National Training Aircraft Symposium (NTAS) | 2020 - Perspectives: A Vision into the Future of Aviation

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Validation Framework for Autonomous Aerial Vehicles

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Validation Framework for Autonomous Aerial Vehicles

Research Efforts on the V&V of Autonomous Vehicles

03/03/2020

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Outline

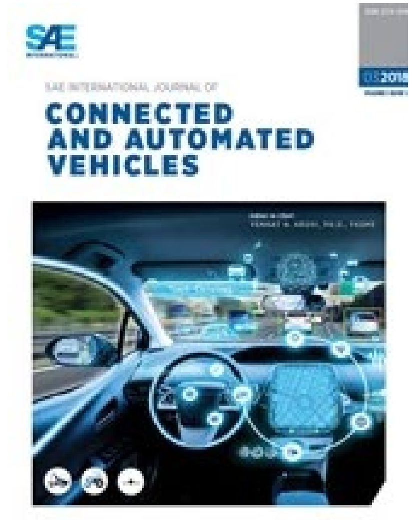
- About Our Research
- Rise of Autonomy and Challenges
- Validation Framework
- Related Research Themes
- Summary

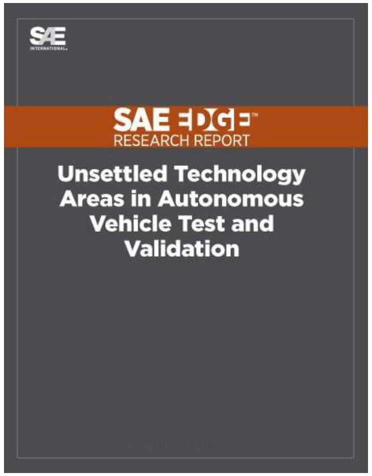
About Our Research

- **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

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- Rise of Autonomy and Challenges
- Testing Framework
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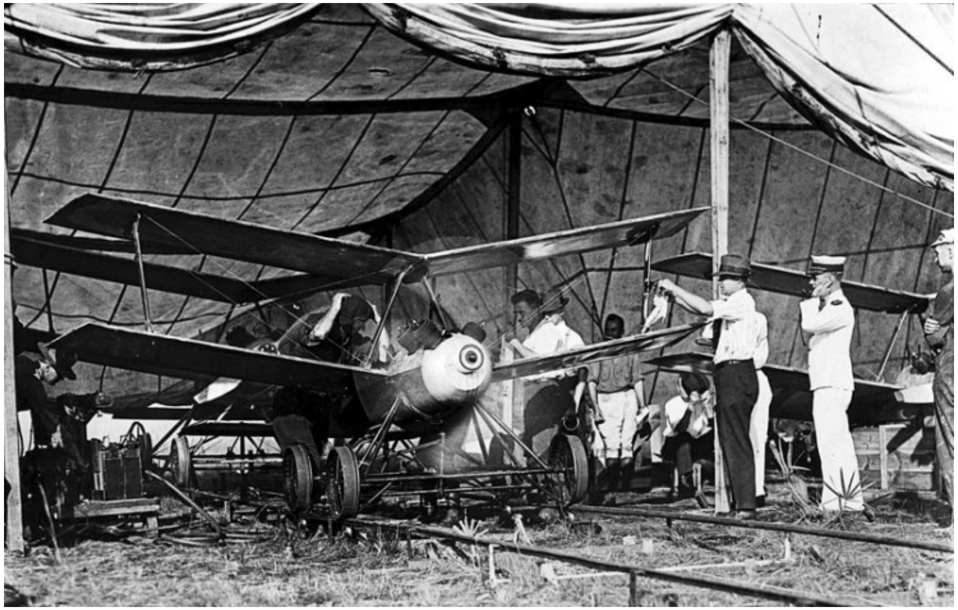
Self-Driving Cars

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

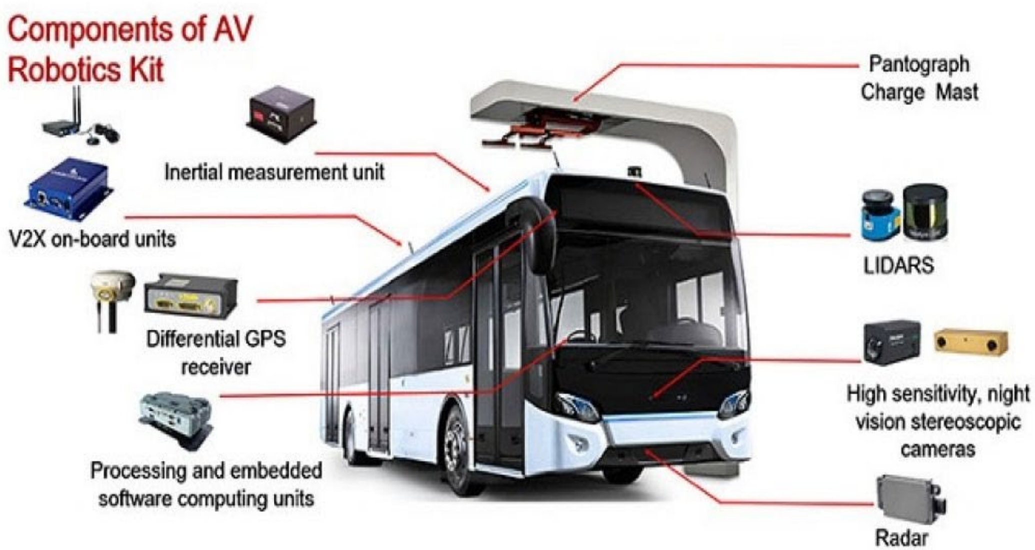
Autonomous Cars

- 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



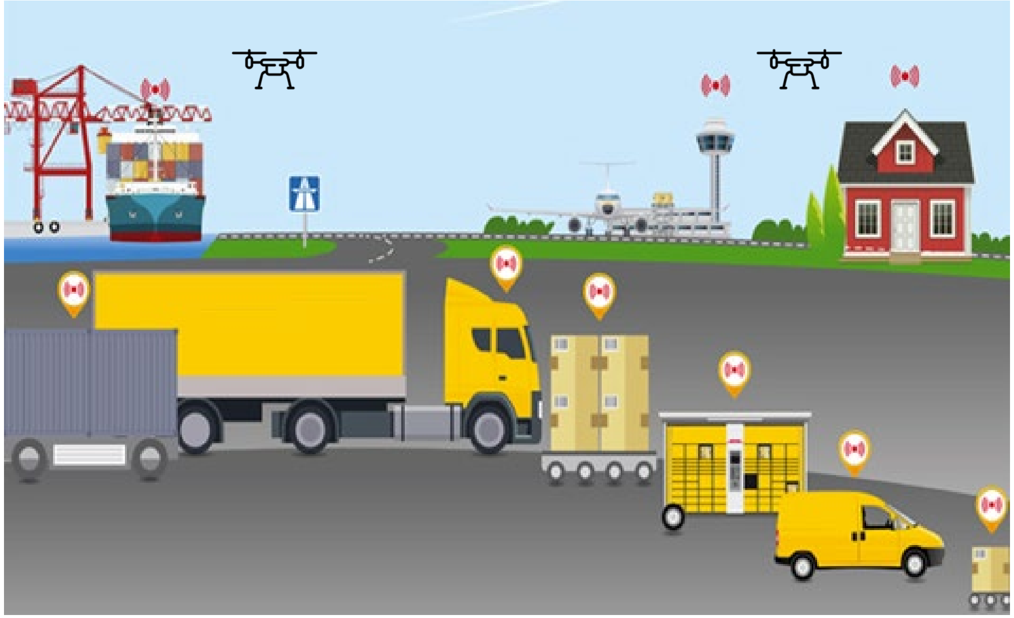
Potential Impact:

- 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

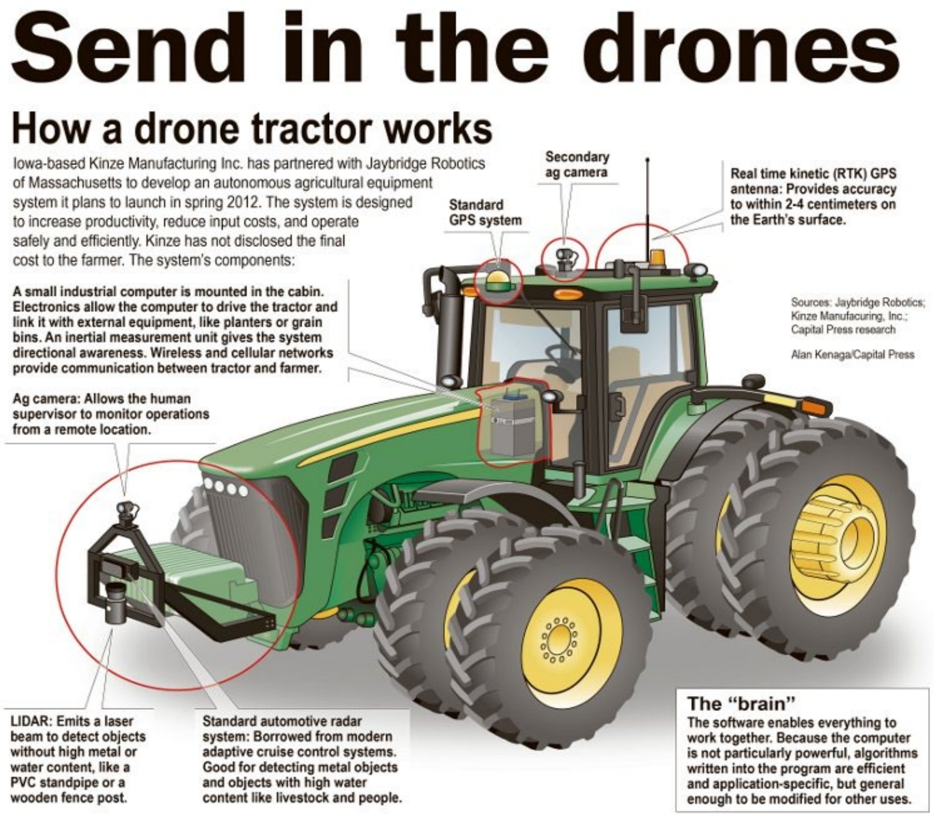
Potential Impact:

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

Simplifications:

- Lower Speeds
- Controlled Environments
- Less Complex Interaction Models

Agriculture



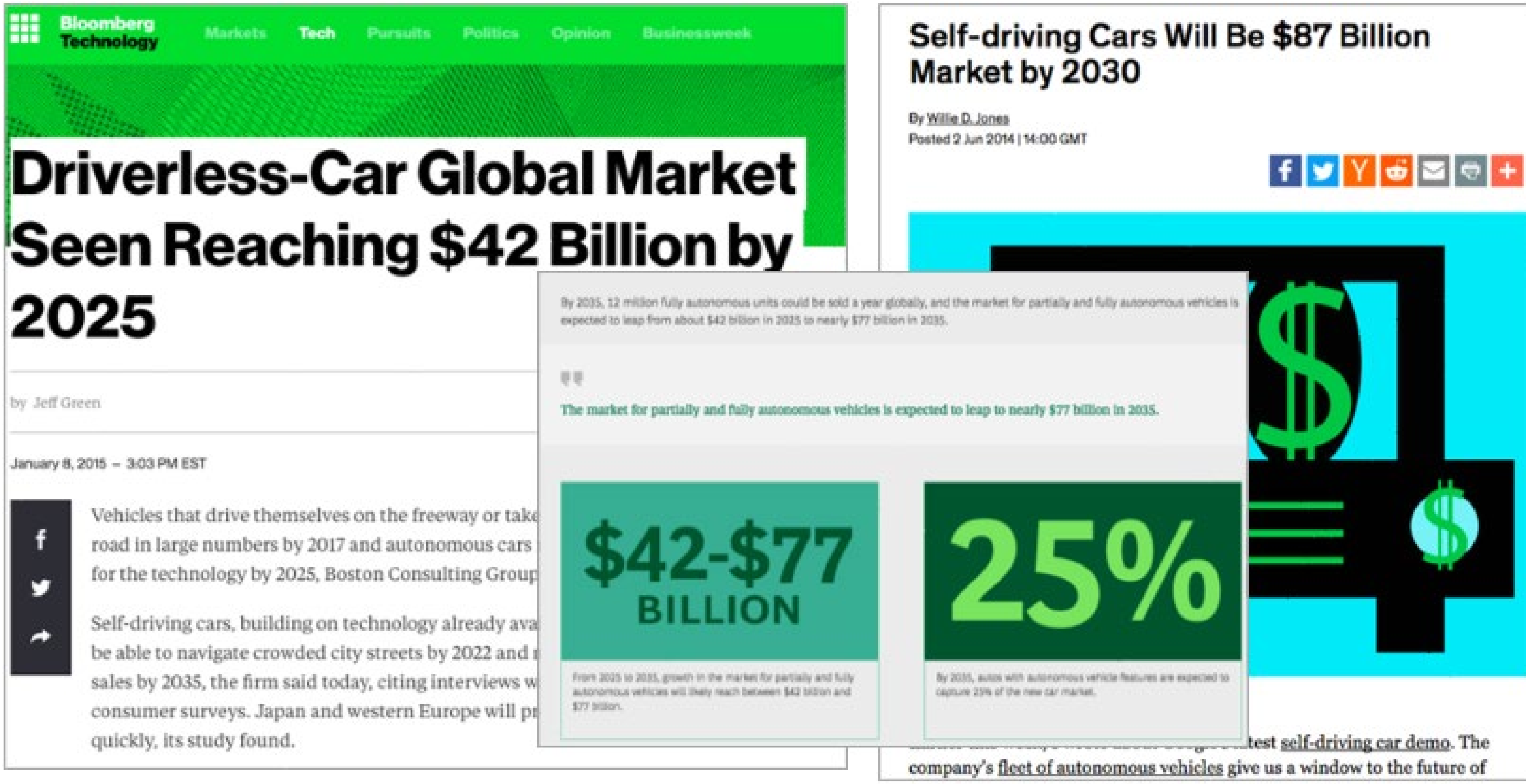
Potential Impact:

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

Simplifications:

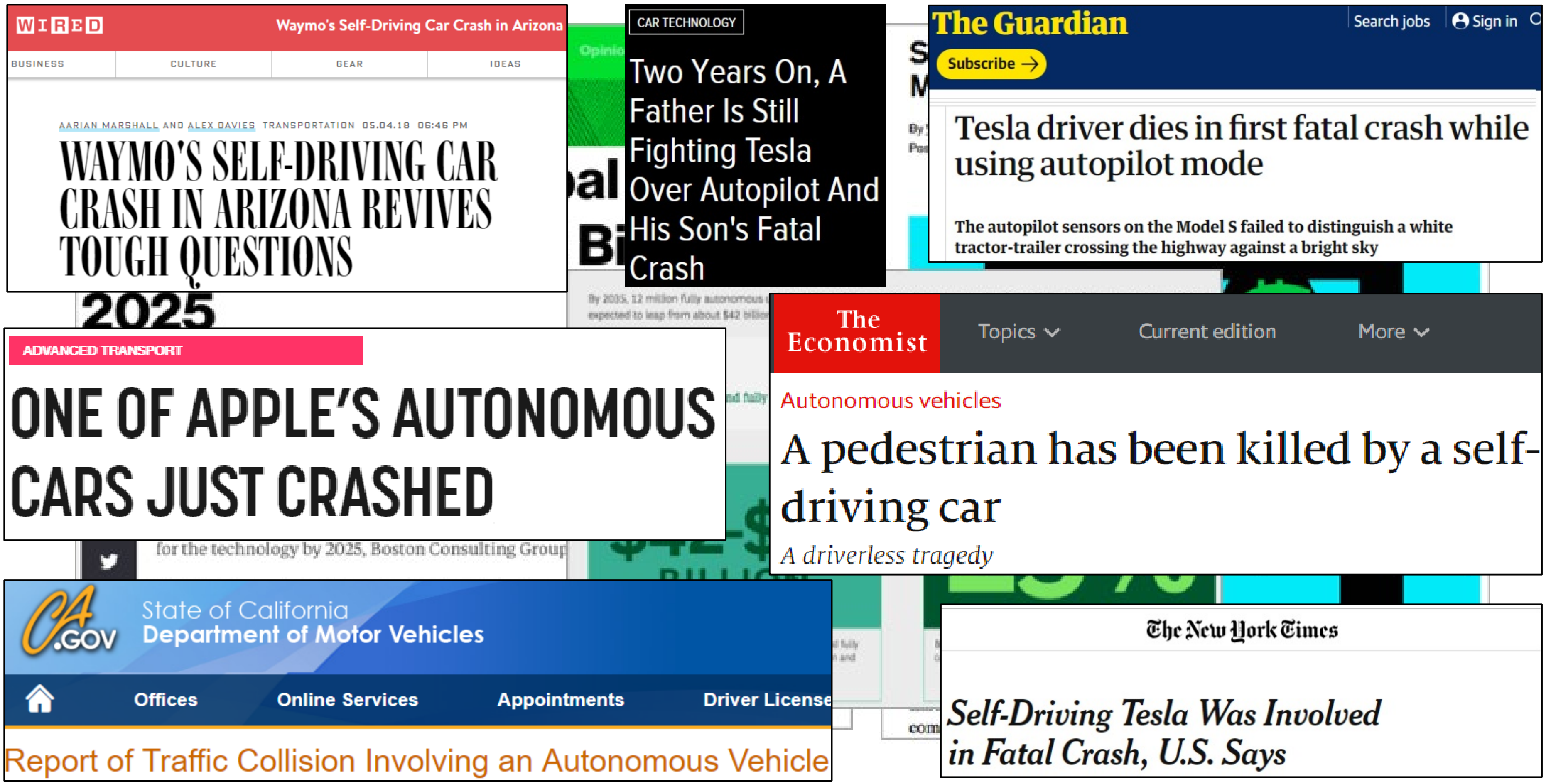
- Lower Speeds
- Less Complex Interaction Models

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

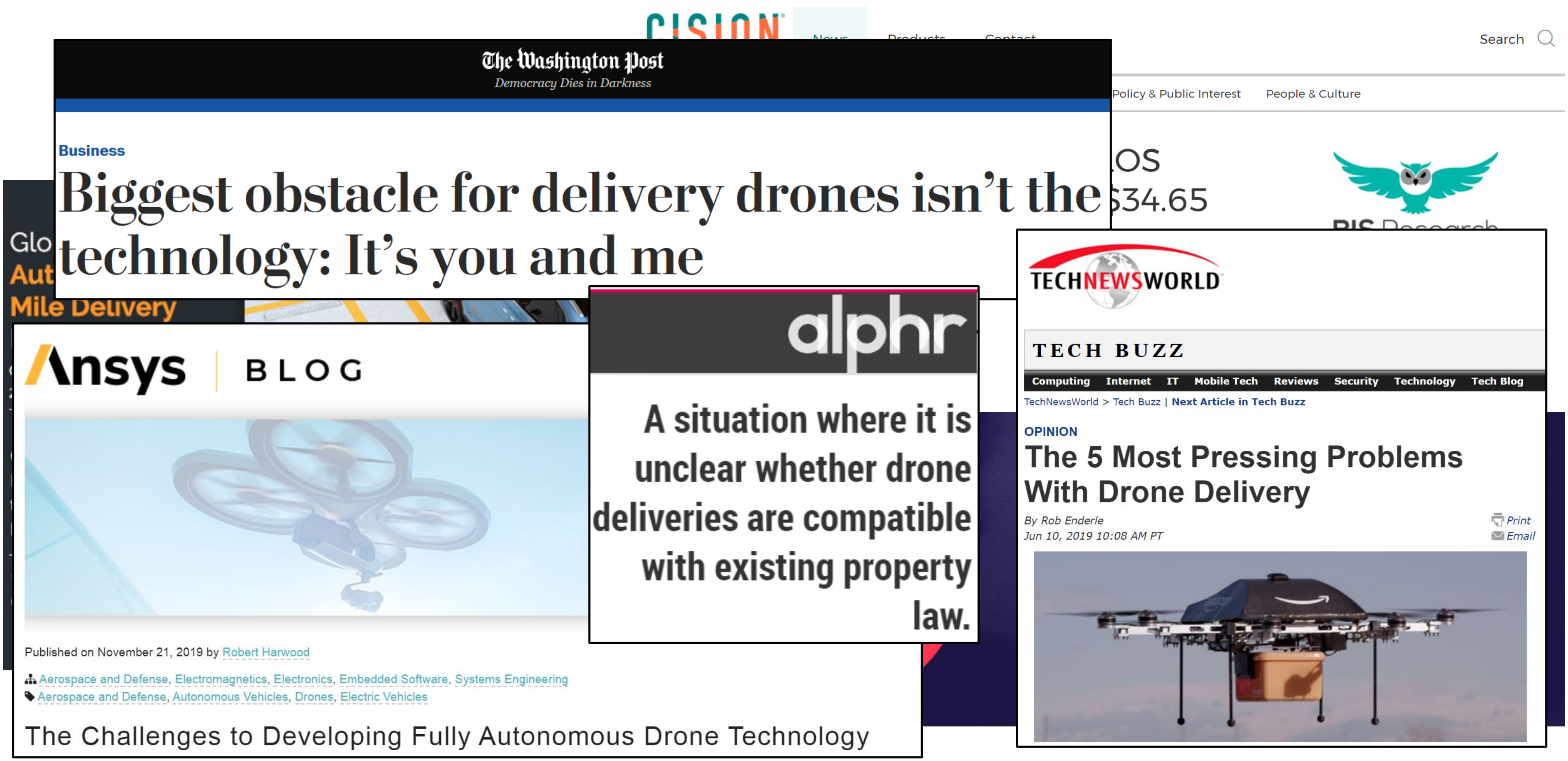


Market estimates vary but several groups estimate the market over $80 Billion in just under fifteen years

Autonomous Drone Market Estimates

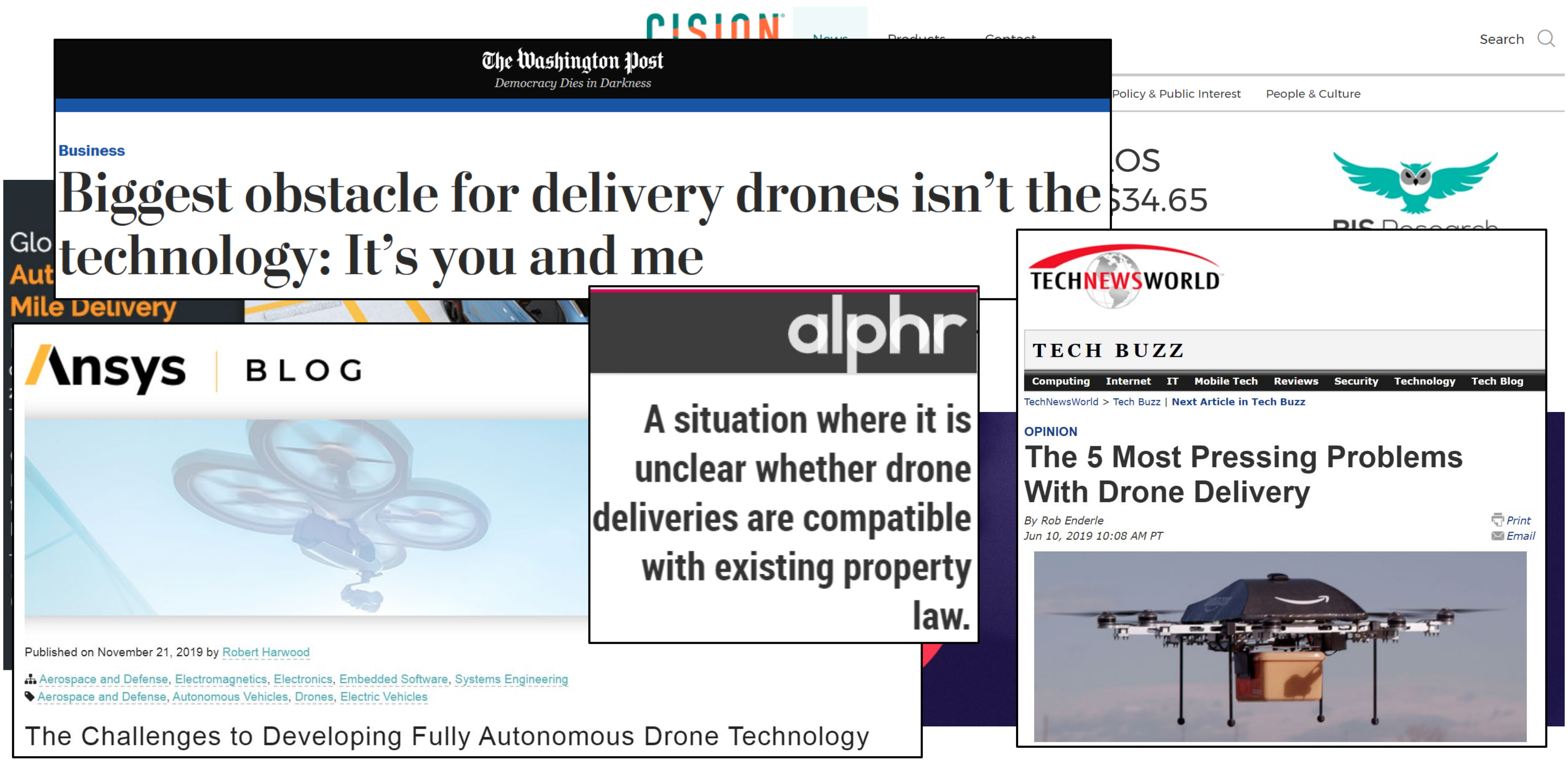
Market estimates vary but several groups estimate the market over $40 Billion in just under fifteen years

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


The Test Track Is King Of the Road No More

High Tax-Free N.Y. Bond Yields!

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

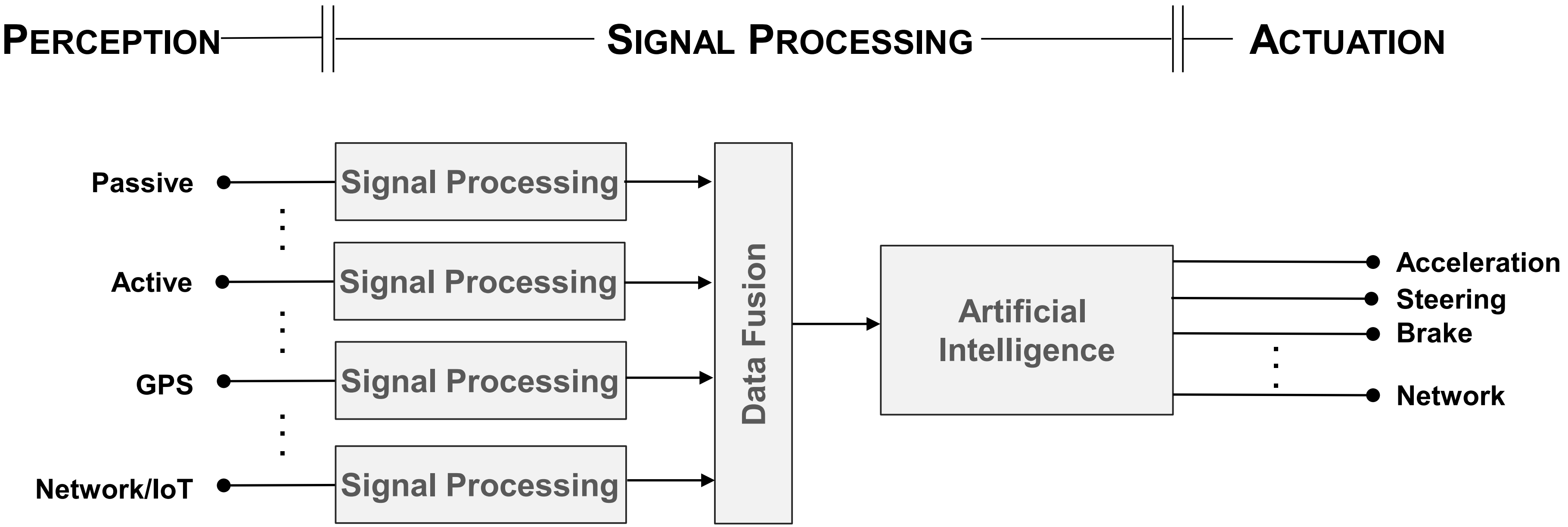
- 3D environment
- Shifting regulations
- Challenging last 10 feet of delivery
- Possible high number of adversarial actors

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

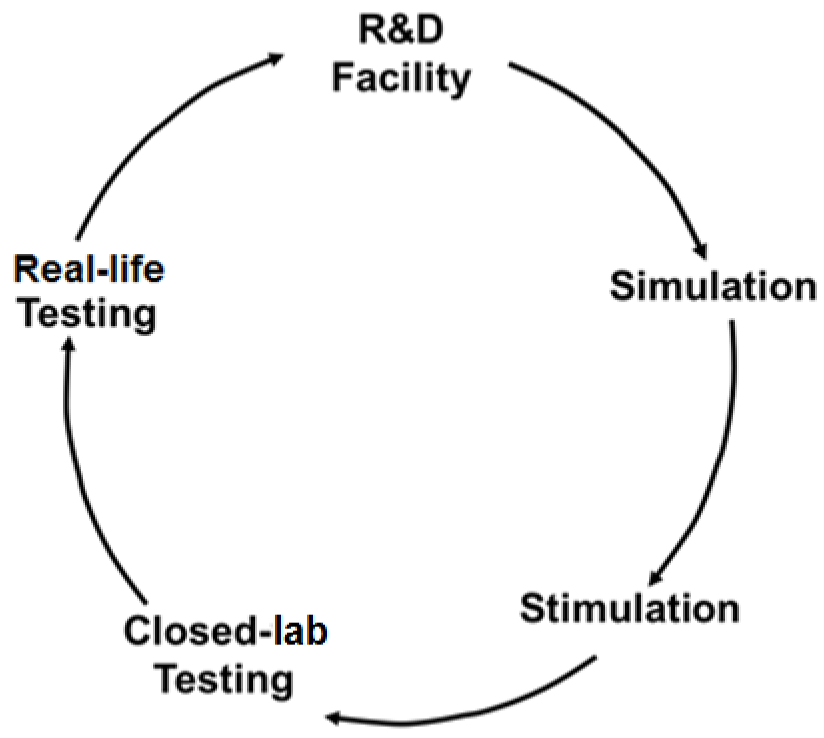


- Hard-wired **vehicles operated by people** replaced by software-defined & networked **computers operated by intelligent agents**
- Fundamental technology is a traditional **networked sensor and signal processing chain with a decision support system**

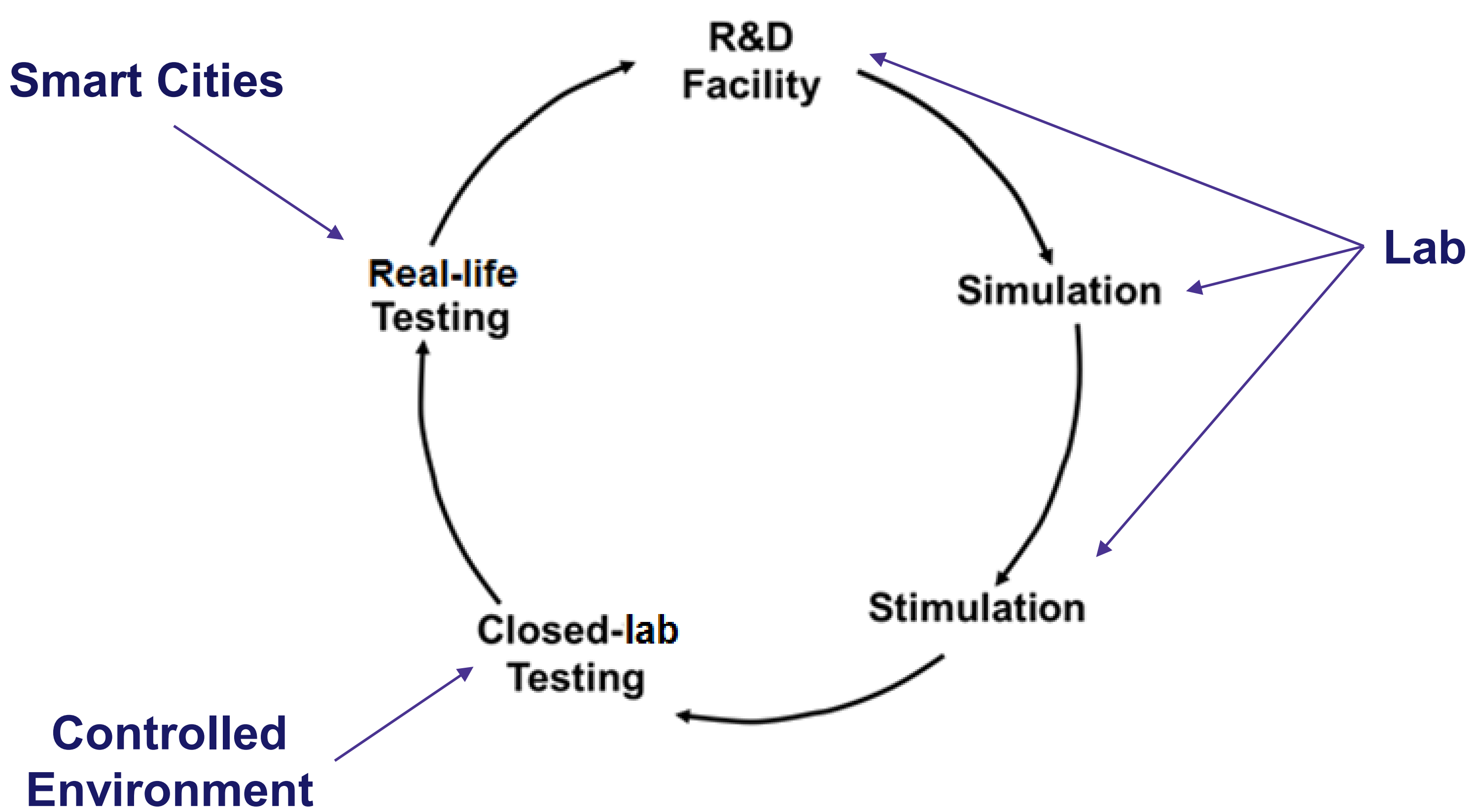
Critical Issues

- **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 **abstraction** 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

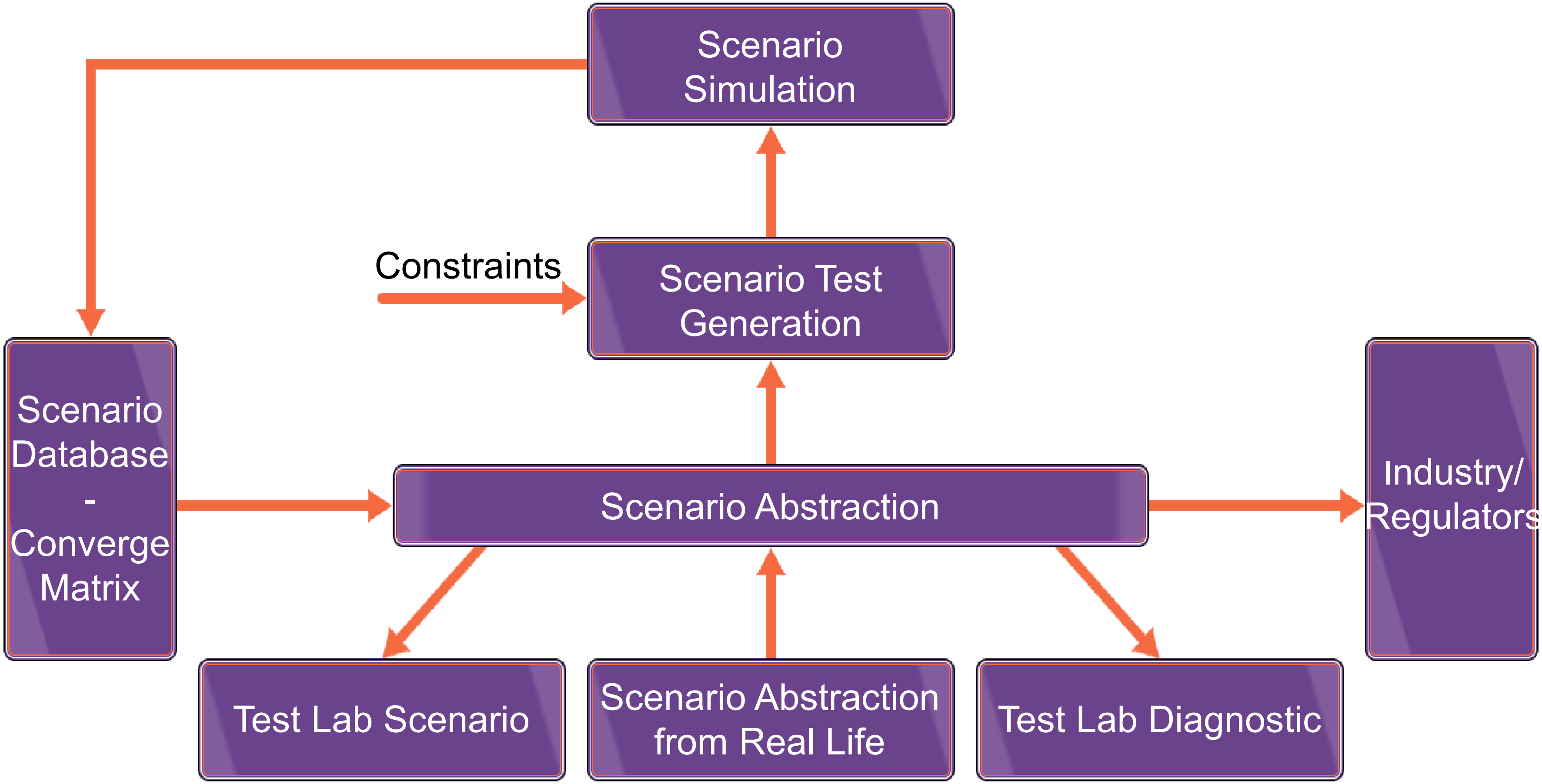
Our solution aims to use the powerful methods of hardware and software V&V for Autonomous Vehicles

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

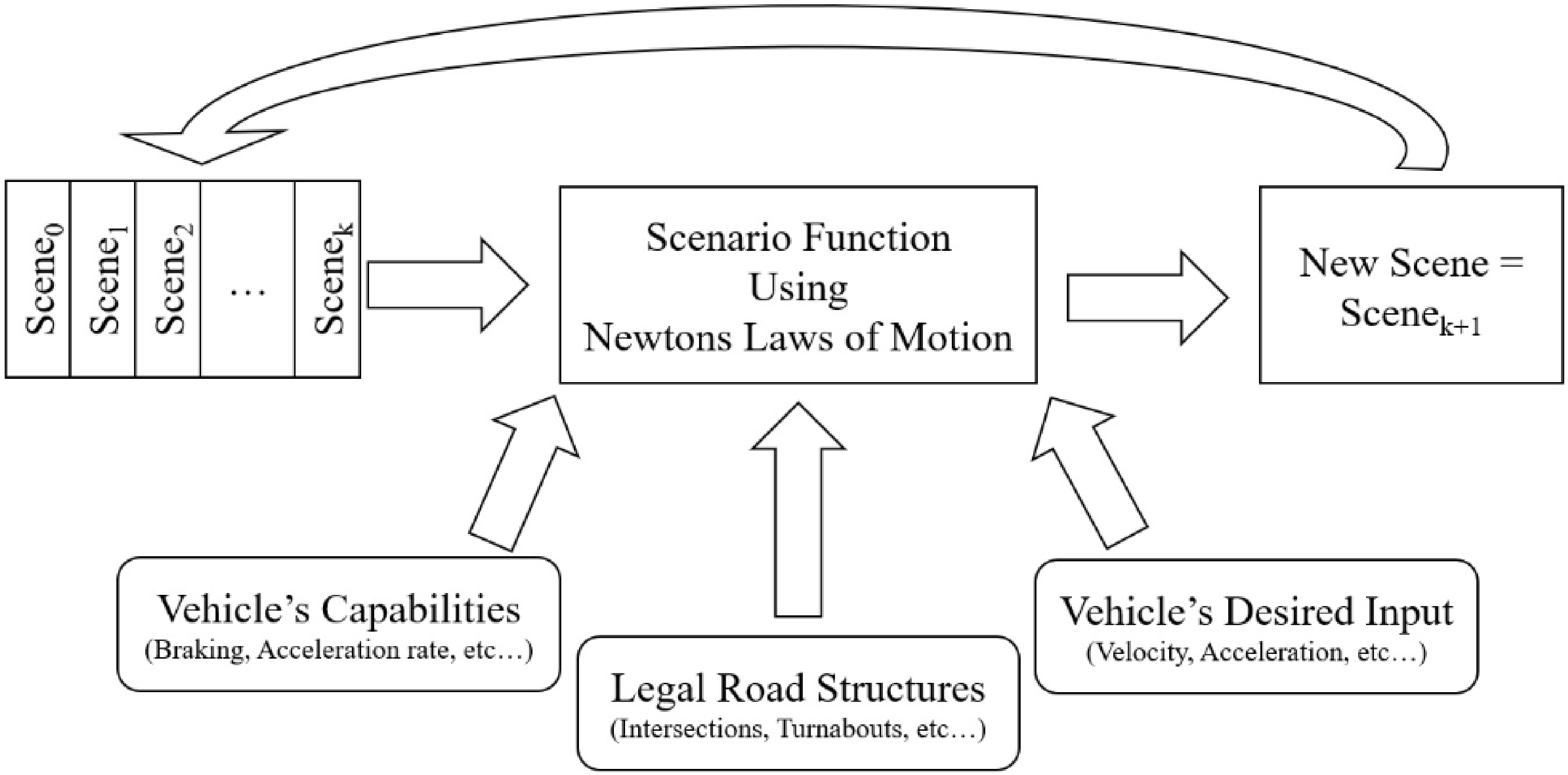
The solution is focused on the Decision Making of Autonomous Vehicles

Scenario Abstraction



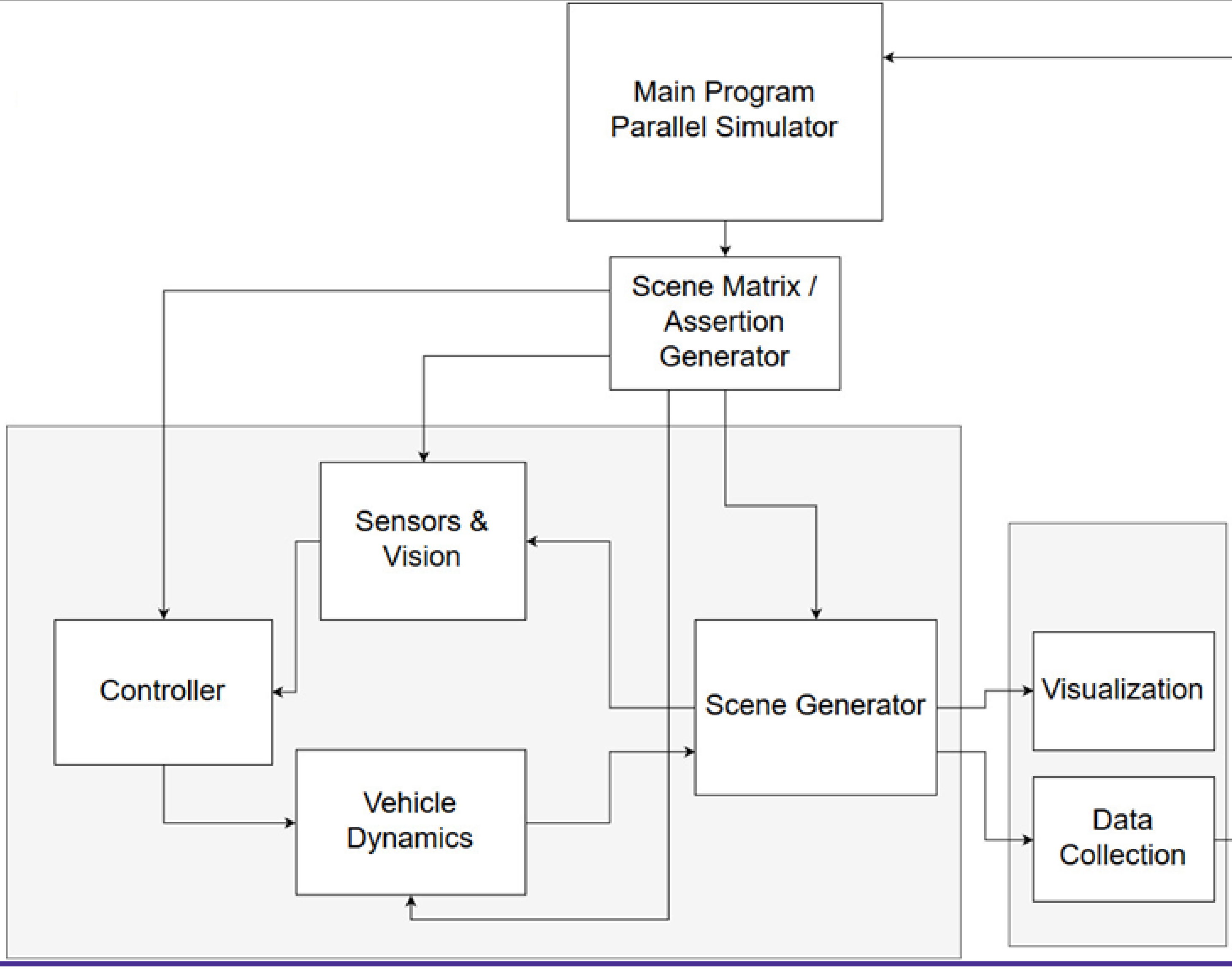
The framework serves as a ground truth for testing other sources of error such as environmental conditions or sensor failures

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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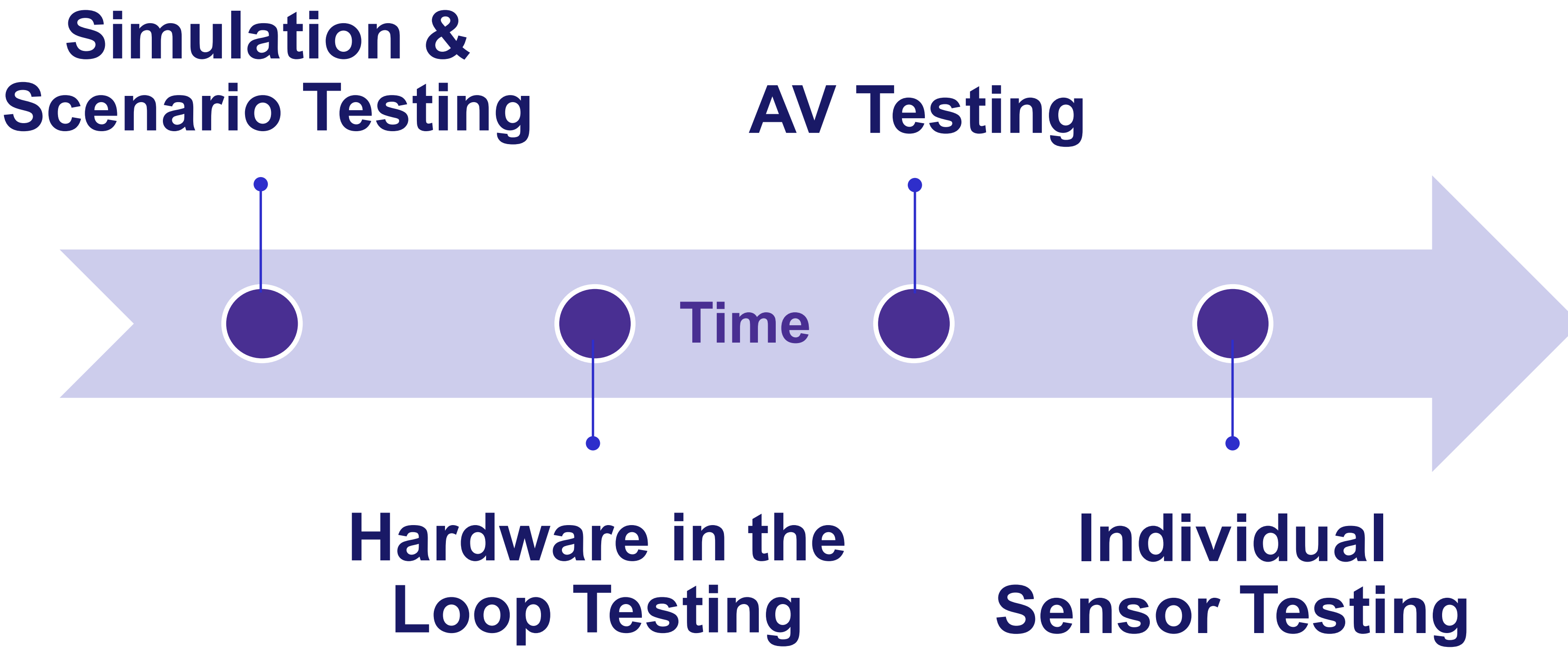
View Streaming Video

AV Testing Framework Roadmap



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**

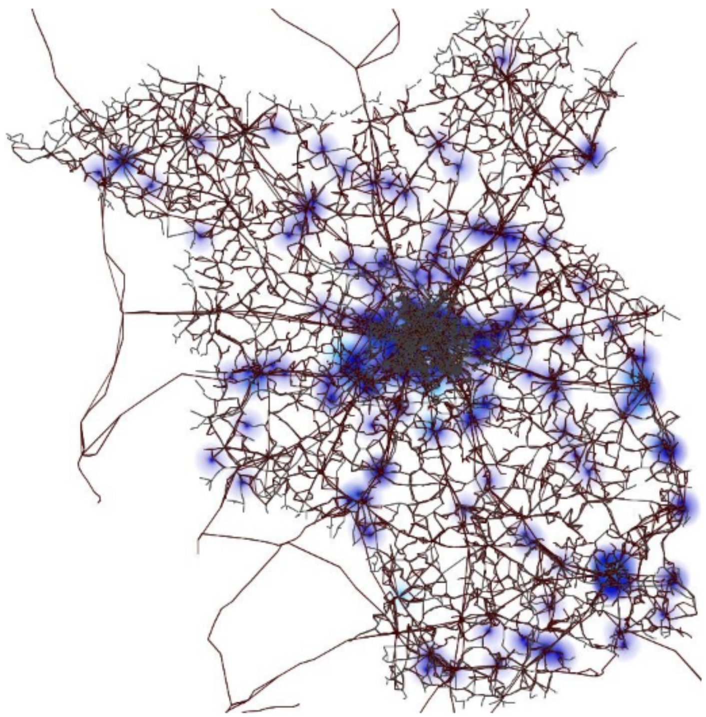
Transportation Operating System

- Transportation System is inefficient
- Utilization of **Market Economics** and Network Ideas

What if we could dynamically use the transportation system resources?

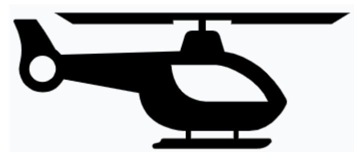
Incentive Mechanisms for Mobile Crowdsensing

- **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

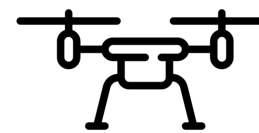


Cooperation of AVs with Human Operators

- 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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