# Cutting-Edge Operations Concepts:
## Intelligent Infrastructure, Cooperative Driving, Signal Control, and Curbside Management

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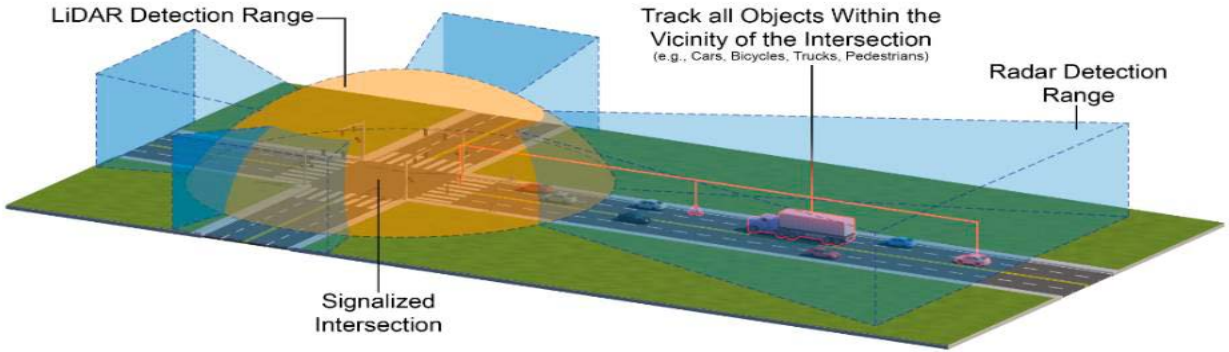
*Photo by Dennis Schroeder, NREL 55200*

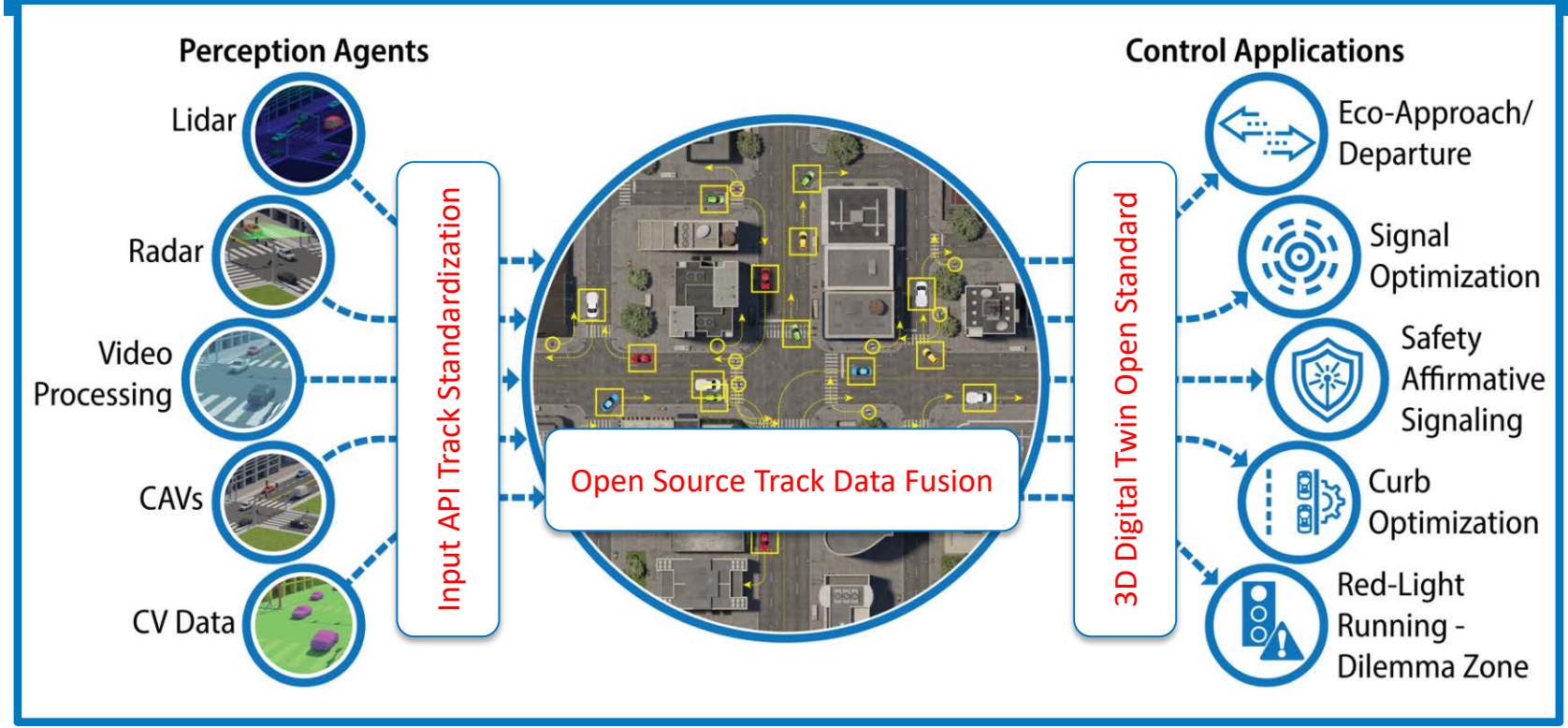
# Hypothesis

***The lack of highly reliable, robust, full state-space awareness of the roadway situation is the current bottleneck for the development and deployment of near-term applications to enhance safety, improve traffic flow, and decrease energy usage – "smart infrastructure control".***




1. Lack of state space awareness of the surrounding traffic situation inhibits any kind of intelligent **mission-critical or safety-critical** infrastructure control today
2. Current attempts are fragmented, not integrated, and largely proprietary.
3. Sensor technology (radar, LiDAR, and video imaging) is maturing rapidly.
4. Objective: Develop and share open framework for processing and messaging of state-space of all objects to accelerate benefits of Infrastructure Perception and Control (IPC) integrated with CAVs, saving lives and energy.

# Overall Cooperative Perception Pipeline Summary




**Data** → **Information** → **Control**

# The Test


Are you willing to cross a busy intersection BLINDFOLDED based wholly on the traffic control info? ---- - That is **Safety Critical**

# Colorado Springs Data Collection – April 2022




# Team & Collaborators

Charles Tripp
Computational Science
Learning and Intelligent Systems

Jeff King,
Wind Energy Systems

Peter Graf
Complex Systems
Simulations and
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## Partners / Collaborators -












# Technical Objectives

**IPC Framework**

- **Open-source referential data fusion engine**
- **Open APIs to any type of sensor**
- **Reference 3D Object Structure (object list) to include**
  - All moving objects
  - Position, velocity, acceleration
  - Confidence and error measures ('co-variance matrix')

**IPC Application Development**

- Serve a variety of applications
- **Automated calibration/health of sensors**
- Broader and faster application development by standardizing input, processing and outputs
- **Strong industry partners and consortia**
- Avoid proprietary traffic control of the past

Field Data Collection – Nevada & Platt – Colorado Springs

# The IPC lab

- Bench space, processing, wall-mount monitors for real-time data feed and visualization
  - Outfitting of lab – in process (controllers, sensors, bench equipment, monitors, etc.)
  - Fully build out summer/fall 2023
- Test track – MOU with CSP in process
- Field deployment (partners – Lakewood, Colorado Springs)
- https://www.nrel.gov/news/program/2023/new-infrastructure-perception-and-control-lab-merges-transportation-and-computational-science.html

Laboratory Space – Building 16

Test Track – Colorado State Patrol


Field Deploy – Partners

# Mobility Infrastructure & Information Interdisciplinary Integration Initiative (MI5)

M: Stan Young

## Infrastructure Perception and Control Laboratory

**Q: Qichao Wang**

Integrating 3D Object Perception for Intersection, Roadway, & Infrastructure Benefits

## Automated Mobility Platforms Lab

**Q: Andrew Duvall**

Light-weight, purpose driven, human engineering mobility for efficiency, equity, and efficacy

## Big Mobility Data for Planning, Operations, and Energy Lab

**Q: ???????**

Data once only used in planning is now critical fuel for real-time mobility systems

## Human Behavior Adoption Lab

**Q: Andy Duvall**

Monitoring, analyzing and feeding human behavior feedback is critical for operational systems

# IPC Projects: Colorado Springs : Perception-Based Adaptive Traffic Management


- **Funding** - 2023 USDOT SMART Grant Awardee
- **Objectives**
  - Protections for vulnerable road users and emergency service respondents
  - Protections against red light runners during low traction & reduced visibility
  - Optimization for emission and travel time reductions

- **Technologies**
  - Real-time, 3D sensors – radar, LiDAR, and video
  - Connected vehicles – private and public including busses, plows, and emergency services
  - Weather sensors – microclimate & precipitation
- **Partners**
  - City of Colorado Springs – LEAD
  - El Paso County, NREL – IPC sensor fusion
  - ISU – improved adaptive algorithm
  - UA – connected vehicle telemetry integration
  - UNCC – simulation and optimization validation
  - Econolite – sensor tech & controller hardware

# Auto-Valet with Active Curb Management

## Automated Parking And Curb Management For Airports: Catalyzing Sustainability, Energy Efficiency And Open-Standards For Enhanced Airport Access

DFW POC: Robert Horton, P.E., rhorton@dfwairport.com
Team Member Organizations: STEER Tech LLC and the National Renewable Energy Laboratory (NREL)

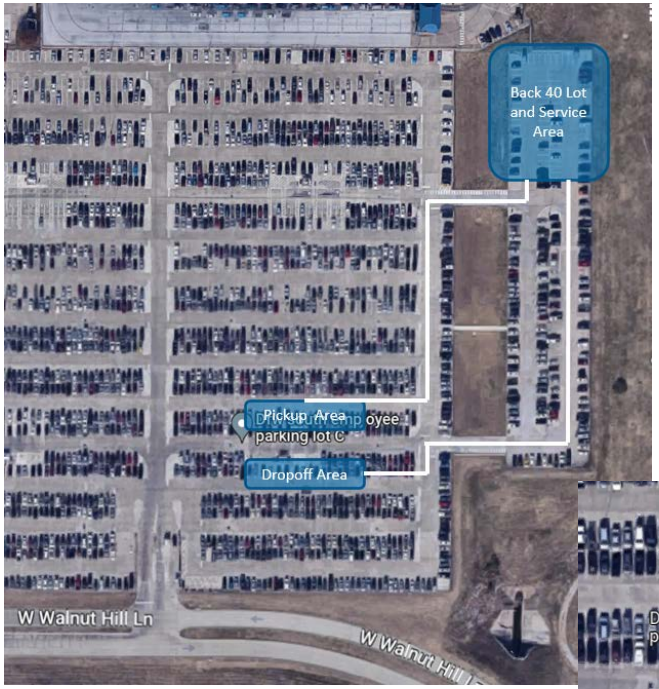
Overview: Emerged from
**ROADMAP TO AUTOMATED MOBILITY SYSTEMS: INFORMING THE PLANNING OF A SUSTAINABLE, RESILIENT TRANSPORTATION ECOSYSTEM FOR DFW AIRPORT**

Three subsystems -

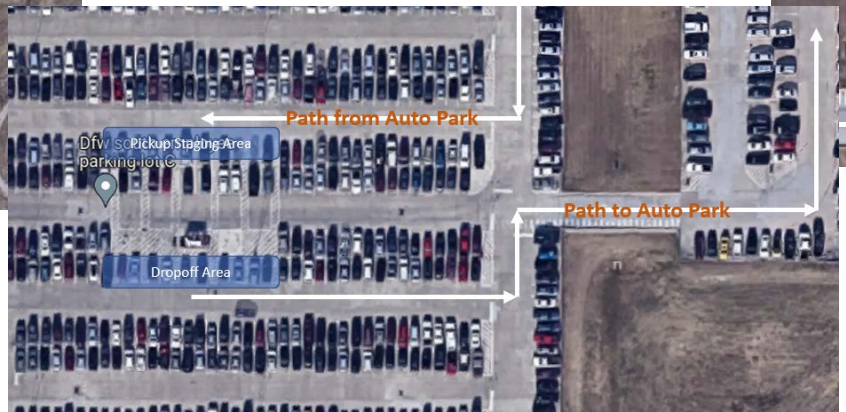
1. **Automated Parking using Low-Speed Vehicle Automation (LSVA)**
   Automated drop-off and pick-up and parking funtions.
2. **Supervisory Parking Management (SPM) for autonomous vehicles (AVs)**
   Includes services such as charging, re-positioning, etc.
3. **Active Curb Management (ACM) system**
   Vehicle-pedestrian-curb interactions, optimize curb space, & airport monitoring

Funded through USDOT grant administered through NCTCOG
Incontracting – anticipated 2024

# Enhanced Employee Parking – Travel Time, Equity, and Energy




- **Remote parking and shuttles can add over 1 hour to employee commute**
- **Growth of DFW requires additional employee parking OR intelligent employee parking**
- **Auto-valet offers higher density parking, automated services (charging), and less travel time**

# Provocative Statements

- Infrastructure needs to be as intelligent (or more intelligent) than the vehicles that drive upon it.
- Intelligent roadway infrastructure provides a path to **near-term, equitable benefits** while complementing CV and CAVs futures.
- **Safety-critical** applications can be enabled through infrastructure perception and control, allowing for increased safety, less congestion, and decreased fuel and GHG
- An IPC framework and robust application development should be priority research areas rivaling CAVs and CV

# Breakout Session Questions

- What are the near-term opportunities to increase safety, reduce congestion and improve energy impact/GHG emissions through advanced traffic operations?
- How can intelligent roadway infrastructure (infrastructure perception and control) provide near-term, equitable benefits while complementing CV and CAVs futures?
- What are the equity considerations for traffic operations? (Are CAVs/CV only applications inherently biased or non-equitable?)
- What are the research gaps?

# Thank You

**www.nrel.gov**

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