The Transportation Futures Research Fellowship
Cascadia Center for Regional Development

PAVEMENT MARKINGS

PAVEMENT QUALITY
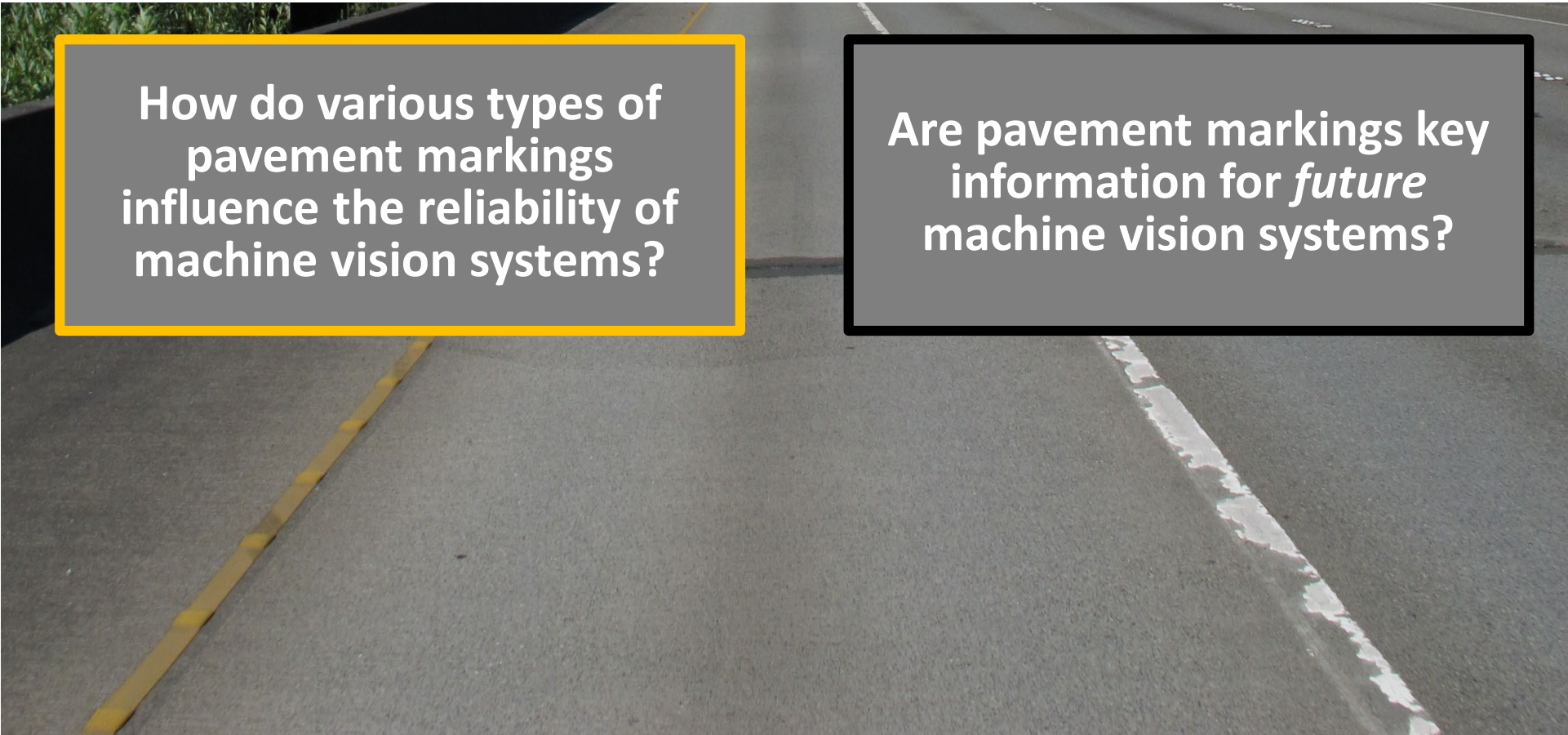
How do various types of pavement markings influence the reliability of machine vision systems?

Are pavement markings key information for *future* machine vision systems?

- **What is the RAS-SDT?**

- **Background**
  - Machine Vision and the Driving Task
  - Issues and Tactics

- **RAS Inputs and Outputs**

- **RAS System and Suite of Tools**

- **RAS Products and Revenue**
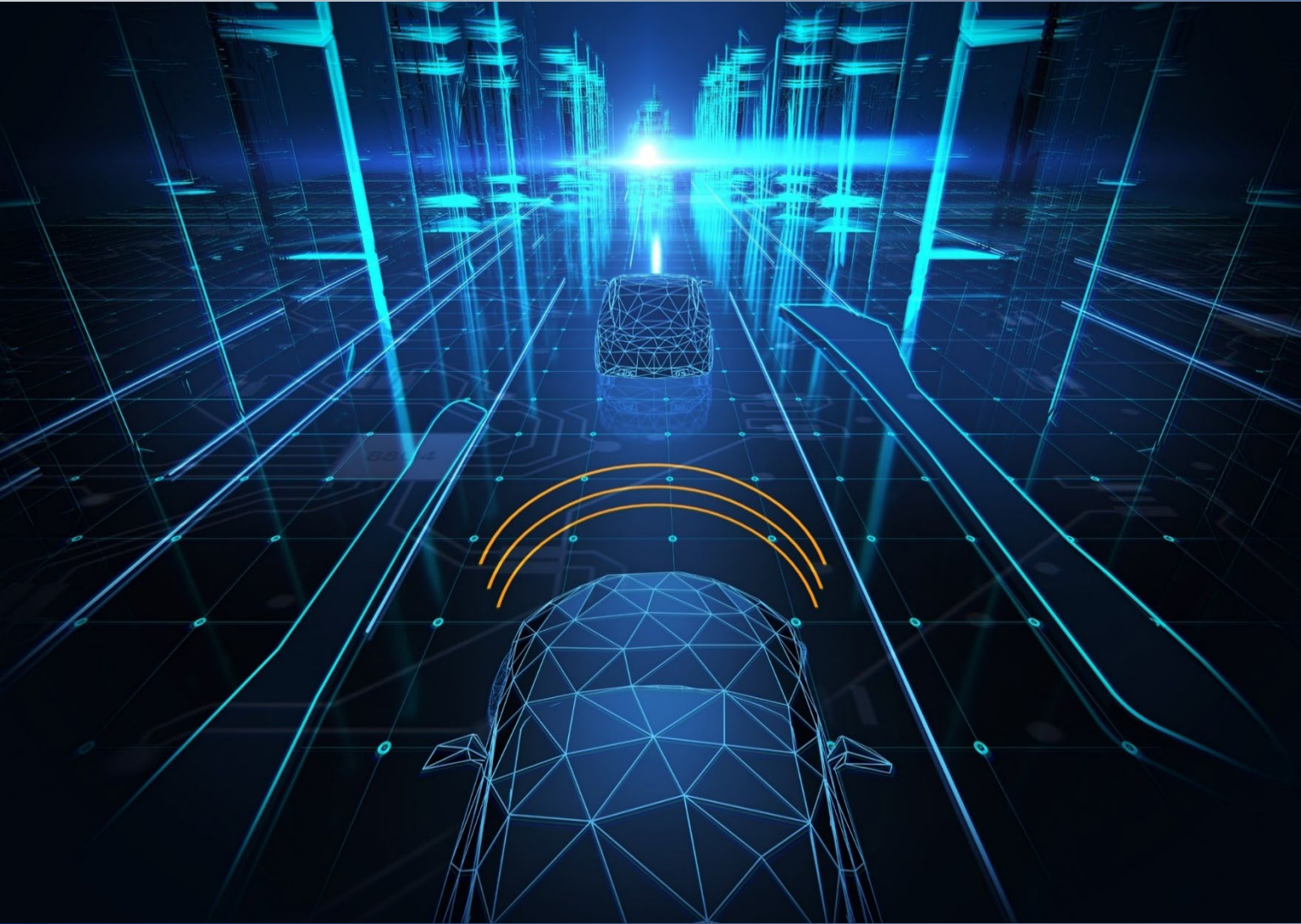
Identify key characteristics of a roadway segment

Compute multi-criteria grade based on features as a function of their relative contribution to risk across various ODDs

Provide that information to vehicle systems

(Edge computing selects an operating regime based on the roadway segment's qualities and state).

NAV

GUIDANCE

OPERATION

INCREASING COMPLEXITY

INCREASING PRIMACY

TASK SATURATION

Passive Systems
- **Visual Light Detection cameras**
- **Infrared cameras**

Active Systems
- **LIDAR**
- **Radar**
- **Lasers**
- **Ultrasonic**
- **GNSS HD Mapping**
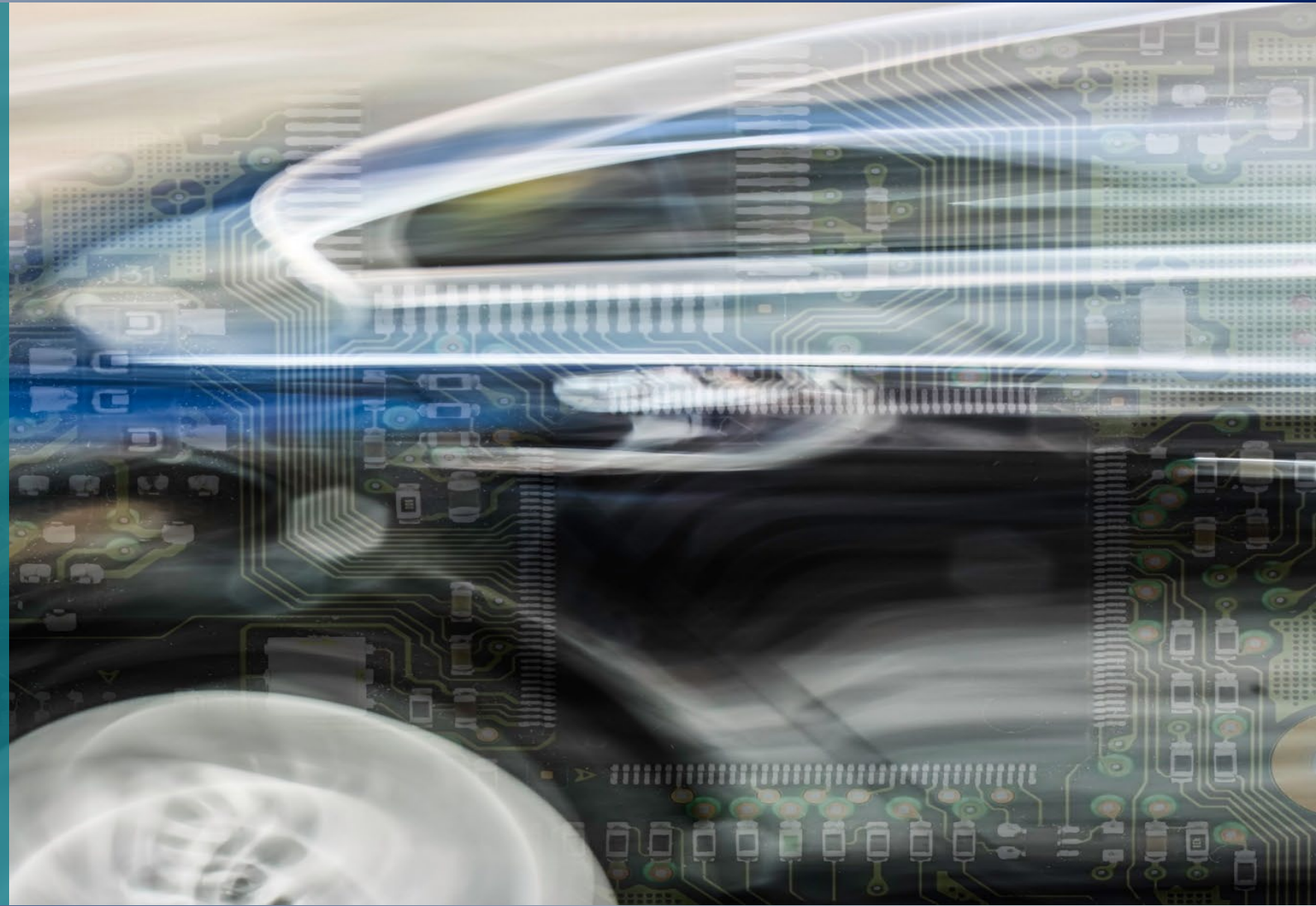
The RAS-SDT identifies the features of roadway segments so that self-driving vehicles can assess the likely workload, anticipate handoff to human operators, and ensure seamless transitions away from Level 4 (HAV) and Level 3 (Conditional) operations.

NOT a certification!
NOT "readiness"!

No warranties
implied or given

Framework for assessment and classification

Risk-based identification of relationship between
SAE Levels of Automation with Operating Design Domain

Clearinghouse for
agencies, manufacturers, and end-users

May supplant government regulations as arbiter of
consistency and uniformity

An essential pathway for agencies to demonstrate the
quality and variety of roadways for testing purposes

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- Your signs

- Your markings

- Your signals

- Your delineators

- Your work zones

- Innovations you add to signing and markings

- Your assertion that these devices work

- ODD definition and responsibility
- Limited correlation with SAE Levels of Automation
- Evolution of system capabilities
- Maintaining interoperability with humans
- Funding and priorities
- Jurisdictional policy differences
- Agency acceptance of scrutiny
- Connected Vehicles (CV) and DSRC applications

- CV can address transient/unexpected events

- CV technology is evolving while CV market penetration is small in many markets

- The end result of CV will be transformative but ADAS needs system information now

- NCHRP 20-24(112) addresses rating for CVs but not assessing roads for the SDT that exists today (whether ADAS for HAV)

- Defining operating regime can be undertaken independently of CV technology

- Delivery of RAS-SDT data can be undertaken independent of CV technology

- Design Criteria and Characteristics

- Functional Classification and Access Control

- Safety Performance [Functions]

- Traffic Volume and Vehicle Behavior

- Consistency of Traffic Control Devices

- Responsiveness of maintenance for pavement condition, weather, signing, and markings

- Environmental conditions and seasonal variations

- A statement of "This road has these characteristics" is different from a guarantee of "This road is suitable for this Operating Design Domain"

- A single "grade" to evaluate a road segment is far too simple

- Different machine systems have differing capabilities but all are subject to task saturation, primarily affected by ambient conditions and unanticipated changes in roadway state

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MULTI-CRITERIA RATING SYSTEM

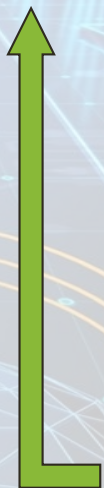## 2 . 1 . 1 . 4 . A . B . 3 . D

Pavement Markings

Roadside Delineation

Regulatory and Warning Signing

Guide Signing

Reliability Grade/ Asset Maintenance

Reliability Grade/ Weather Maintenance

Responsiveness Priority

SDT Failsafe Zone Availability

- **The output is a segment-by-segment multi-criteria rating where each criterion can be used independently**

- **This rating considers the interaction of ODD and infrastructure characteristics, largely independent of vehicle machine vision capabilities**

- **Goal is to allow manufacturer's vehicles to self-select operating regime for a roadway based on machine vision capabilities in any given ODD**
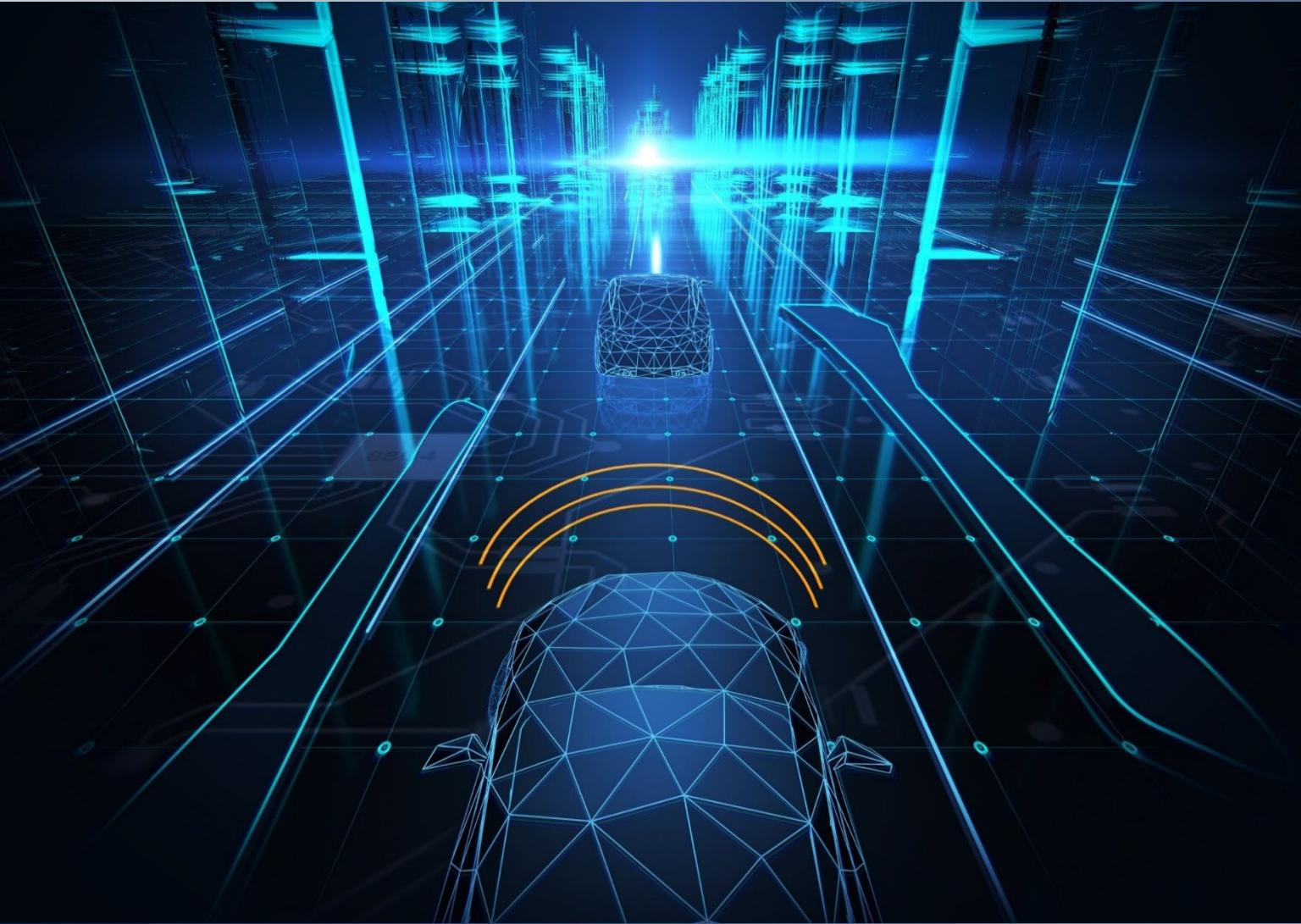
- **Architecture and Criteria**

- **Assessment Process**

- **Assessor Certification**

- **Database Portals**

- **Product Delivery**

Architecture → Process → Certification → Database → Delivery

- **Applicable to all roads of any type**
- **Considers many criteria, yet . . .**
- **Capable of being readily understood**
- **Designed to differentiate between capabilities of similar roads while providing a means of comparing roads with vastly differing characteristics**
- **Considers both SAE Level of Automation and Operating Design Domain but is not dependent on those for establishing capabilities matrix**

Architecture | **Process** | Certification | Database | Delivery

- **Defined process with discrete steps**

- **Documentation readily available to subscribers of the data outputs and data set for deep analysis**

- **Secure, designed to avoid tort exposure**

- **Capable of being deployed with agencies of any size**

- **Designed around mobile interfaces**

| Architecture | **Process** | Certification | Database | Delivery |

Data Collection

Dedicated

Specialized vehicles are used to collect the requisite data or it is sourced using existing contractors and/or data collection systems within transport agencies

Crowd-Sourced

As vehicle camera systems and mobile networks evolve, data on roadway state and vehicle dynamics can be collected without the need for dedicated equipment and perhaps without any funding from the transport agency itself

Architecture | **Process** | Certification | Database | Delivery

Data Processing

Manual Processing

Imagery collected is sent to field staff in the data collection vehicle for manual evaluation; this method will be used for small-scale deployments and cross-checking of automated assessments.

Automated Processing

Imagery and data collected will be processed using machine learning systems. Automation will be used for data reduction and output verification with confidence checks by field staff.

| Architecture | **Process** | Certification | Database | Delivery |

Assessment

- Assign scores to each rated element

- Determine raw harmonized score

- Determine inferred harmonized score

- Conduct risk assessment for various ODD/SAE regime intersections

- Output final Multi-Criteria Score Matrix by map segment

Architecture → Process → **Certification** → Database → Delivery

Contributions of data, feedback, and assessments can be made by any organization with a certification

- vehicle manufacturers
- system suppliers
- transport agency owners and operators
- transit systems
- any organization with the ability to conduct the assessment

Architecture → Process → **Certification** → Database → Delivery

- **Contributions to the dataset would be made by companies certified by a consortium to conduct readiness assessments**

- **Any entity providing contributions or assessments would be required to submit to regular audits and subject to ongoing quality verification**

- **Certification could eventually be assigned to independent organizations such as professional societies**

Architecture | Process | Certification | **Database** | Delivery

Dataset would be managed by the consortium in cooperation with a mapping services provider

Data could be licensed to other mapping services providers, providing revenue for the operation of the system.

Architecture → Process → Certification → Database → **Delivery**

- **Multi-Criteria Rating Matrix delivered via GNSS-enabled mapping systems**

- **Age and reliability information included**

- **Assessor Certification and Quality Verification confidence intervals delivered with matrices**

- **Data expiration capabilities will ensure improper use is mitigated**

Architecture | Process | Certification | Database | **Delivery**

- This data can be delivered through mapping services via localized CV communications hardware and other means and low-latency mobile data

- In partnership with SDT manufacturers, we can obtain data on SDT interactions with TCDs at micro- and macro-scopic levels

- This data is the foundation of what will essentially be a massive naturalistic driving study with information on the roadway and roadside

- A non-profit with membership from numerous organizations, government agencies, and sector businesses
- Funded initially with venture capital and government grants
- Returns funds to founding organizations and establishes R&D fund for future
- Board appoints Executive Director for operations
- Member organizations receive discounted access

- All member organizations provide direction to the consortium Board

- Transport agencies receive valuable information on roadway system state, performance, and needs

- Tier 1 suppliers and OEMs receive performance outcomes from the system; this helps them refine how SDT manufacturers selected a level of autonomy appropriate for any given ODD
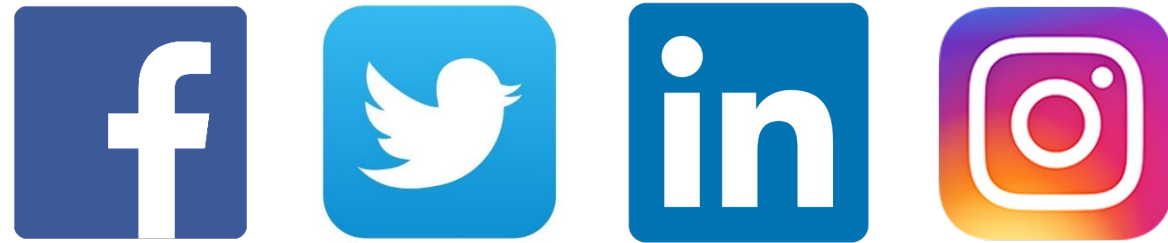
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- **Agencies pay (in kind?) for the assessment service and access to the system**

- **Manufacturers pay to access the data and the tools for development purposes**

- **Vehicle operators pay to use the data from the system for the purposes of vehicle operation regime selection**

- **Researchers and academic institutions pay for the data for the purposes of inquiry and analysis**

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