Sensing and Sensibility for Smart City with Intelligent Transportation

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9/8/2016
Outline

• Mega trends of smart city and intelligent transportation

• Use cases of smart city with intelligent transportation

• Sensor’s roles and technology trends in intelligent transportation

• Conclusion
Future of city and its challenges

- Increasing urban population:
  - 58% of world’s population resided in cities in 2015. => 70+% in 2050

- Growing mega cities (>10M people):
  - 35 in 2015. => >100 in 2050

Source: ITRI/IEK(2016/09)
Smart city is a solution to urbanization

6 key components for smart city - Boyd Cohen in 2012

- Smart city: A city seeking to address public issues via ICT-enabled solutions on the basis of a multi-stakeholders, municipal-based partnerships.
  - European Parliament

Source: ITRI/IEK(2016/09)
Transportation challenges and opportunities in smart cities

- **Challenges:** Time and energy waste, accidents, air pollution, economic losses, etc.
  - Truck congestion wastes $27 billion in time and fuel annually
  - 30% of traffic in business districts is attributed to looking for parking
  - Transportation sector as 2nd largest source of greenhouse gases

**Transportation Challenges**

**New Opportunities**

- **Sharing Economy**
  - Car sharing, bike sharing, ridesharing, and pop-up bus services

- Opportunities exist in intelligent transportation system together with devices and big data analytics to improve authority’s decision making process

Source: USDOT; ITRI/IEK(2016/09)
Intelligent transportation system for smart city

- Although reduction of emissions and incidents, plus traffic congestion alleviation are all major driving forces for ITS market growth, interoperability and standardization issues still need to be resolved by industries.

Source: ITRI/IEK(2016/09)
IoT Devices enabling intelligent transportation

- Advancement and affordability of sensing technology together with IoT deployment will accelerate realization of intelligent transportation
- Value-add will depend on benefit vs. (cost + privacy) trade-off

Source: ITRI/IEK (2016/09)
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San Francisco SFpark system for more availability of on-street parking

- SFpark helps drivers quickly find open spaces with a smart pricing system that periodically adjusts meter and garage pricing up/down for the demand.
- Demand-responsive pricing encourages drivers to park in underused areas and to reduce demand in overused areas.

Parking usage is monitored via sensors placed in the asphalt.

changing prices according to location, time of the day, and day of the week.

the availability and prices can be checked via SFpark.org and smart phone apps.

**Benefit**

- Parking citations dropped from 45% to 20% of total parking revenue.
- A March 2014 study found that SFpark met its 60-80% occupancy goal and cruising for parking is down by 50%.

Source: ITRI/IEK(2016/09)
Olli- Local Motors’ first self-driving vehicle

Powered by IBM’s Watson

• Olli, an electric-powered mini bus, can carry up to 12 people designed by Local Motors

• The cars will start operations first in Washington DC, before expanding to deployments in Miami-Dade County and Las Vegas later this year (2016)

3D-Printed: Use 3D printing to bring down the cost of making cars

IBM Watson: IBM Watson’s capabilities help to improve the passenger experience and allow natural interaction, but do not control or navigate or drive Olli

Sensors: About 30 sensors embedded in the vehicle to collect transportation information

Self-Learning: Olli’s knowledge will grow based on those interactions that generate data been collected and analyzed afterwards

Source: IBM
Intelligent Transportation Cases in Taiwan

Today:
- 1.5M/day cars
- 14M/day transactions
- 99.97% accuracy
- 2015 ITS World Congress Industry Award

Future development:
- Integrated Smart Transportation Services
- Customized Business Model and Services
- Enabling Smart City
- Export Integrated systems

ETC/eTag

4G Traffic Control Initiative
Complete monitor equipment

- 4G traffic detector
- Other traffic information
- Accident information (Public sector)

Traffic control cloud
Real-time traffic control

Traffic information cloud
Real-time traffic information App

Source: ITRI/IEK(2016/09)
ITRI's deployment project for U.S. V2V Mandate

Intersection Movement Assist (IMA)

IMA: Warns the driver when it is not safe to enter an intersection, ex. when something is blocking the driver’s view of opposing or crossing traffic.

1. **IMA V2V Alert**
   - WAVE/DSRC Wireless Comm.
   - Follow U.S. V2V Mandate

2. **IMA R2V Alert**
   - Integrate mmWave Radar
   - Integrate traffic controller to alleviate congestion

3. **IMA Signage Alert**
   - Allow the car without OBU to access the alert from outside

Source: ITRI/IEK(2016/09)
Summary

• Most of presented use cases deliver true values to fulfill citizen’s unmet needs, either for time and energy savings or emission and carbon reductions.

• Olli powered by IBM’s Watson, further demonstrates an ideal interactive experience for passengers with autonomous vehicle taking advantage of advanced sensors and AI capability to explore more values to customers.

• Sensor industry and vendors should partner with SI and service providers for value-add to end users/customers while developing new sensor technology and product.

Source: ITRI/IEK(2016/09)
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3 forces to drive intelligent transportation and sensors market growth

- New market opportunities for sensor vendors will span from 3 driving forces:

  1. **Policy & Legislation**
  2. **ICT Innovation & Autonomous Vehicle**
  3. **New Service Model**

Source: ITRI/IEK(2016/09)
Sensor market growth in transportation application will reach 11.6%, above average growth for the period 2015-2020. The worldwide sensor application market forecast is as follows:

- **2015**: $24,143 M
- **2016(e)**: $28,221 M
- **2017(f)**: $31,502 M
- **2018(f)**: $33,865 M
- **2019(f)**: $38,368 M
- **2020(f)**: $41,326 M

**Transportation Application** includes Roadside Surveillance System, Air Monitoring System, and Automotive Electronics System. The CAGR for this application is 11.6% from 2015 to 2020.

*Source: ITRI/IEK (2016/09)*
Roadside surveillance & autonomous vehicle fuel strong market growth of CMOS Image & IR sensors

- Sensor market growth will reach 11.3% (CAGR), while **CMOS Image and IR sensors** will enjoy the highest growth due to the needs for intelligent transportation applications.

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**Worldwide Sensor Market Forecast**

- **CMOS Image Sensor** (2015~2020 CAGR 11.6%)
- **IR Sensor** (2015~2020 CAGR 12.5%)

- Other Sensor (Other Optical Sensor, Hall Sensor, Printed Sensor)

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Source: ITRI/IEK(2016/09)
Worldwide sensor market in roadside applications will reach 2.5 billion in 2020

Source: ITRI/IEK(2016/09)
Sensing technology trend in roadside application, multi-sensor fusion, algorithm, new materials

- CMOS Image/IR Sensor need to integrate image pre-processing and AI capability with multi-protocol support.
- Multiple sensor fusion solution (ex.3D image + NIR + FIR sensors) will become the mainstream for various traffic monitoring applications.
- Air monitoring system with gas sensors need to integrate multi-sensing database and algorithm and special material to achieve high sensibility and low power consumption.

<table>
<thead>
<tr>
<th>System</th>
<th>Sensor Type</th>
<th>Requirement</th>
<th>Short Term</th>
<th>Long Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveillance System</td>
<td>CMOS Image/IR Sensor</td>
<td>Traffic monitoring capability</td>
<td>Smart Image Pre-Processing Algorithm</td>
<td>Multi-Protocol Support, AI (Machine Learning)</td>
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<td></td>
<td></td>
<td>Night Vision capability</td>
<td></td>
<td>Big Data Analytics, Cloud Computing</td>
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<td></td>
<td></td>
<td>Accurate Object Recognition (Pedestrian, Animal...)</td>
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<td>NIR/FIR Sensor Fusion</td>
</tr>
<tr>
<td>Air Monitoring System</td>
<td>Gas Sensor</td>
<td>Multi-Gas Sensing (Oxygen/NO/NO2 ...) Capability</td>
<td>3D Image + NIR/FIR Sensors, Multi-Cameras</td>
<td>Multi-Gas Sensing Database and Algorithm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High Sensibility</td>
<td></td>
<td>Special catalytic materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low Power</td>
<td></td>
<td>Special Thin Film materials</td>
</tr>
</tbody>
</table>

Source: ITRI/IEK(2016/09)
Automotive electronics systems consist of four sub-systems: Powertrain, Body & Chassis, Infotainment, and Safety & Assistant.

Each sub-system needs different types of sensors to detect crash, roll, yaw, direction, etc. to ensure drivers’ and vehicle’s safety.

- **Powertrain**
  - Engine/Transmission Control Module
  - Throttle Position/Air Control Valve Sensor
  - Turbo Charger Sensor
  - Current Sensor
  - Gas Sensor...

- **Infotainment**
  - Navigation
  - HMD
  - HUD
  - Rear Seat Display
  - Entertainment System...
  - CMOS Image Sensor
  - G-Sensor
  - Gyroscope
  - Magnetic Sensor
  - MEMS Microphone...

- **Body & Chassis**
  - Body: Lighting, Climate
  - Electronic Control Units (ECU)
  - Temperature Sensor
  - Flow Sensor
  - UV Sensor...
  - Chassis: ABS, Stability Control Unit, TPMS, Steer/Brake by Wire
  - IMU, Pressure Sensor...

- **Safety & Assistant**
  - ADAS: Camera Module, Control Module, Event Data Recorder...
  - CMOS Image Sensor, Radar, Ultrasonic Sensor, LIDAR, IR Sensor...

>200 Sensors

Source: ITRI/IEK(2016/09)
Safety & Assistant and Infotainment System is the fastest growing applications for smart vehicles.

- Safety & Assistant System includes Passive and Active Safety Systems
- Infotainment System includes HMI and Video/Audio Systems

Smart Vehicle Sensor Application Market Forecast

- 2015–2020 CAGR 10.7%
- (2015–2020 CAGR 10.5%)
- (2015–2020 CAGR 13.1%)
- (2015–2020 CAGR 12.4%)
- (2015–2020 CAGR 6.6%)

Source: ITRI/IEK(2016/09)
Sensing technologies empower ADAS for drivers’ & passengers’ safety

- Sensors (3D Image/IR Sensor, Ultrasound, mmWAVE Radar, LIDAR...) integrated into ADAS can detect the condition from forward/rear/surround views of the car to ensure the safety of people.

Lane Departure Warning, Traffic Sign Recognition, High Beam Assist, Cross Traffic Alert...
Side Impact Detection
Lane Change Assistance, Remote Control Parking

Source: ITRI/IEK(2016/09)
ADAS developments promise a future for sensor industry

- NHTSA defines 5 levels for driving automation, and most of existing ADAS in smart vehicle can only reach Level 2 to control speed or direction via Adaptive Cruise Control, Autonomous braking, Lane Keeping Assist, and Park Assist.
- ADAS will continue to upgrade thus bring about huge business opportunities for sensor industry.

Source: NHTSA(National Highway Traffic Safety Administration); ITRI/IEK(2016/09)
Sensing, Understanding, Action as 3 key requirements for autonomous vehicle

- **Sensing**: Variety of sensors (CMOS Image /IR Sensor, mmWAVE Radar, LIDAR, Ultrasound...) will need to work together thus a multi-sensing fusion solution is required.
- **Understanding**: Sensor fusion solution will need to work with high performance CPU/GPU with AI (Machine Learning, Deep Learning) capability to understand the environment completely around the car.
- **Action**: The controller/actuator/communication system will start to work and process to realize autonomous functions.

Autonomous Vehicle

<table>
<thead>
<tr>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1: Driver Assistant</td>
<td>L2: Partial Autonomy</td>
<td>L3: Limited Self-driving</td>
<td>L4: Full Self-driving</td>
<td>L5: Self-driving only</td>
</tr>
</tbody>
</table>

- **Sensing**
  - Stereo Cameras (CIS, FIR)
  - mmWAVE Radar, Ultrasound
  - LIDAR

- **Understanding**
  - High Performance CPU/GPU
  - Big Data, Cloud Computing
  - AI Algorithm (Machine Learning, Deep Learning...)

- **Action**
  - Actuator, Controller
  - V2V Communication
  - Other Connected Car Communication Protocol

Source: ITRI/IEK(2016/09)
V2Xs fuel sensor market growth opportunities

V2X: V2V(Vehicle to Vehicle) ▪ V2C(Vehicle to Consumer) ▪ V2I(Vehicle to Infrastructure)

* Adaptive Cruise Control: Adjusts the vehicle speed to maintain a safe distance from other vehicles.
* Lane Departure: Warns the driver by vibrating the seat, steering wheel, or sound.

* Anti-collision/Auto Emergency Braking: Detects the distance between and around the car, especially in heavy fog and rain.

* Automatic Parking: Displays obstacles surrounding the vehicle, compares the parking space and vehicle length, and performs automatic steering control.

* Night Vision: Detects pedestrians or animals at night, projects warning signs onto the windshield.

* Infrastructure Recognition: Detects traffic sign changes, snow road ahead, and adjusts the drive status.

Sensors:
- Camera (CIS) for surround
- mmWAVE Radar
- Ultrasound Sensor
- Short Range Radar
- NIR/FIR Camera
- LIDAR

Source: ITRI/IEK(2016/09)
Camera (3D CIS) for surround、LIDAR、mmWAVE Radar market should be targeted by sensor vendors

- In 2020, Camera (3D CIS) for surround will be the largest segment in ADAS of autonomous vehicle
- mmWAVE Radar and LIDAR module will enjoy the highest growth rate in next 5 years

**Sensor Market for Automotive Active Safety System**

- **2015~2020 CAGR**
  - LIDAR module: 60%
  - mmWAVE Radar module: 52%
  - Short range Radar: 40%
  - NIR/FIR Sensor: 268
  - Ultrasound Sensor: 212
  - Stereo Camera(CIS): 40
  - Camera (3D CIS) for surround: 998

**Market Size in 2020 ($M)**
- LIDAR module: 2,368
- mmWave Radar Module: 1,262
- Short Range Radar: 1,449
- NIR/FIR Sensor: 1,672
- Ultrasound Sensor: 1,033
- Stereo Camera(CIS): 808
- Camera (3D CIS) for surround: 998

Source: ITRI/IEK(2016/09)
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Taiwan eyeing on emerging market trend with R&D in next-generation sensing solutions

- Taiwan not only developing new sensor technology, but also advanced algorithm to meet the requirement of next-generation intelligent transportation applications
- Taiwan’s IC design houses are aggressive developing sensor solutions for ADAS

### Taiwan Sensor Solution Development Status for Intelligent Transportation

<table>
<thead>
<tr>
<th>Inertial Sensor</th>
<th>Magnetic Sensor</th>
<th>MEMS Microphone</th>
<th>Image/IR Sensor</th>
<th>Sensor Algorithm &amp; AI</th>
<th>mmWAVE Radar</th>
<th>LIDAR</th>
<th>Gas Sensor</th>
<th>Pressure Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitronix</td>
<td>Isentek</td>
<td>ZIL-TEK</td>
<td>ITRI</td>
<td>ITRI</td>
<td>DSTI</td>
<td>ARTC</td>
<td>HOST</td>
<td>ITRI</td>
</tr>
<tr>
<td>HighTek</td>
<td>Voltafield</td>
<td>ITRI</td>
<td>ITRI</td>
<td>ITRI</td>
<td>ITRI</td>
<td>ARTC</td>
<td>NARLabs</td>
<td>ITRI</td>
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<tr>
<td>MEMS</td>
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</tbody>
</table>

### Applications

- Roadside  
  - Surveillance
  - Air Monitoring System
- Car  
  - Driving Recorder
  - Video Camera
  - mmWAVE Radar
  - LIDAR
  - TPMS
  - Car Navigation
  - Car Infotainment
  - Alcohol Detector

Source: ITRI/IEK (2016/09)
Taiwan’s value chain and ecosystem growing stronger in intelligent transportation market

- Taiwan’s growing ecosystem with existing competitiveness in TPMS and Reversing Radar and PCB/Connector will be a strong supporting base to accelerate our sensing industry’s growth.

### Key Component / Module

- **Sensor**: Sitronix, POI, RichTek, Himax, mCube, Sentek, SOI, ...
- **Other Semiconductor**: MediaTek, HOLTEK, nuvoTon, Sunplus, meltrend, winbond, INNOLUX, ...
- **Display**: AUO, HannStar, ...
- **PCB, connector, RCL, camera module**: CHIN POON, MICROELECTRONICS, KST, LITEON, YAGEO, WAIN, ...

### System / Sub-System

- **Surveillance**: VIVOTEK, EverFocus, AVECHTECH, GeoVision, TVS, ...
- **TPMS & ADAS (Radar…)**: CUB, ITC, VISION, ...
- **Telematics & Car Infotainment**: E-LEAD, GlobalSat, MITAC, HOLUX, ...

### System Integration

- **System Integration**: ADVANTECH, AxiomTek, iEI, iBASE, ...

### Cloud & Insurance Service

- **Cloud & Insurance Service**: ASUS-cloud, Acer, BYOC, ...

Source: ITRI/IEK(2016/09)
Conclusion

- Emerging projects and pilots in a large number of cities of intelligent transportation, such as traffic management and parking system and self-driving vehicle, will bring about new market opportunities for sensor vendors.

- Policy & Legislation, Autonomous Vehicle/ICT Innovation, and New Service Model are driving forces to a rapid growth of intelligent transportation and new sensing solution markets.

- Multi-sensor fusion with AI capability is key for sensor vendors to sustain competitive advantage.

- Sensor vendors need to partner with SI and service providers in the eco-system to maximize the value-add of total sensing system.

Source: ITRI/IEK(2016/09)
Appendix
Total sensing solutions for smart transportation ready to grow

- Sensor modules integrated with **algorithm and data fusion capability** as a total sensing solution
- Rapid market growth and new technology requirement of sensing solution will accelerate **M&A, Investment, and Partnership** between Automotive/Automotive electronics and ICT Vendors, thus making the ecosystem more dynamic

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**Product Life Cycle**

**Policy & Legislation Driving Force**

- Sensor modules integrated with algorithm and data fusion capability as a total sensing solution
- Rapid market growth and new technology requirement of sensing solution will accelerate **M&A, Investment, and Partnership** between Automotive/Automotive electronics and ICT Vendors, thus making the ecosystem more dynamic

**ICT Vendors**

- Intel, Apple, Google, Microsoft, Bosch, STM, ibeo, Valeo, Mobileye, Emotient, Turi...

**Automotive and Automotive Electronics Vendors**

- BMW, Tesla, FCA, Ford, Toyota, Delphi, Denso, Continental, ZF...

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Source: ITRI/IEK(2016/09)
Sensing technologies in roadside-surveillance and air monitoring applications

**Application Scenario**

**Traffic Statistics**
- *Congestion in Highway at Rush Hour*

**License Plate Recognition**
- *Suspects detection*

**Object Detection**
- *Traffic Accident Liability Clarification*

**Air Monitoring System**

**City Air Pollution**
- *PM$_{2.5}$ Detection*

**Vehicle Emission**
- *PM$_{2.5}$, CO/CO$_2$ ... detection*

**Sensor Requirement**

- **CMOS Image Sensor**
- **IR Sensor**
- **Gas Sensor**

Source: ITRI/IEK(2016/09)
### 3 major applications of sensor in smart vehicles: Passive Safety, HMI, Active Safety (ADAS)

- **Sensors for Passive Safety**: G-sensor detect collision of accident and trigger airbags
- **Sensors for HMI (Human Machine Interface)**: Detect drivers’ condition such as Face Fatigue sensing
- **Sensors for Active Safety**: Detect the conditions inside/outside/around the car automatically and sending alert before potential accident
- **ADAS (Advanced Driver Assistant System)** is one of the key systems that sensors play important role to realize Active Safety application

#### Sensor Application in Smart Vehicle

<table>
<thead>
<tr>
<th>S/W Platform Cloud Service</th>
<th>Car Play OS, Android Auto OS, S/W, API, Big Data Analytics, Cloud Service…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Messaging</td>
<td>ECU (Analysis, Judgment, Command Control)</td>
</tr>
<tr>
<td>Application System</td>
<td></td>
</tr>
<tr>
<td>Sub Systems</td>
<td>Passive Safety</td>
</tr>
<tr>
<td></td>
<td>HMI</td>
</tr>
<tr>
<td></td>
<td>Active Safety</td>
</tr>
<tr>
<td>Sensing/RF Module</td>
<td></td>
</tr>
<tr>
<td>Sensor</td>
<td>Power Train/Body &amp; Chassis Systems</td>
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<tr>
<td></td>
<td>Infotainment Systems</td>
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<td></td>
<td>ADAS (Advanced Driver Assistance Systems)</td>
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<td></td>
<td>Data acquisition module</td>
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<tr>
<td></td>
<td>IMU, Tire Pressure Sensor Module</td>
</tr>
<tr>
<td></td>
<td>CAN, Ethernet, Cellular WAN…</td>
</tr>
<tr>
<td></td>
<td>CMOS Image/IR Sensor, mmWAVE Radar, LIDAR, Ultrasound…</td>
</tr>
</tbody>
</table>

Source: ITRI/IEK (2016/09)
High Angular Resolution and Long Range drive sensor technology in autonomous vehicle

Higher Angular Resolution

NIR Camera
Camera (3D CIS) for surround
FIR Camera
LIDAR

Short Range
Short Range Radar
Ultrasound Sensor

Long Range
mmWAVE Radar

Lower Angular Resolution

Source: ITRI/IEK(2016/09)
# Sensor technology trend for active safety application: Recognition and Data Fusion

- Major technical challenge to sensor in ADAS system is **recognition enhancement** especially in poor weather and environment
- **Sensor data fusion (mmWAVE Radar + Image Sensing…)** is another target for technology development

<table>
<thead>
<tr>
<th>System</th>
<th>Sensor Module</th>
<th>Requirement</th>
<th>Short Term</th>
<th>Long Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous</td>
<td>Camera (3D CIS) for Surround</td>
<td>Environmental Z-axis measurement</td>
<td>3D Image Recognition</td>
<td>IR Sensor Integration</td>
</tr>
<tr>
<td>Vehicle</td>
<td></td>
<td>Anti-glare and backlight</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Long Range measurement(&lt;100m)</td>
<td></td>
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</tr>
<tr>
<td>mmWAVE Radar</td>
<td></td>
<td>Accurate Angular Resolution</td>
<td>Improve Vision Range (Horizontal &amp; Vertical angle)</td>
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<td>Anti-reflection wave interference</td>
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<tr>
<td></td>
<td></td>
<td>Object recognition ability</td>
<td></td>
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</tr>
<tr>
<td>LIDAR</td>
<td></td>
<td>precise identification in poor weather</td>
<td>SPAD (Single Photon Avalanche Diode) LIDAR : 1,550nm short wavelengths IR</td>
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<td>360° Surround View</td>
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<td></td>
<td></td>
<td>Laser Diode Performance</td>
<td>VESEL Steering (Solid-state LIDAR)、Optical Phased Array</td>
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</tbody>
</table>