National Training Aircraft Symposium (NTAS)

2020 - Perspectives: A Vision into the Future of Aviation

Mar 3rd, 10:45 AM - 12:00 PM

Validation Framework for Autonomous Aerial Vehicles

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Akbas, Mustafa Ph.D., "Validation Framework for Autonomous Aerial Vehicles" (2020). *National Training Aircraft Symposium (NTAS)*. 36.
https://commons.erau.edu/ntas/2020/presentations/36

Validation Framework for Autonomous Aerial Vehicles

Research Efforts on the V&V of Autonomous Vehicles
03/03/2020

M. Ilhan Akbas, Ph.D.

Assistant Professor of Electrical and Computer Engineering

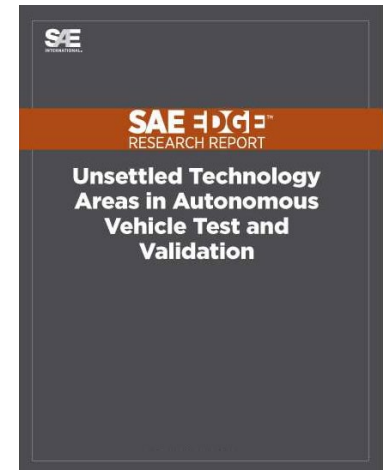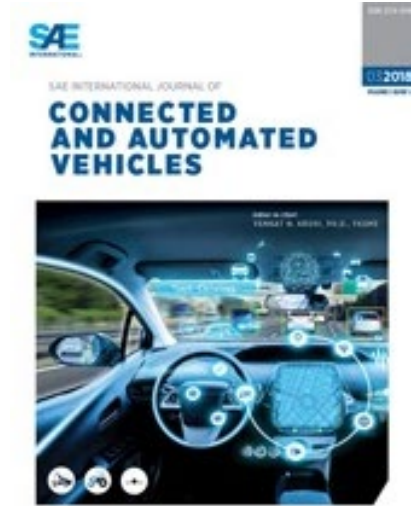**Embry-Riddle Aeronautical University**

Outline

- **About Our Research**

- **Rise of Autonomy and Challenges**

- **Validation Framework**

- **Related Research Themes**

- **Summary**

About Our Research

- **M. Ilhan Akbas**
  - BS in EE, MS and PhD on Communication Technologies
  - Post Grad Work on Modeling & Simulation Projects
  - Industry Experience in Defense, NATO Projects

- **Research** on AVs, CPS, Intelligent Mobility
- **Projects** from NSF, Cyber Florida, State

- **Published** in SAE, IEEE Trans., ACM
- **Teaching** AV, M&S, Soft. Eng, Networks, Security

Outline

- **About Our Research**

- **Rise of Autonomy and Challenges**

- **Testing Framework**

- **Related Research Themes**

- **Summary**

Self-Driving Cars

LEAVE THE DRIVING TO US

1960—The Radio Corporation of America and General Motors are proud to present the future of transport: cars that can drive themselves! You've heard about them for years, but now they're nearly here. Using sophisticated magnetic sensors and radio control, these cars steer autonomously, following guidance wires embedded in the road. Meanwhile, feel free to read, chat with your companions, or get some work done. Major highway systems could be in place as early as 1975, so we can promise that this technology will be coming very, very soon to a road near you. ◼

McKinsey defines the DNA of Industry 4.0 convergent disruption as the proliferation of big data, adv. analytics, HMI and dig.-to-physical transfers.

Autonomous Drones

McKinsey defines the DNA of Industry 4.0 convergent disruption as the proliferation of big data, adv. analytics, HMI and dig.-to-physical transfers.

Market Disruptions

Autonomous Cars
- Changing car ownership, MaaS.
- Insurance, maintenance, towing etc.
- Disabled and elderly will have access to mobility.
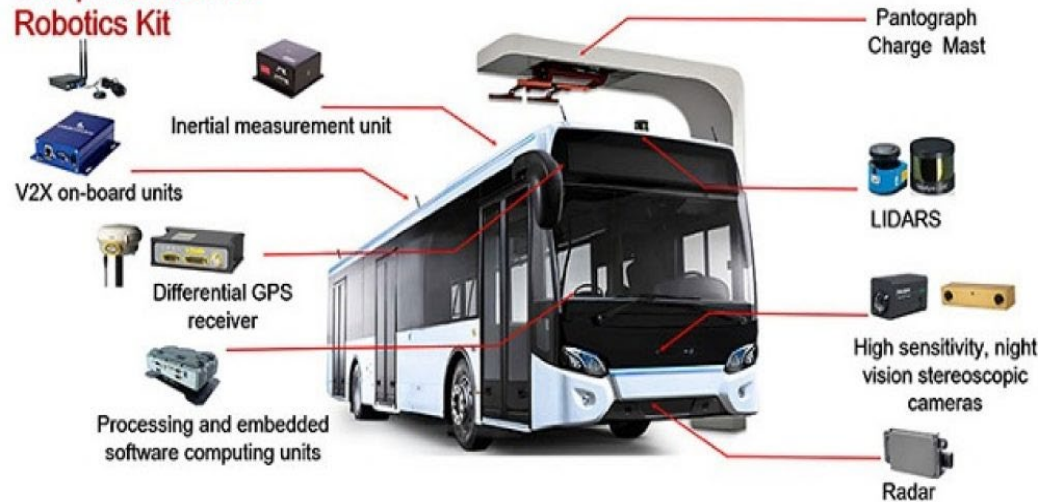- Parking practices will change.

Autonomous Drones
- Ground delivery vs drone delivery.
- Air taxis, MaaS.
- Efficient services such as surveillance, mapping.
- Airline/helicopter piloting changes.

Public Transport

Components of AV Robotics Kit

- Inertial measurement unit
- V2X on-board units
- Differential GPS receiver
- Processing and embedded software computing units
- Pantograph Charge Mast
- LIDARS
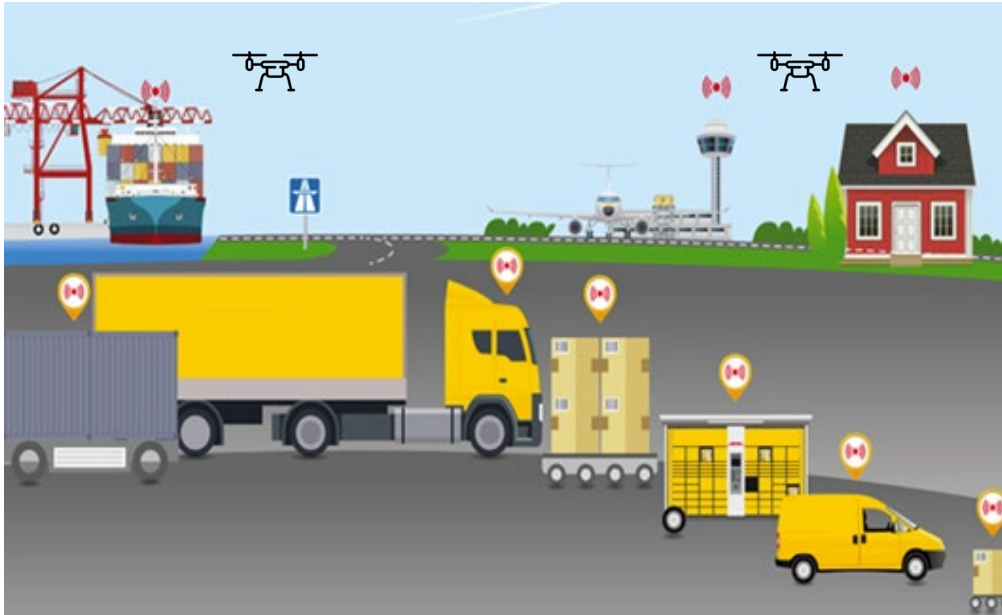- High sensitivity, night vision stereoscopic cameras
- Radar

Potential Impact:

- 24x7 Access
- Reuse of Infrastructure (Utilization)
- On-call Access

Simplifications:

- Limited Paths
- Managed Intersections and Pedestrians
- Lower Speeds

Logistics

Potential Impact:

- Warehouse Operations
- Outdoor Logistics Operations
- Long Haul and Last Mile

Simplifications:

- Controlled Environments
- Human Leverage ("follow-me" model)

Planned Communities

Potential Impact:

- Enable driverless elderly communities
- Increase Safety and Health Simultaneously
- Efficient Architectural Designs

Simplifications:

- Lower Speeds
- Controlled Environments
- Less Complex Interaction Models

Agriculture

Potential Impact:

- 24x7 Operation
- Higher Level of Capability (e.g. Fruit Picking Robots)

Simplifications:

- Lower Speeds
- Less Complex Interaction Models

Autonomous Car Market Estimates

Market estimates vary but several groups estimate the market over $80 Billion in just under fifteen years

Autonomous Car Market Estimates

WIRED — BUSINESS | CULTURE | GEAR | IDEAS
Waymo's Self-Driving Car Crash in Arizona
AARIAN MARSHALL AND ALEX DAVIES TRANSPORTATION 05.04.18 06:46 PM
WAYMO'S SELF-DRIVING CAR CRASH IN ARIZONA REVIVES TOUGH QUESTIONS

CAR TECHNOLOGY
Two Years On, A Father Is Still Fighting Tesla Over Autopilot And His Son's Fatal Crash

The Guardian — Search jobs | Sign in
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Tesla driver dies in first fatal crash while using autopilot mode
The autopilot sensors on the Model S failed to distinguish a white tractor-trailer crossing the highway against a bright sky

ADVANCED TRANSPORT
ONE OF APPLE'S AUTONOMOUS CARS JUST CRASHED
for the technology by 2025, Boston Consulting Group

2025
By 2035, 12 million fully autonomous expected to leap from about $42 billion

The Economist — Topics ∨ | Current edition | More ∨
Autonomous vehicles
A pedestrian has been killed by a self-driving car
A driverless tragedy

CA.GOV State of California
Department of Motor Vehicles
🏠 | Offices | Online Services | Appointments | Driver License
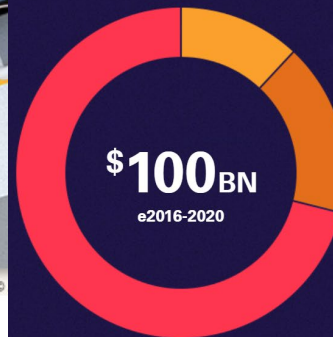Report of Traffic Collision Involving an Autonomous Vehicle

The New York Times
Self-Driving Tesla Was Involved in Fatal Crash, U.S. Says

Market estimates vary but several groups estimate the market over $80 Billion in just under fifteen years

Autonomous Drone Market Estimates

Global
Autonomous Last Mile Delivery Market

OPPORTUNITIES AND FORECAST, 2021-2030

Global Autonomous Last Mile Delivery Market is projected to reach **$75.6 billion** by 2030.

Growing at a **CAGR of 23.7%** (2021-2030)

CISION PR Newswire

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Global Autonomous BVLOS Drone Market to Reach $34.65 Billion by 2029

BIS Research
Emerging Technology Market Intelligence

$100BN
e2016-2020

THE OPPORTUNITY AHEAD

Between now and 2020, we forecast a $100 billion market opportunity for drones—helped by growing demand from the commercial and civil government sectors.

Source: Goldman Sachs Research

Market estimates vary but several groups estimate the market over $40 Billion in just under fifteen years

Autonomous Drone Market Estimates

Market estimates vary but several groups estimate the market over $35 Billion in just under fifteen years

Research Goal

Our research goal is focused on building a framework to identify complex rare scenarios for AV Validation

Current Efforts in AV Validation

- ## Real World Testing
  - Low probability tests are difficult to produce
  - Extremely slow and costly

- ## Test Tracks & Labs
  - Recreates various situations
  - Can't be the sole solution for scenario analysis

- ## Image Dataset Based Testing
  - Datasets of images for assisted control
  - Still slow and costly

- ## Simulation Based Testing
  - Current solutions are not progressive

NY Times - 1991

All current verification efforts are slow, costly, hard to repeat and not progressive

Challenges

Autonomous Cars

- 2D environment
- Established regulations
- Congested operation domain
- More prescriptive (roads, signs etc.)

Autonomous Drones

- 3D environment
- Shifting regulations
- Challenging last 10 feet of delivery
- Possible high number of adversarial actors

Autonomous technology is applicable in both domains with similar challenges and different constraints

Outline

- **About Me**

- **Rise of Autonomy and Challenges**

- **Validation Framework**

- **Other Research Themes**

- **Summary**

Technology Core
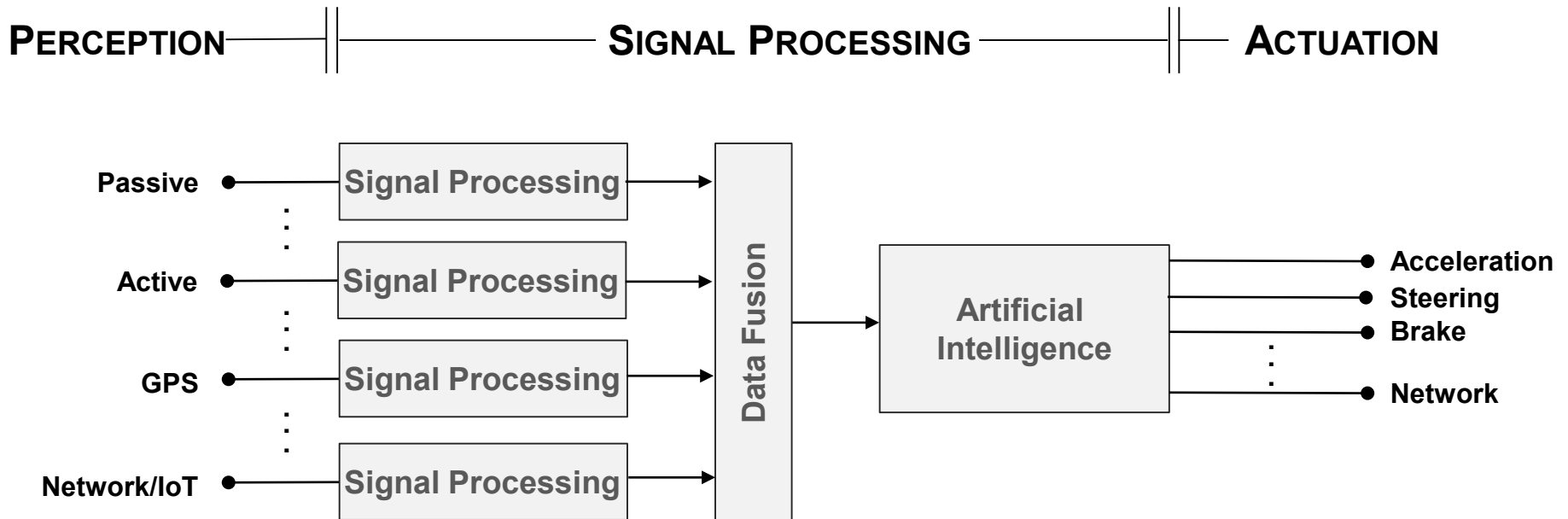
- Hard-wired **vehicles operated by people** replaced by software-defined & networked **computers operated by intelligent agents**

- Fundamental technology is a traditional **networked sensor and signal processing chain with a decision support system**

Critical Issues

- **Conceptual Model**: What are the conceptual models for decision making and perception stages?

- **Test Regime**: What is the test regime that can build confidence for the operation of the AV?

- **Completeness**: How do we understand the state space sufficiently?

- **Accumulative Learning**: How do we know the next version of the AV is safer?

AV Testing Solution
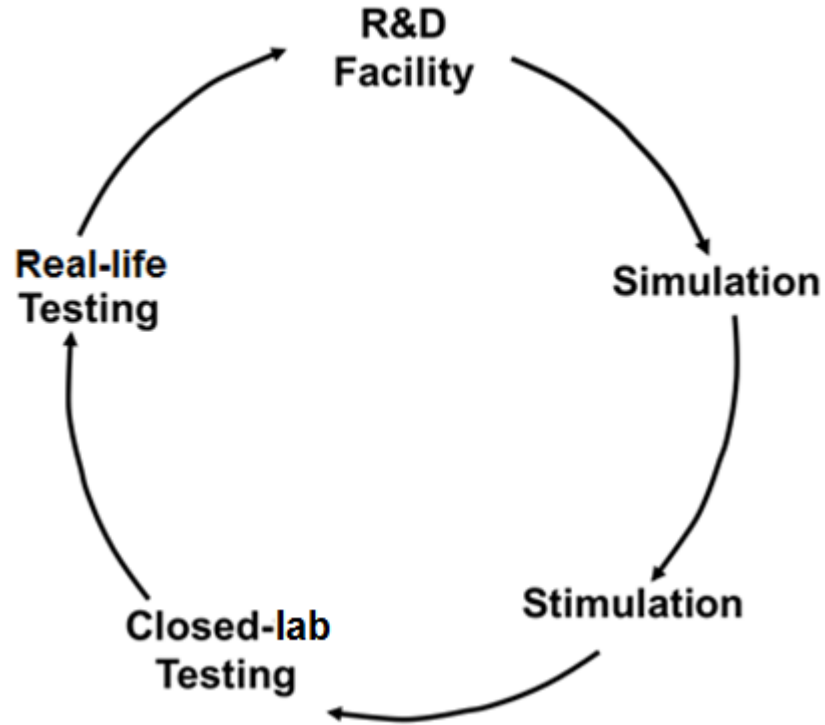
AV Testing Solution
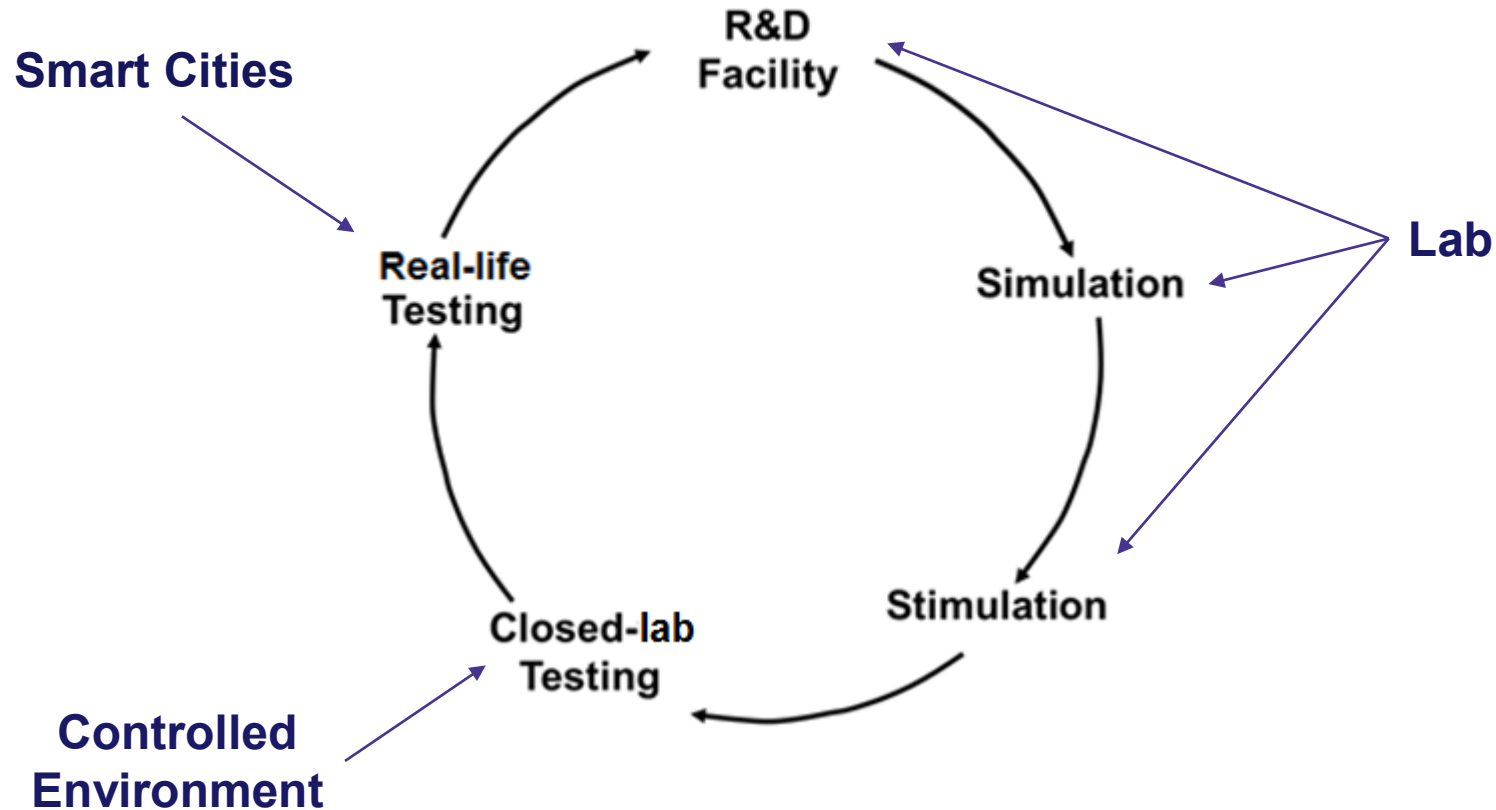
Our research aims to create a full framework to conduct research, development and testing of AVs

Similarities to Hardware V&V

- Semiconductor chips are composed of **complex components**

- Most semiconductor chips can be simulated in the low kilo-hertz **range** while run in giga-hertz range

- There is a need to compress long learning cycle into a **reasonable development cycle**

- There is a need for **robustness to environmental conditions**

- There is a need for **completeness** and **accumulated learning**

Solutions from Hardware V&V

- Use of **<u>abstraction</u>** to decompose the problem

- Development of various **abstraction levels** (transistor, gate, RTL, micro-architecture, architecture, network)

- At the highest level:
  - Formal verification
  - Constrained-random test generation
  - Real-world test injection
  - Coverage analysis

Our solution aims to use the powerful methods of hardware and software V&V for Autonomous Vehicles

Scenario Testing Solution

- ## Characterization
  - Decompose data sets from physical world into atomic blocks

- ## Scenario generation
  - Build virtual models using atomic elements

- ## Coverage analysis
  - Track cross-product cases

- ## Certification
  - Based on coverage completion

**The solution is focused on the
Decision Making of Autonomous Vehicles**

Scenario Abstraction
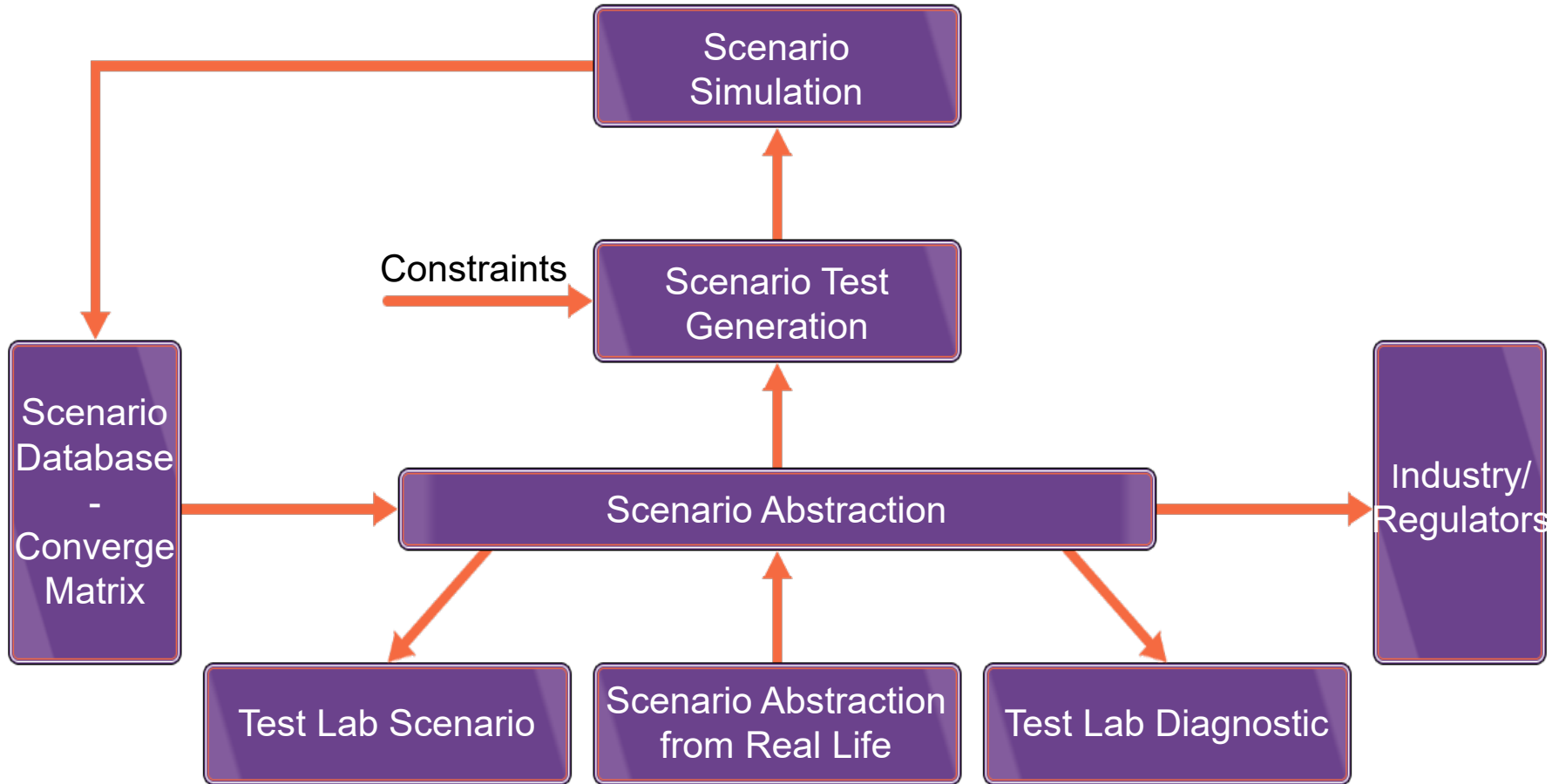
The framework serves as a ground truth for testing other sources of error such as environmental conditions or sensor failures

Formulation of Test Scenarios

Assertion functionality on top of this inner core provides the concepts of good/bad or pass/fail

Simulation Architecture

Implementation

- **Semantic language is used to define scenarios**

- **Actors, environment are created/validated**

- **Low fidelity simulator is the first step for implementation**

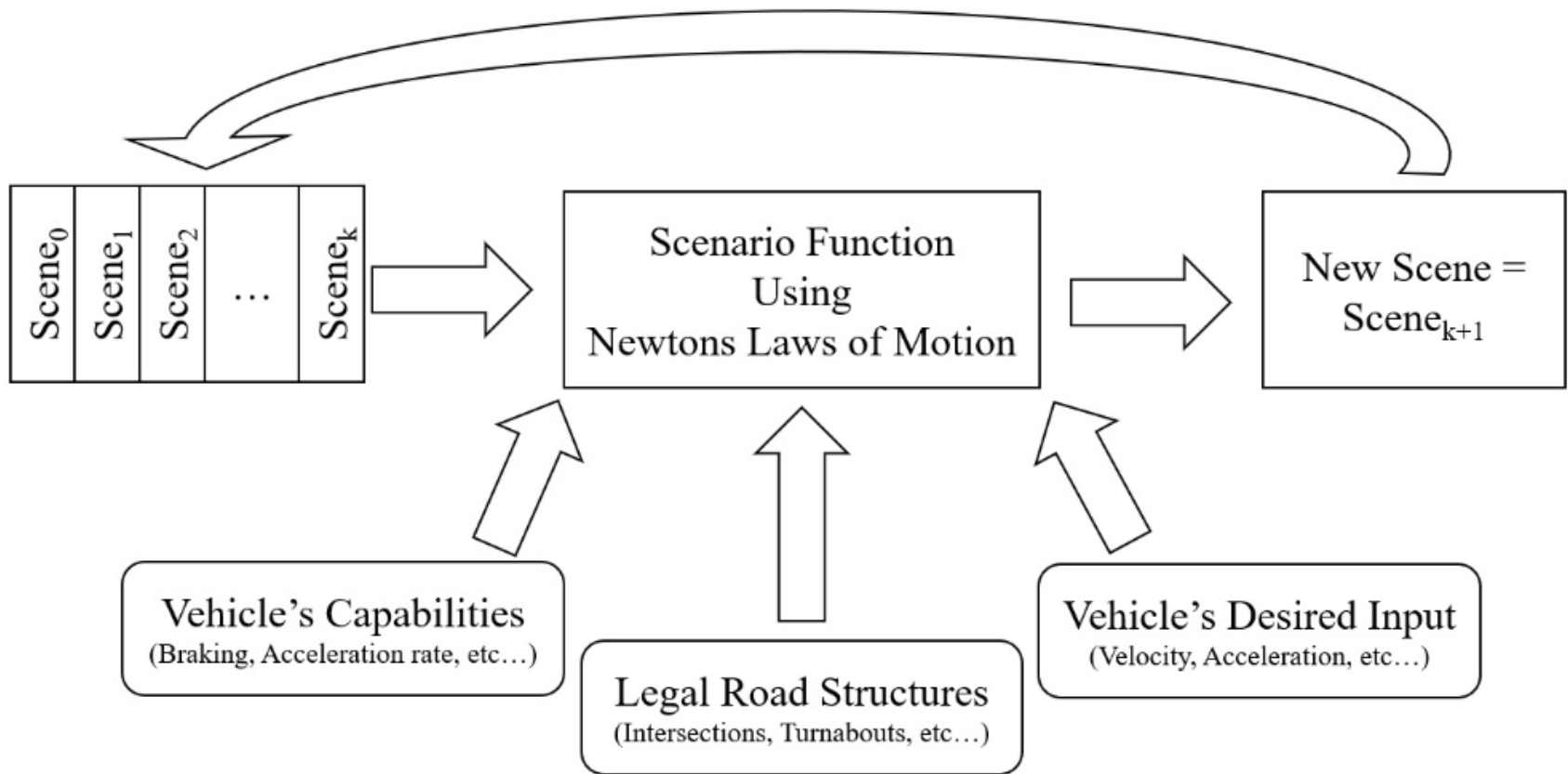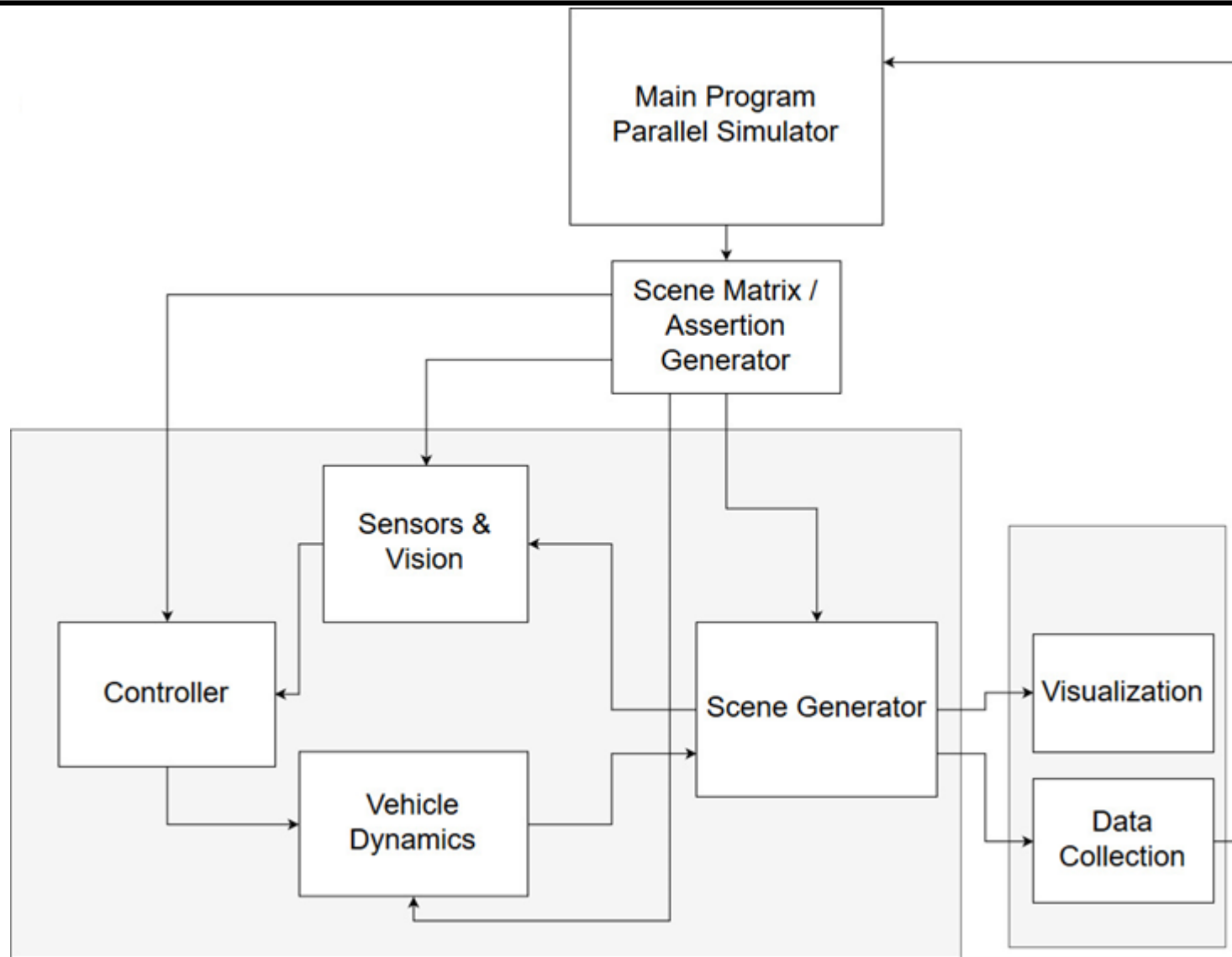|									
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2	1.0000000e+00	8.0000000e+01	3.0000000e+00	1.0000000e+00	0.0000000e+00	2.4587200e+01	2.0000000e+02	8.9486000e-03	-1.3291000e-02
3	1.0000000e+00	1.2000000e+02	1.0000000e+00	1.0000000e+00	1.0000000e+00	1.7881600e+01	2.0000000e+02	-5.0939000e-03	-1.2988000e-02
4	1.0000000e+00	1.1000000e+02	1.0000000e+00	1.0000000e+00	1.0000000e+00	3.1292800e+01	1.0100000e+02	-1.1618000e-02	-1.6683000e-02
5	1.0000000e+00	1.5000000e+02	5.0000000e+00	1.0000000e+00	1.0000000e+00	3.3528000e+01	2.0000000e+00	2.0745000e-02	-7.3204000e-03
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7	1.0000000e+00	1.0000000e+02	3.0000000e+00	1.0000000e+00	1.0000000e+00	2.6822400e+01	1.2000000e+01	-1.2991000e-02	-2.7227000e-03
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10	1.0000000e+00	1.1000000e+02	1.0000000e+00	1.0000000e+00	0.0000000e+00	3.5763200e+01	1.2200000e+02	-1.6165000e-02	1.1489000e-02
11									
12	2.0000000e+00	2.0000000e+00	2.0000000e+00	-3.0000000e+00	1.0000000e+00	2.0000000e+00	2.0000000e+00	1.1000000e-01	0.0000000e+00 5.6000000e-01
13	1.0000000e+00	3.0000000e+00	2.0000000e+00	0.0000000e+00	8.0000000e+00	3.0000000e+00	1.0000000e+01	8.4000000e-01	1.0000000e+00 4.9000000e-01
14	2.0000000e+00	3.0000000e+00	2.0000000e+00	3.0000000e+00	7.0000000e+00	4.0000000e+00	6.0000000e+00	2.0000000e+00	0.0000000e+00 7.3000000e-01
15	2.0000000e+00	3.0000000e+00	2.0000000e+00	0.0000000e+00	1.0000000e+00	5.0000000e+00	1.0000000e+01	7.9000000e-01	0.0000000e+00 4.6000000e-01
16	1.0000000e+00	1.0000000e+00	1.0000000e+00	3.0000000e+00	7.0000000e+00	2.0000000e+00	5.0000000e+00	5.0000000e-02	0.0000000e+00 7.4000000e-01
17	2.0000000e+00	2.0000000e+00	1.0000000e+00	1.0000000e+00	1.0000000e+01	5.0000000e+00	6.0000000e+00	6.0000000e-02	0.0000000e+00 9.6000000e-01
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19	2.0000000e+00	1.0000000e+00	2.0000000e+00	2.0000000e+00	8.0000000e+00	4.0000000e+00	8.0000000e+00	1.4000000e-01	0.0000000e+00 4.2000000e-01
20	2.0000000e+00	1.0000000e+00	2.0000000e+00	2.0000000e+00	1.0000000e+01	4.0000000e+00	3.0000000e+00	2.5000000e-01	1.0000000e+00 9.7000000e-01
21	2.0000000e+00	2.0000000e+00	1.0000000e+00	2.0000000e+00	9.0000000e+00	1.0000000e+00	3.0000000e+00	8.4000000e-01	1.0000000e+00 3.2000000e-01

View Streaming Video

AV Testing Framework Roadmap

Simulation & Scenario Testing

AV Testing

Time
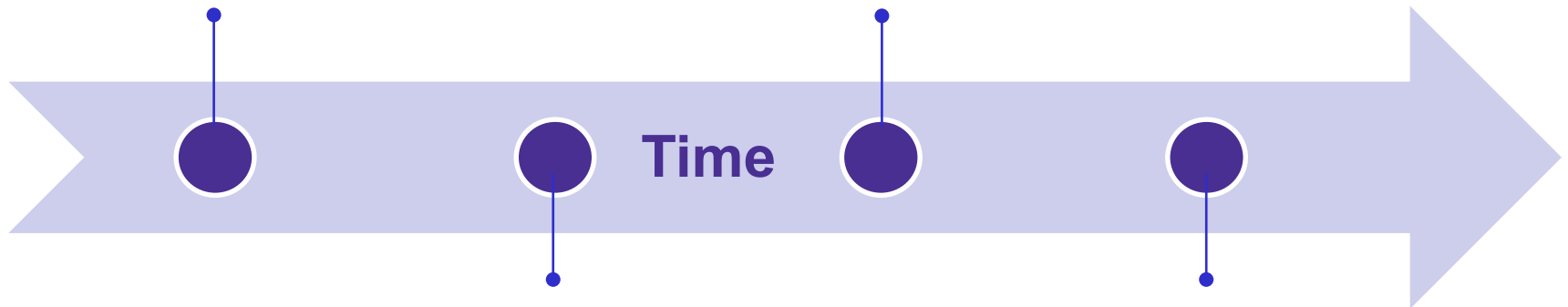
Hardware in the Loop Testing

Individual Sensor Testing

Next: Automatic test pattern generation to find edge cases, collaboration with environmental and HiL Simulators

Outline

- **About Me**

- **Rise of Autonomy and Challenges**

- **Testing Framework**

- **Related Research Themes**

- **Summary**

Transportation Operating System

- Transportation System is inefficient

- Utilization of **Market Economics** and Network Ideas

What if we could dynamically use the transportation system resources?

Incentive Mechanisms for Mobile Crowdsensing

- **Spatial and temporal coverage** for sampling in a target area and isolated sub-regions is important

- An **incentive mechanism** that dynamically assigns compensation for data collection in the sub-regions
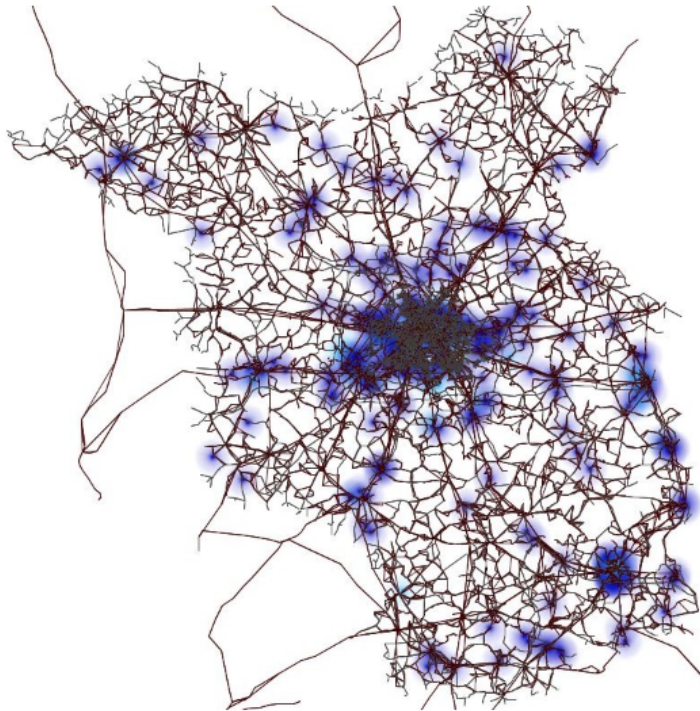
How can we incentivize users of ITS for coverage?

Cooperation of AVs with Human Operators

- Humans have operating languages, AVs need it as well

What about the tourists and residents?
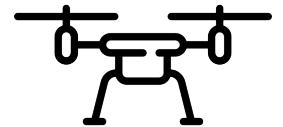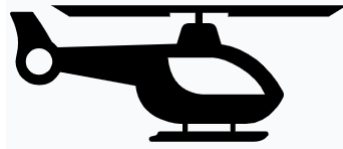
Outline

- **About Me and Florida Poly**

- **Rise of Autonomy and Challenges**

- **Florida Poly Solution**

- **Florida Poly Research Themes**

- **Summary**

Thank You!

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