safety
- Low noise
- Time saving
- Dense Urban areas (25-35 US cities)
- ~50 miles radius
- More predictable than ground-based driving



“On-Demand Ridesharing: The Next Commercial Aviation Market”—plenary talk by Mark Moore, Director of Aviation at Uber, at the AIAA Aviation Forum 2017

UAM Progress

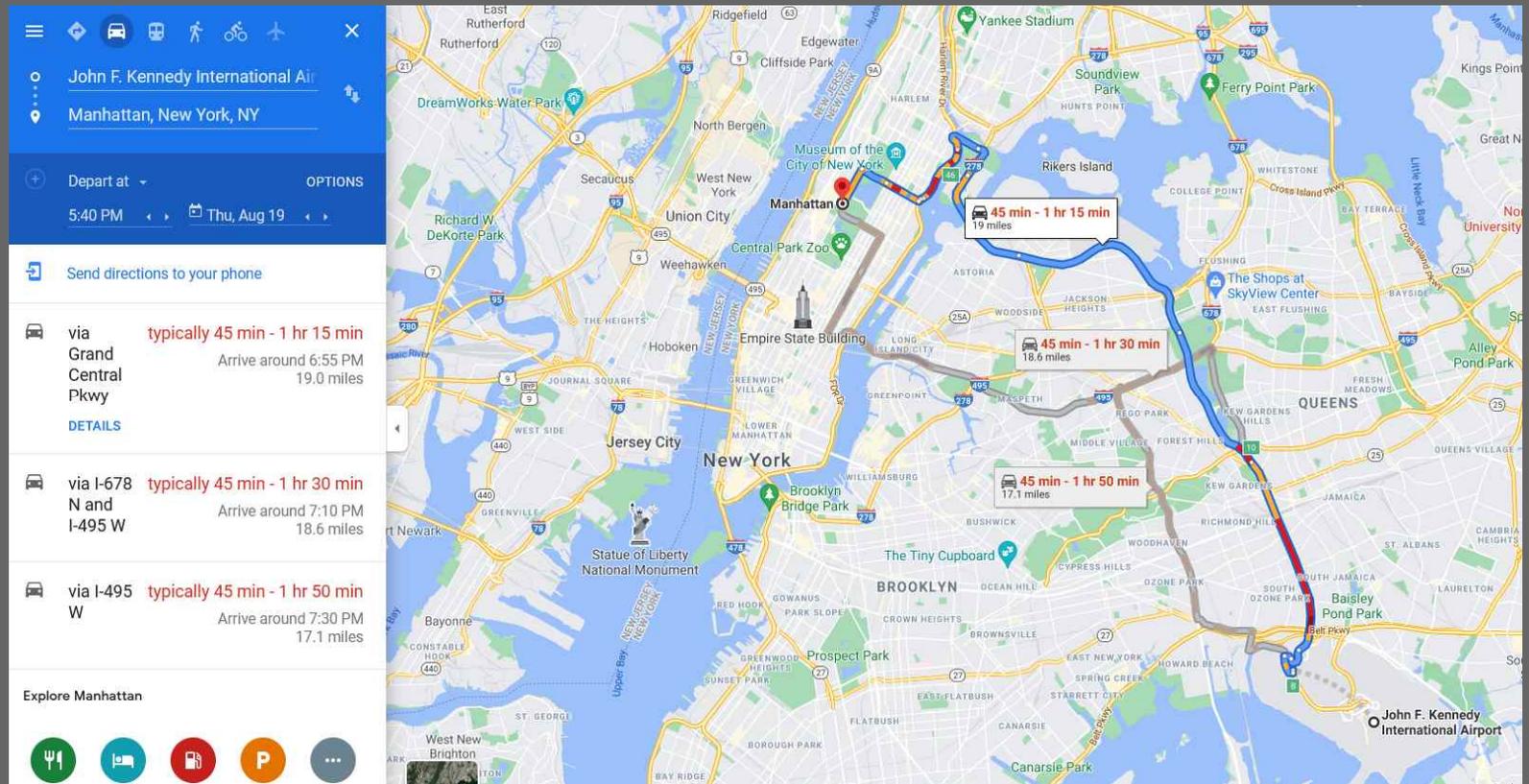
Many announced with more to come



The Vertical Flight Society, The Electric VTOL News World eVTOL Directory. October 2019

UAM Case Study

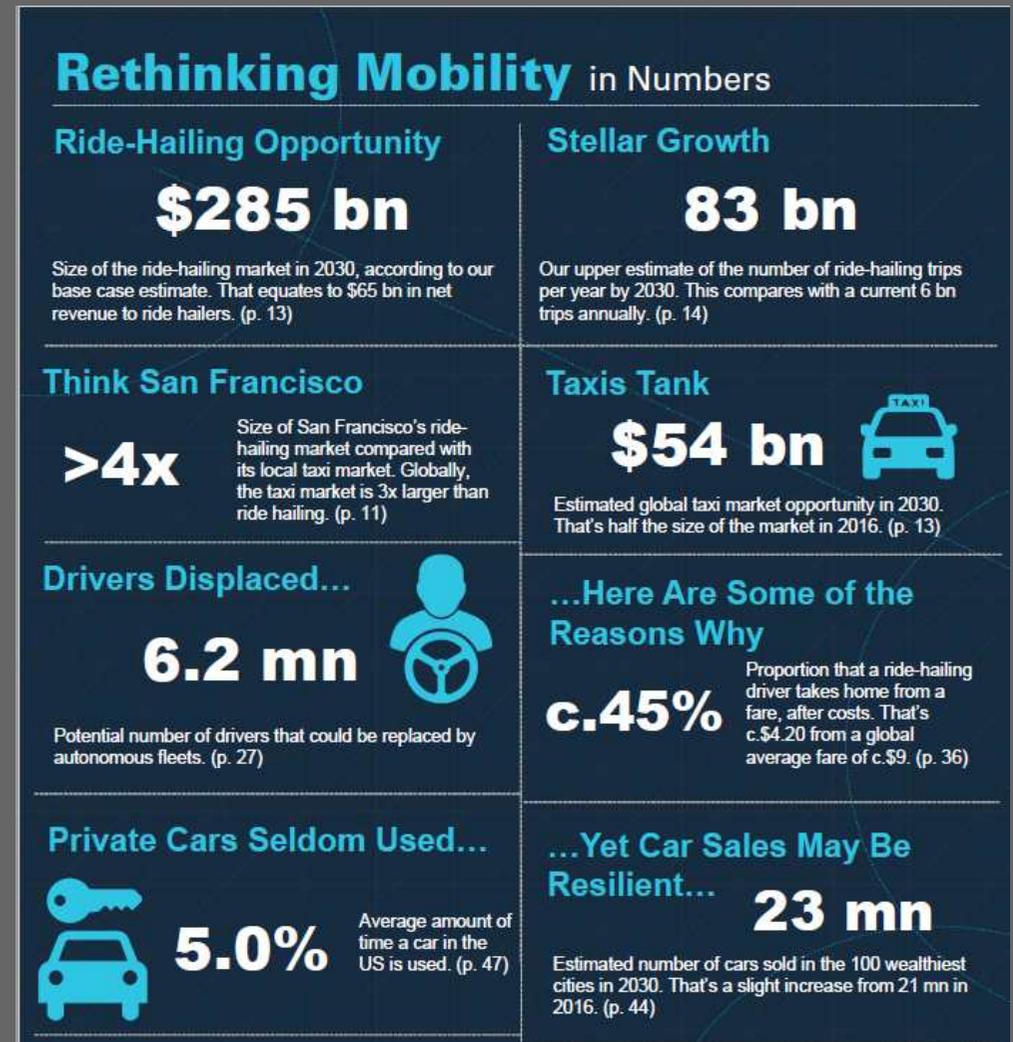
- > Manhattan to JFK takes over an hour during peak time
- > Uber costs \$60-\$90 and also takes an hour
- > Helicopter travel time is ~20min and costs ~\$1K
- > Expected cost of eVTOL is \$60-\$100 with ~20min travel time



Route	Distance	Typical Time	Arrival Time
via Grand Central Pkwy	19.0 miles	45 min - 1 hr 15 min	Arrive around 6:55 PM
via I-678 N and I-495 W	18.6 miles	45 min - 1 hr 30 min	Arrive around 7:10 PM
via I-495 W	17.1 miles	45 min - 1 hr 50 min	Arrive around 7:30 PM

Pay-as-you-go Mobility

- > Separating car usage from ownership
- > Ride hailing target is over 70% utilization compared to traditional 50% taxi utilization
- > Typically, ride-hailing drivers takes 40% of the total ride cost which is \$22/hour in the NY case (excluding fuel)
- > Necessity to deploy fleets of robo-taxis and AV trucks



Driver Assist vs Full Autonomy – Truth

Tesla Inc. has been charging customers up to \$10,000 for “full self-driving” technology for nearly five years. The problem is that such technology does not exist. The company’s cars are equipped with a driver-assistance system, or ADAS, known as Autopilot, which is free of charge.

- › Consumers deserve the truth
- › EV competition will eliminate such hypes



<https://www.msn.com/en-us/autos/news/its-time-for-elon-musk-to-start-telling-the-truth-about-autonomous-driving/ar-AAKn79I>

Driver Assist vs Full Autonomy - Safety

Bloomberg | Bloomberg

Tesla Autopilot Probed by U.S. Over Crash-Scene Collisions

- › Only camera-based ADAS is not enough
- › Tesla removed radar to save cost
- › EV competition will guarantee higher safety

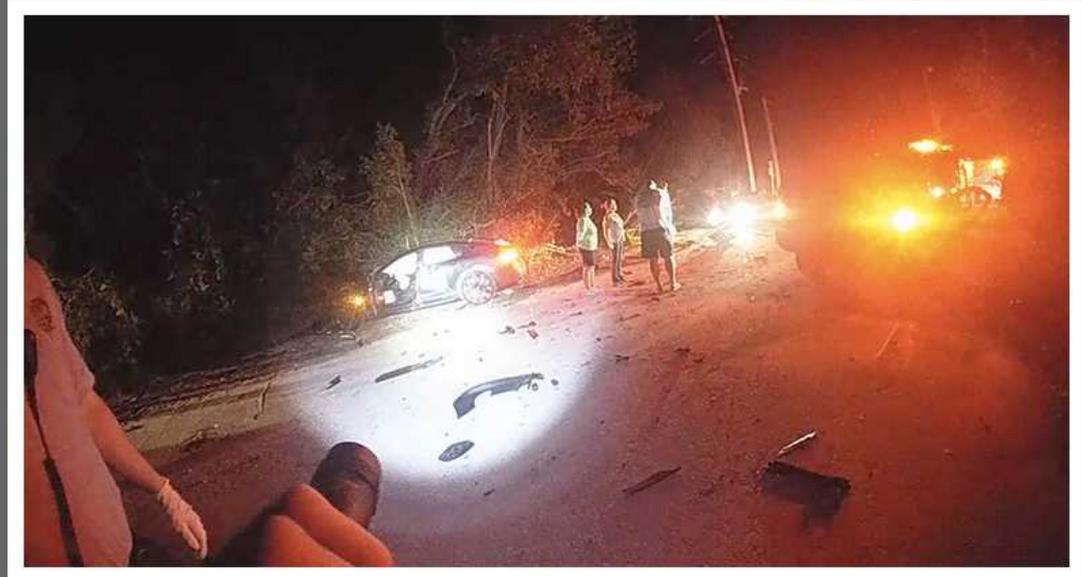
“Most incidents took place after dark and the crash scenes encountered included scene-control measures such as first-responder vehicle lights, flares, an illuminated arrow board and road cones,” the agency said in the document. “The involved subject vehicles were all confirmed to have been engaged in either Autopilot or Traffic Aware Cruise Control during the approach to the crashes.”

https://au.finance.yahoo.com/news/tesla-autopilot-investigated-again-u-120223737.html?soc_src=social-sh&soc_trk=tw&tsrc=twtr/

Driver Assist vs Full Autonomy – Radar is a MUST

'It Happened So Fast': Inside a Fatal Tesla Autopilot Accident

- › Driver got distracted and put his trust in a system that did not see and brake for a parked car in front of it
- › Basic RADAR-based Automatic Emergency Braking developed years ago failed!!
- › EV competition will always use SMART RADARS



<https://unitednewspost.com/news/technology/it-happened-so-fast-inside-a-fatal-tesla-autopilot-accident/>

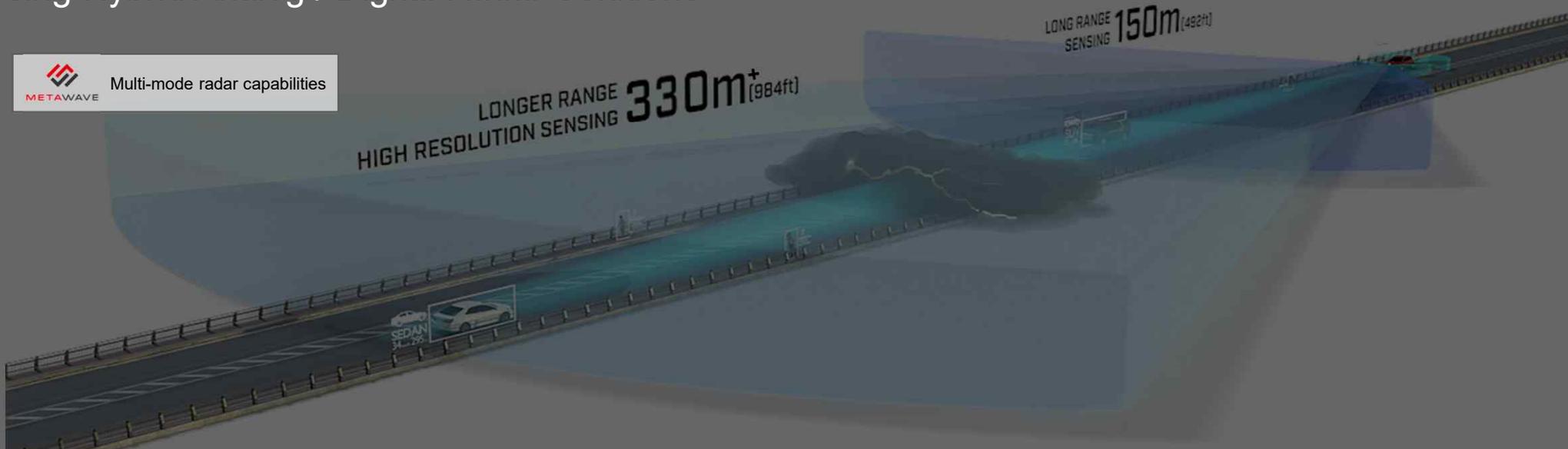
Welcome to Metawave SPEKTRA Radar technology and AWARE edge perception

Metawave Technology is Solving Multiple Issues For Mobility Sensors...

- ✓ All-Weather Operability
- ✓ Object Detection vs. "Clutter"
- ✓ Long-Range Detection
- ✓ Reduced Size and Weight
- ✓ Low Cost & Low Power Consumption
- ✓ 3-D Mapping Capabilities
- ✓ Aerial Compatibility



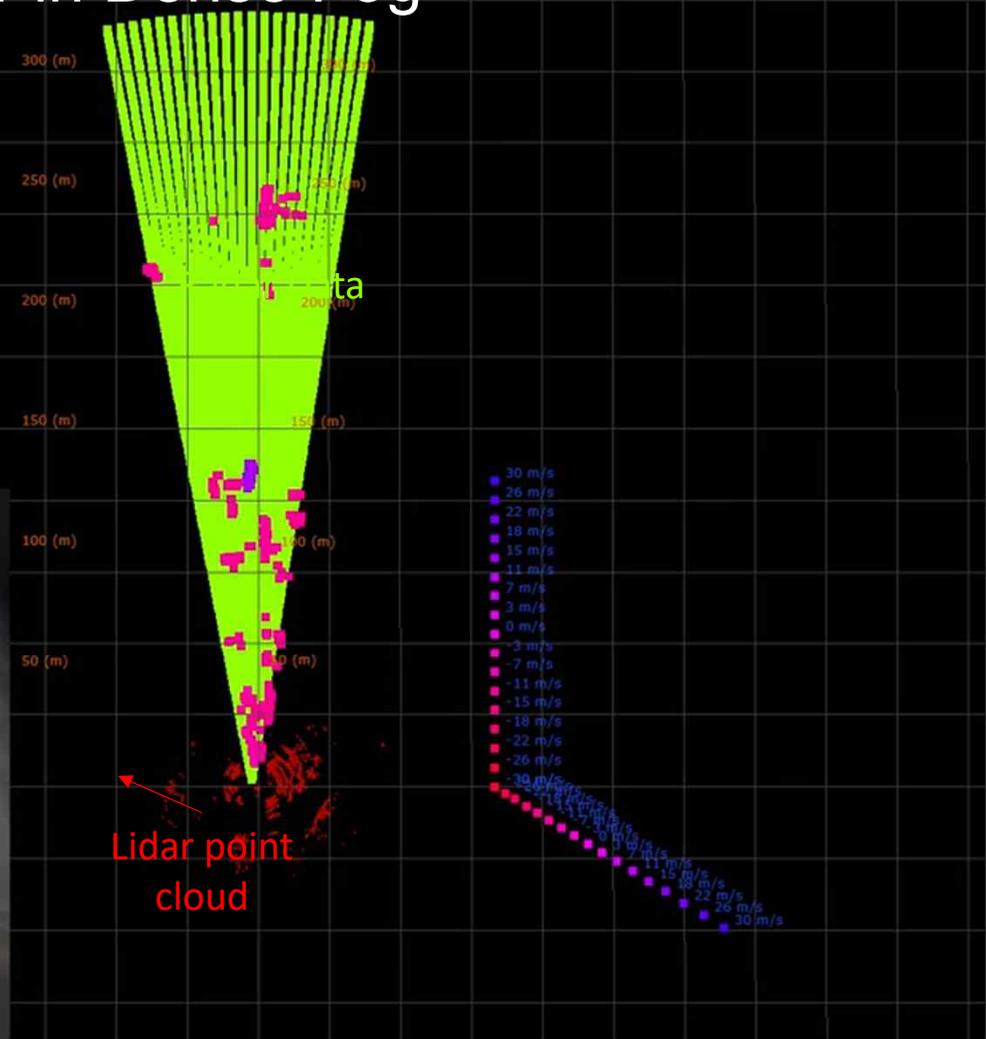
Bringing Driver Assistance Systems to the Mass Market and Enabling AV Technologies Using Hybrid Analog / Digital Radar Solutions



Unmatched radar performance in all weather conditions:

- ✓ **Superior Range**
+330m
- ✓ **Angular Resolution**
1.2 → 1 degrees
- ✓ **Angular Accuracy**
0.4 → 0.2 degrees at 300m
- ✓ **Doppler Resolution**
High range detection accuracy
- ✓ **Field of View**
45 → 120 degrees 15-25 Hz
- ✓ **Frame Rate**
15-25 Hz
- ✓ **Antenna Module**
Integrated, electronically-steerable antennas and transceiver chipsets
- ✓ **Range Resolution**
< 1m at 330m range and 0.25m at 100m

Safety: Radar, Camera, and Lidar in Dense Fog



Camera: <https://www.flir.com/products/blackfly-s-usb3/>

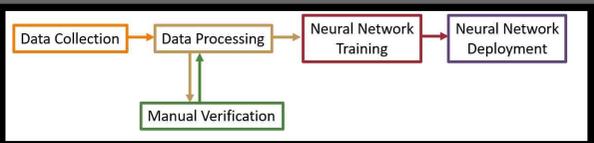
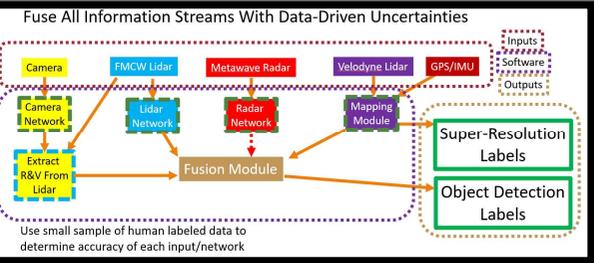
Lidar: <https://velodynelidar.com/products/puck/>

AWARE @ 94% Accuracy - Metawave Neural Network Training



All boxes are 100% SPEKTRA + AWARE

Blackmore (reference only)
 Pedestrian
 Car
 Static Object



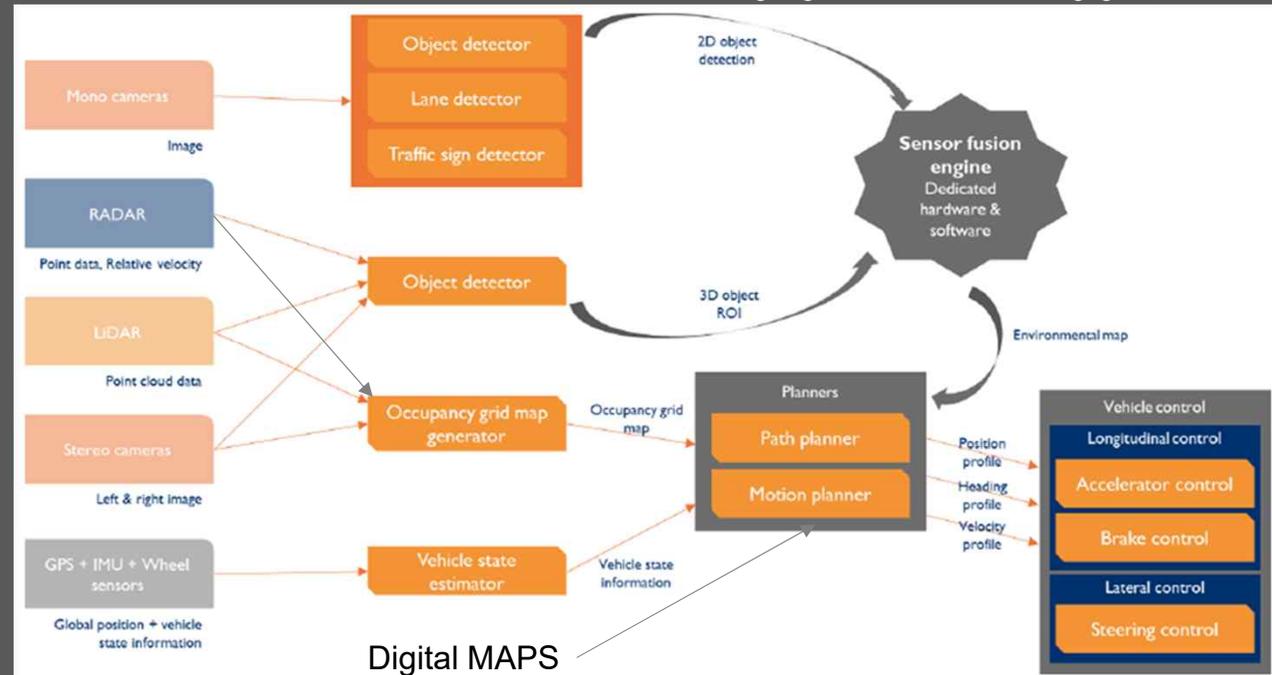
Achieving Perfect ADAS Balance

- 1) Object detection & tracking
 - All-weather and operating conditions
 - Role of primary sensor
- 2) Fast response
- 3) Near-perfect Perception
- 4) Reasonable cost
- 5) Lowest Power-Consumption

Summary Fusion Models

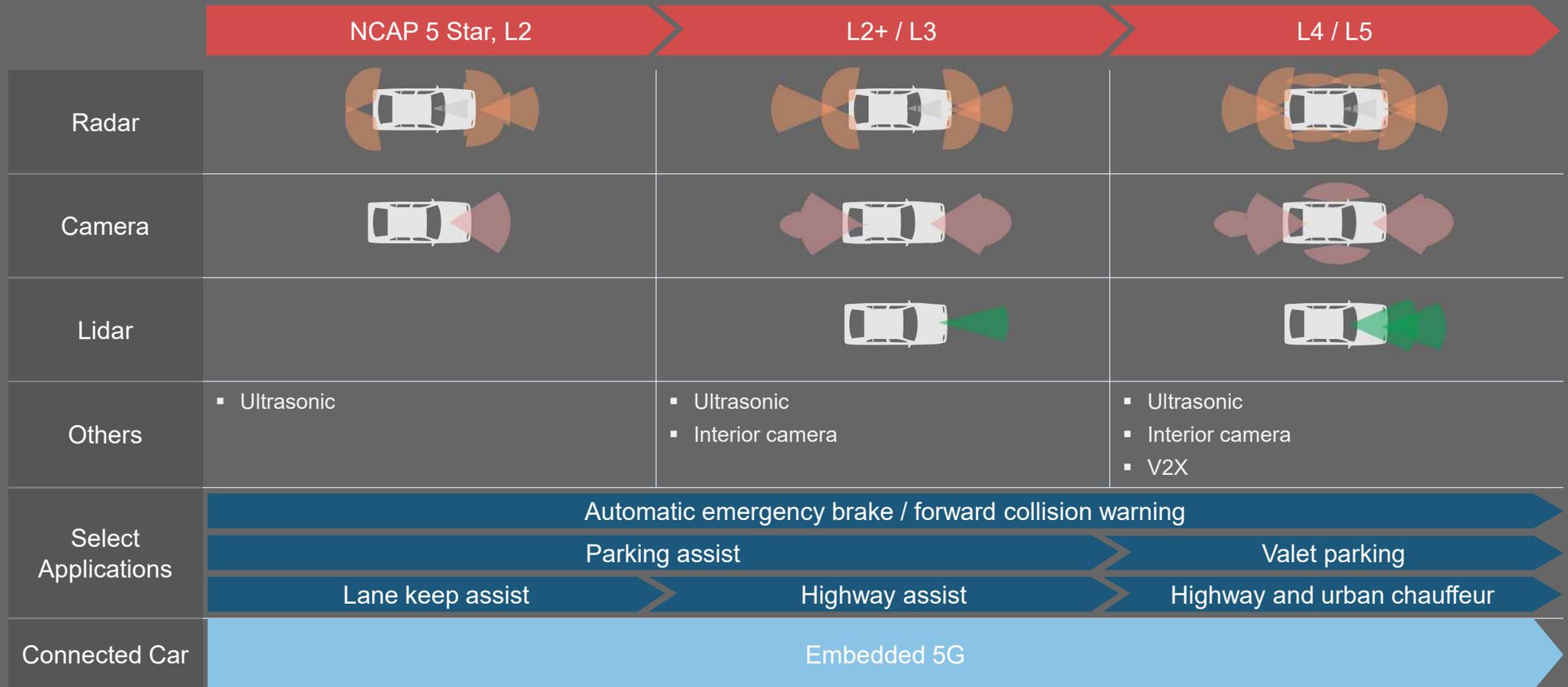
Open and closed loop operation
V2V, V2X, and 5G

- Hazards
- Cut-In
- Cut-Out
- Read
- Detection and tracking
- Drivable Surface Identification
- Small Object Detection at long range
- Moving Obstacles
- Stationary Obstacles
- VRU* Detection
- Adjacent Lane
- Lane Keeping
- Escape Path
- Road Edges
- Unprotected Left Turns
- Merging



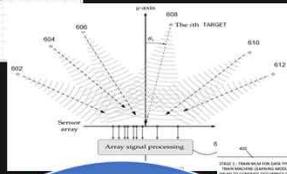
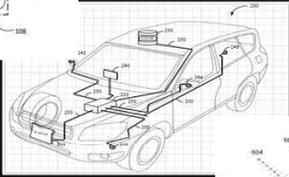
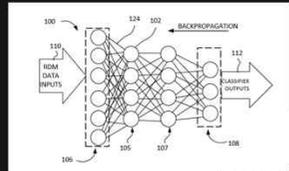
Redundant Sensor Coverage is Critical for ADAS and Autonomy Advancement

More sensors required for increasing levels of automation



Source: VDA (German Association of the Automotive Industry); Society of Automotive Engineers

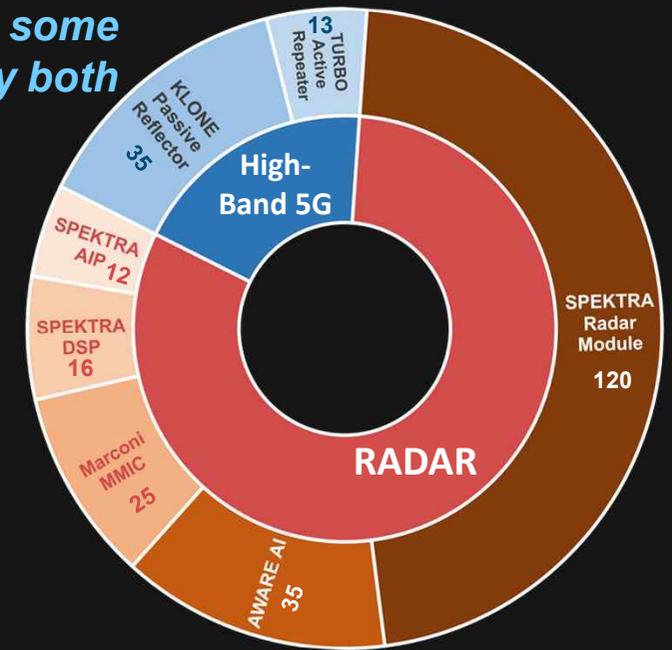
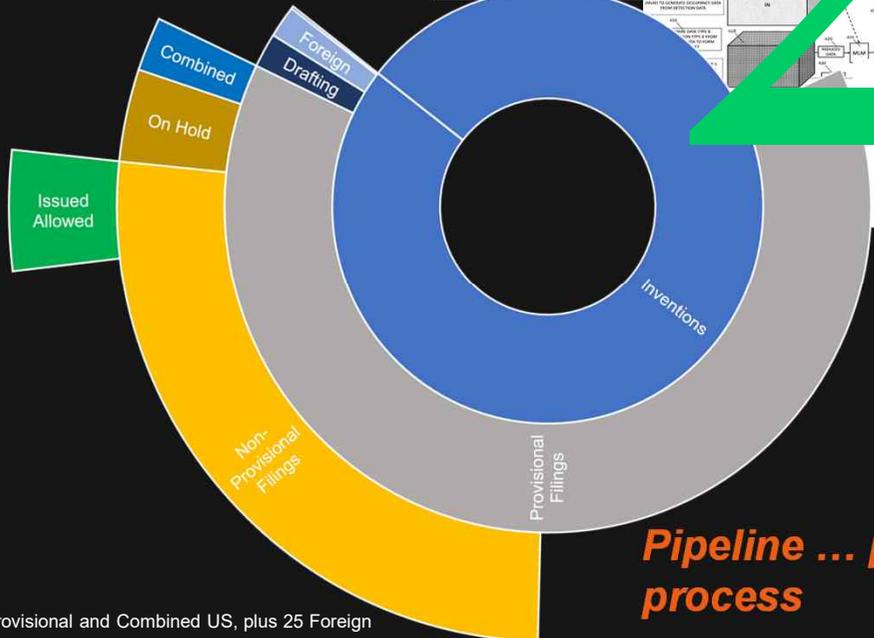
Patent Portfolio



25 issued

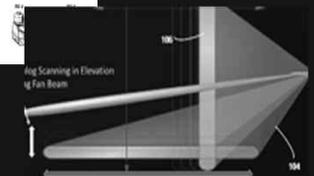
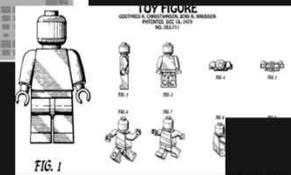
Technology ... some shared by both

filed 26



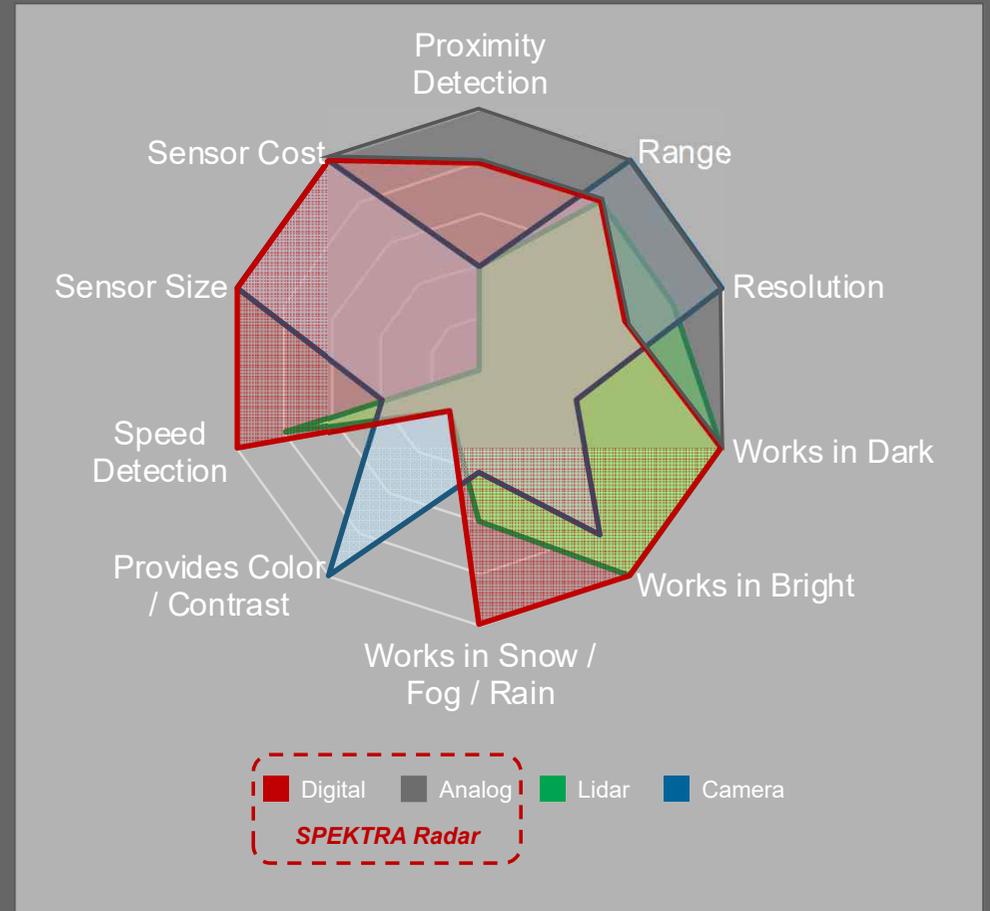
Pipeline ... proven accelerated process

* Provisional and Combined US, plus 25 Foreign



Automotive Sensor Capability Comparison

- Complementary strength of alternative sensors' technologies are required to operate a vehicle safely
- Radar is universally accepted to be an indispensable component of highly-automated driving
 - Used primarily to measure range and velocity
 - Best for tracking objects in motion
- Millimeter wavelengths in radar able to overcome weakness of lidar
- Able to operate seamlessly in all-weather conditions – integral for success and safety of autonomous vehicles and advanced ADAS
- Sensor redundancy among radar, camera, lidar and ultrasonic will be critical in order to achieve automotive safety integrity levels (ASIL)



AV User Experience and Value Chain Evolution

- In July Magana (camera +Lidar) offered to acquire Veoneer (radar) for \$3.8B
- 3 weeks later Qualcomm (Snapdragon) offered \$4.5B in cash

ARTERIS IP
arm
SYNOPSYS
cādence

SoC and Semiconductor Suppliers

METAWAVE

Tier-1 Suppliers

Vehicle Manufacturers (OEM)

Uber



Apple platform



Google platform



Tesla platform



Cruise platform

Next Few Years ...

- ❖ **Safety** Right balanced of sensors, especially radars
- ❖ **Value Chain** Accelerated consolidations across Tier 1, Tier 2, and OEMs
- ❖ **Parading Shift** Convergence between connectivity and mobility

Next Smart City Keynote

Thank You

