Research and Technology Development at George Mason University for Next-Generation Automobiles and Transportation Systems

Kenneth S. Ball, Ph.D., P.E.
Dean, Volgenau School of Engineering

George Mason University
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http://volgenau.gmu.edu

GEORGE MASON UNIVERSITY | Volgenau School of Engineering

GEORGE MASON UNIVERSITY HIGHLIGHTS

- U.S. News & World Report
  - Top "Up-and-coming" University
  - 18th Most Innovative Universities
- Hewlett-Packard/Ponemon Institute
  - 7th Best Schools for Cybersecurity
- Largest Public Research University in Virginia
- Two Nobel Laureates
- Top 200 Shanghai Jiao Tong Ranking

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ACADEMIC DEPARTMENTS VOLGENAU SCHOOL OF ENGINEERING

- Bioengineering
- Computer Science
- Electrical and Computer Engineering
- Information Sciences and Technology
- Mechanical Engineering
- Sid and Reva Dewberry Department of Civil, Environmental, and Infrastructure Engineering
- Statistics
- Systems Engineering and Operations Research

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RESEARCH CENTERS

- Center for Air Transportation Systems Research
- Center for Assurance Research and Engineering
- Center for Configuration Analytics and Automation (NSF I/UCRC)
- Center of Excellence in Command, Control, Communications, Computing and Intelligence
- Center for Secure Information Systems
- Learning Agents Center

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RESEARCH LABORATORIES

- Communications and Network Laboratory
- Computer Vision and Neural Networks Laboratory
- Cryptographic Engineering Research Group
- Laboratory for IT Entrepreneurship
- Networking and Simulation Laboratory
- Radio and RADAR Engineering (REAR) Lab
- Sensor Fusion Lab
- System Architectures Laboratory

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BY-THE-NUMBERS…

- Student Enrollment: 6,222
  - 4,504 Undergraduates
  - 1,718 Graduate Students
- Faculty: 165
  - 151 Instructional
  - 14 Research
- Degree Programs: 33
  - BS: 10
  - MS:16
  - Ph.D.: 7

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RELEVANT AREAS OF EXPERTISE

- Autonomous Systems and Controls
- Robotics and Unmanned Vehicles
- Sensors and Multi-Sensor Fusion
- Trusted Communications and Connected Vehicles
- Cybersecurity and Cyber-Physical Systems
- Safety and Reliability; Resilient Systems
- Signal and Array Processing; Data Analytics
- Artificial Intelligence
- Testing and Evaluation
- Logistics

Cybersecurity of Connected and Automated Cars

Kai Zeng, Ph.D.

Professor of Electrical and Computer Engineeing and Cybersecurity Engineering

Amir Alipour-Fanid

Ph.D. Student

Security and Privacy of Connected and Automated Cars

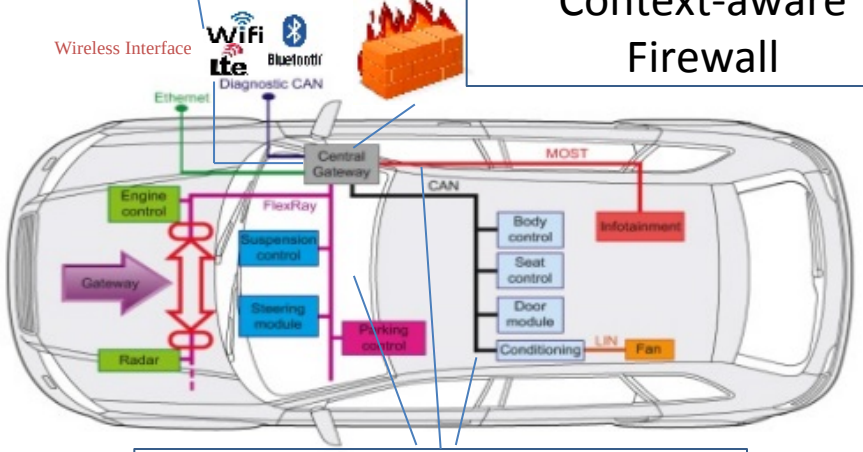
System-wide Massive Attack Detection

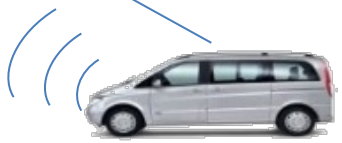
Real-time Remote Vehicle Status Tracking and Diagnostics

Cloud

Cyber Attacks through Wireless Interfaces

Context-aware Firewall



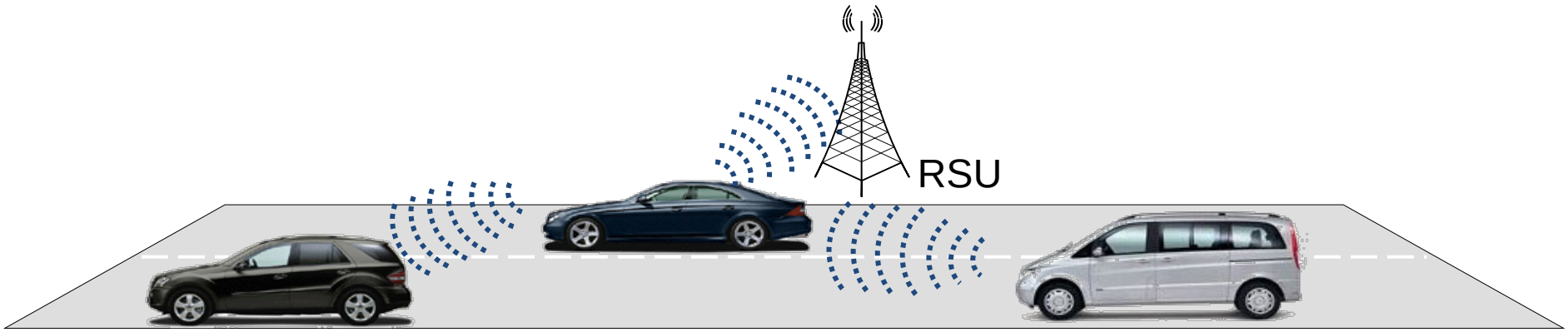


Vehicle to Vehicle (V2V) Networking Security

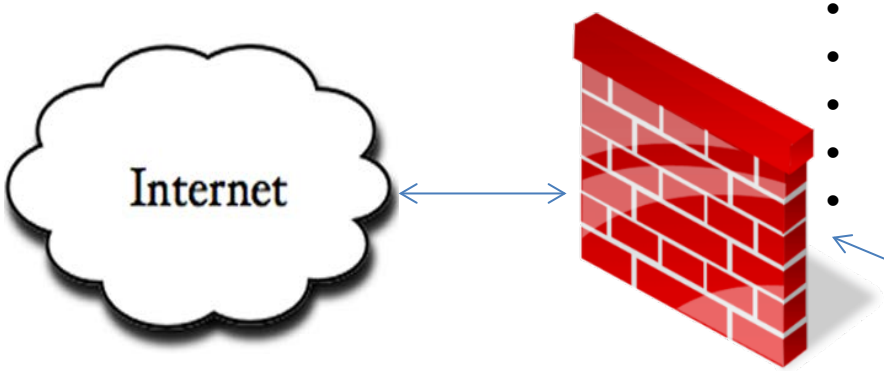
CAN Bus Security, Realtime Authentication

Physical Layer Challenge-Response Authentication

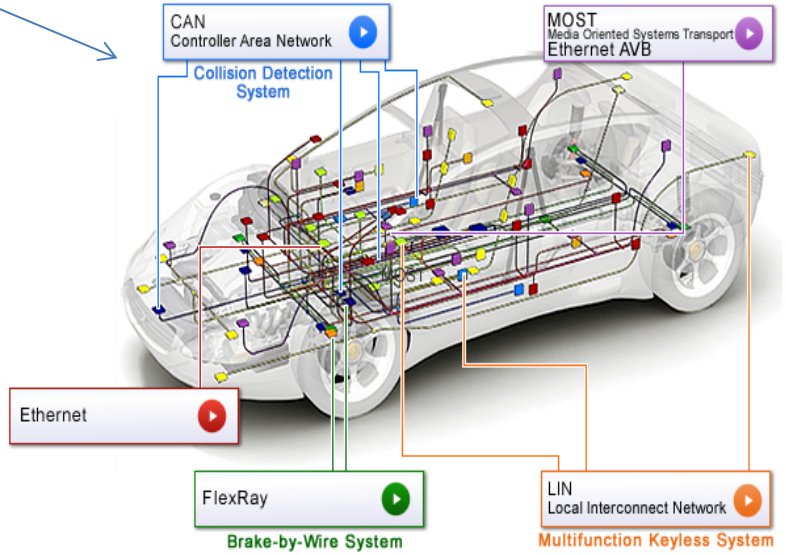
- Application: Used for V2I and V2V authentication
- Mobility: Favor fading channel and dynamic environment
- Security:
  - Immune to replay attack
  - Information-theoretical secure (i.e., security strength is not determined/affected by computing power, but guaranteed by physical laws)
- Scalability:
  - No need to increase key length when attacker's computing power is improved
  - Extensible to multi-user and multi-hop networks



Context-Aware Firewall for Connected and Automated Cars

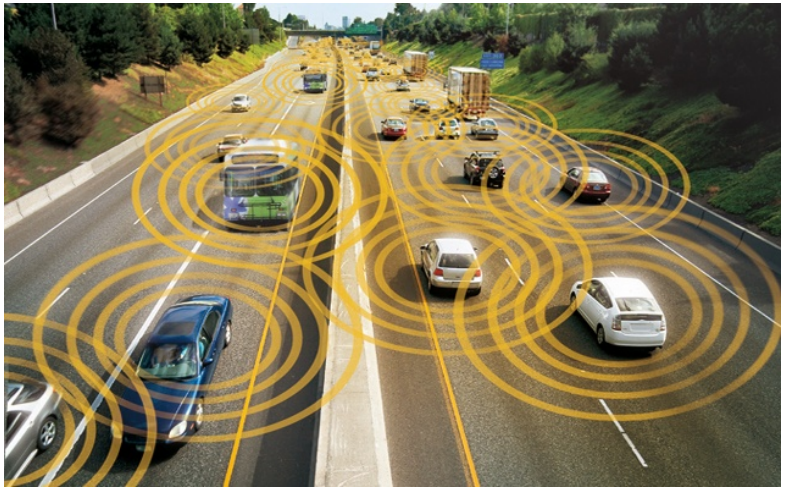


- Header/port of packets/information flow
- Deep packet inspection
- Sensor data (GPS, camera, radar, tire pressure, etc)
- Vehicle mode (automatic/man/hybrid driving)
- Safety rules
- Driver status



GPS Spoofing Attack Detection for Connected and Automated Cars

- **Global Positioning System security**
- GPS spoofing involves two steps: taking over the legitimate GPS satellite signal and then transmitting the spoofing signal.
- **Application: V2V (cooperative safety application)**



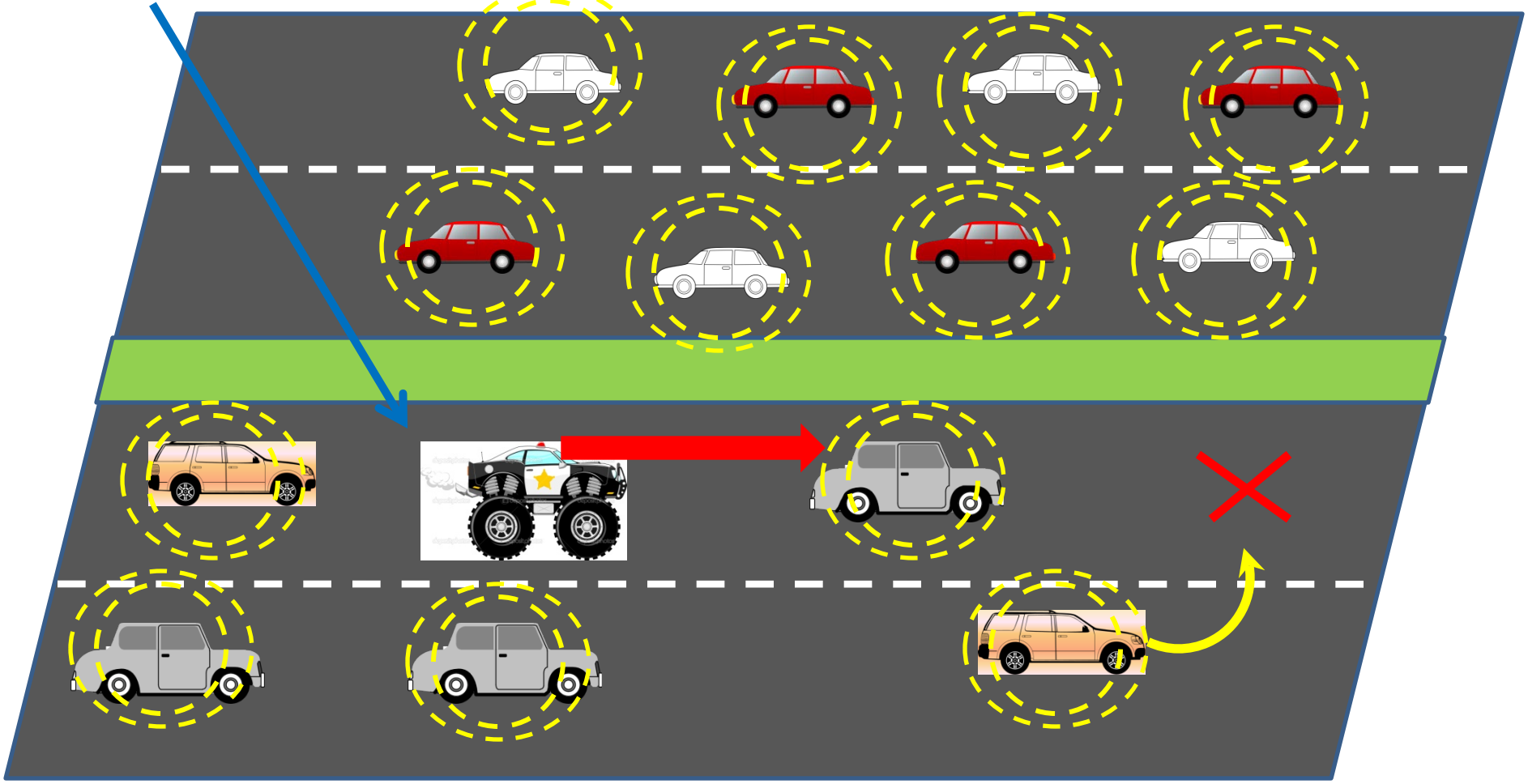
- **Detection**
- **Countermeasure**

Practical view:

Safety application ==➔ Exact Position has a vital role ➔ GPS defines the location

➔ DSRC (Dedicated Short Range Communication) send position info. to other vehicles

Mobile Attacker



1- V2V (for safety) information exchange: Position, Speed, Heading, Brake Status

2- DSRC technology: communication between vehicles is reliable up to a range of around 300 m

3- Safety Applications
Emergency Electronic Brake Lights (EEBL),
Forward Collision Warning (FCW),
Blind Spot Warning (BSW)
Lane Change Warning (LCW)
Do Not Pass Warning (DNPW)
Intersection Movement Assist (IMA)

4- VSC-A relative positioning requirements
Which-Road : relative accuracy level is 5 m
Which-Lane : relative accuracy level is 1.5 m

5- GPS relative positioning methods:
Single Point (SP) and **Real-Time Kinematic (RTK) :**
Single Point : sharing positioning data elements such as latitude, longitude, elevation
Real-Time Kinematic (RTK) : sharing GPS raw data in Radio Technical Commission for Maritime Services (RTCM) v3.0 format, used in the RTK relative positioning method.

Duminda Wijesekera, Ph.D.
Professor of Computer Science

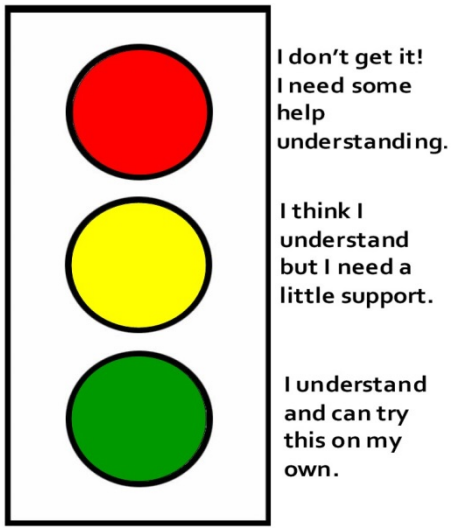
- Trusted Cognitive Radios for Smart Cars
- Trusted Broadcasts for Smart Vehicles
- Secure V2V Communications
- Data dissemination in V2I infrastructures
- Emergency Handling in Smart Highways
- Commercial Mobile Alert System (CMAS)

Trusted Cars and Roads

- Primary Objective: Multiple radios in the CAN network (Controller Area Network) to have secure communications within the (Car) network
- Secondary Objective: Communications between smart cars and smart highway infrastructure to be secure.
- Method: Use a trusted and cognitive radio (communication module) to transmit short-range radio signals.

Trusted Broadcasts for Smart Highways

- Smart Highways Broadcast information for smart cars to use for
  - Safety warning including emergency handling
  - Weather conditions,
  - Asking room for emergency vehicles
  - Traffic lights
- All these will light up inside the dash with voice a – so called in-cab signaling
  - will talk to the break manager if the human driver does not respond
  - Will talk to autopilot



Evolutionary Computation and Evolving Agents

Kenneth De Jong, Ph.D.

Computer Science Department

Collision Avoidance and Navigation

Goal:

Get single agent to reliably perform complex navigation tasks. Extend to multiple cooperating agents.

Approach:

Evolve behaviors offline via simulation

Download & test on real robot

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RAJESH GANESAN, PH.D.
PROFESSOR, SEOR

- Analytical Modeling and Computational Research for Next Gen Automobiles
  - Big Data Analytics (Data-Information-Knowledge)
- Dynamic optimization using artificial intelligence of vehicle operational parameters for
  - Effective cruise control
  - Minimized emissions
  - Maximized fuel/battery/fuel-cell economy
- Simulation and Optimization of system, process, and product design parameters
  - Multi-objective optimization
  - Trade-off analysis of conflating parameters
- Engineering process control and statistical real-time monitoring of advanced manufacturing processes
- Algorithm development for vehicle computers

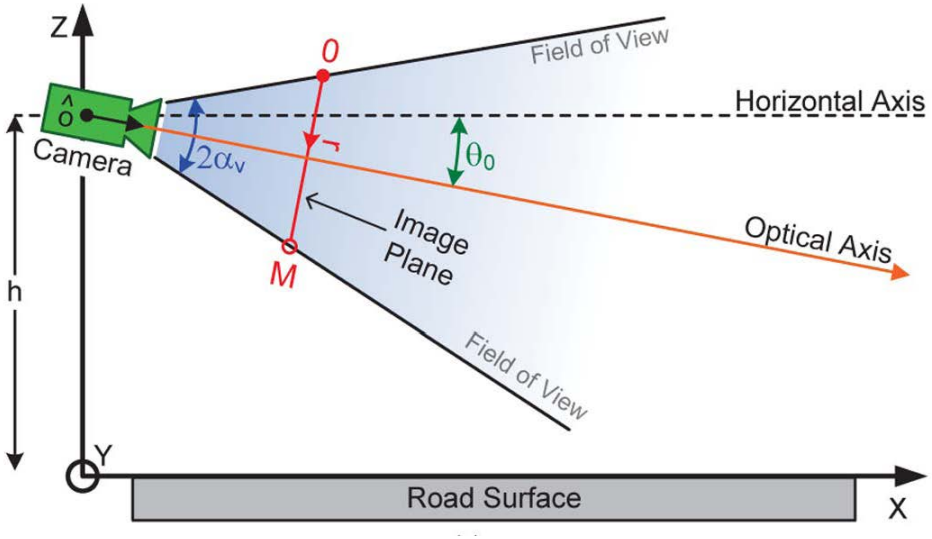
Automatic Steering and Lane Tracking

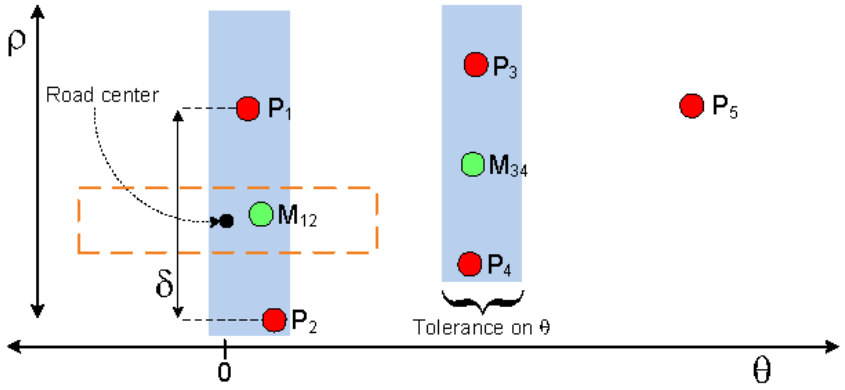
Monson Hayes, Ph.D.
Chair and Professor
Department of Electrical and Computer Engineering (ECE)

Gerald Cook, Ph.D.
Earle C. Williams Professor of ECE

Lane Tracking for Driver Safety

- A multi-stage system involving inverse perspective mapping, matched filters using lane marking standards, Hough transforms, RANSAC, Kalman filtering, among others.
- Single and dual camera (forward and backward looking) systems.
- Performance evaluation using ground truth data.





Hough transform with parallel line and FHA lane marker constraints.

Feature Selection and Evolution Modeling for Tire Wear Analysis

Ideas for Collaboration

Jill K. Nelson and Kathleen E. Wage

Department of Electrical and Computer Engineering

Statistical Signal Processing Lab

Director: Jill K. Nelson, Associate Professor of ECE

Ph.D. in Electrical Engineering, University of Illinois at Urbana-Champaign, 2005

Focus areas:

- Localization and tracking
- Blind source separation
- Signal processing for communications
- Signal processing for music

Funded projects:

- *Tree Search Approaches to Multiple Target Tracking*
  Funded by the Office of Naval Research, 2009-2011
- *Linking Interest and Conceptual Knowledge in Electrical Engineering*
  Funded by the National Science Foundation, 2008-2010
- *Encouraging Innovative Pedagogy through Long-Term Faculty Development Teams*
  Funded by the National Science Foundation, 2010-2012

Students: 3 PhD, 3 MS, and 1 undergraduate

Ocean Acoustic Signal Processing Group

Focus: multidisciplinary problems that require a synthesis of signal & array processing, acoustics, and oceanography

Director: Kathleen E. Wage, Associate Professor of ECE
PhD, MIT/Woods Hole Oceanographic Institution

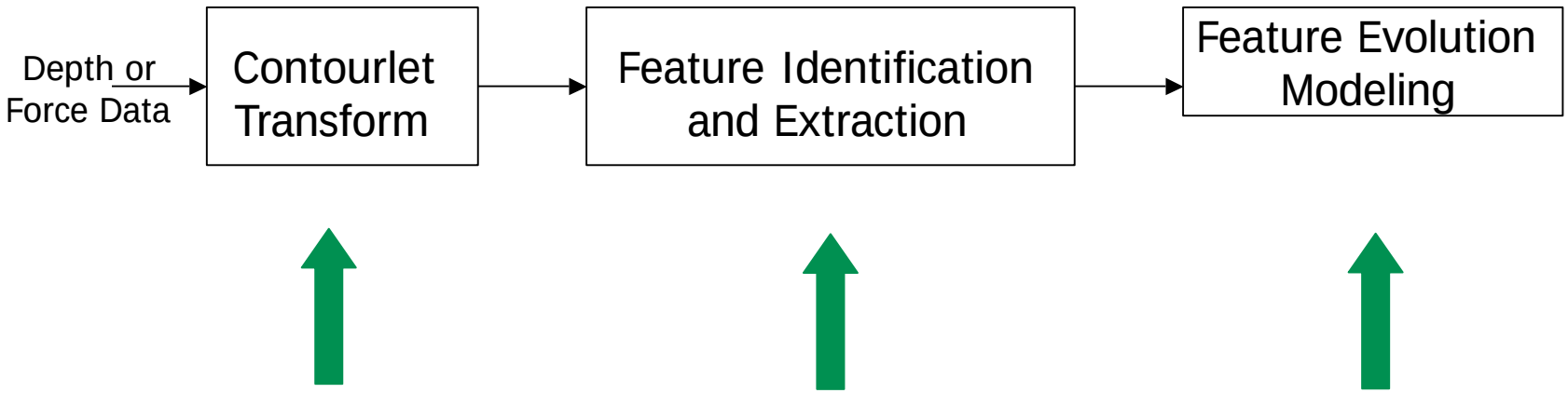
Current students: 3 PhD and 1 MS

External funding: Office of Naval Research (ONR)

- *Stochastic Eigenanalysis for Adaptive Array Processing* (2009-11)
- *Mode Processing & Tomography for the Philippine Sea* (2009-11)
- Selected previous awards:
  - *Signals & Systems Concept Inventory*, National Science Foundation (2005-10)
  - *ONR Young Investigator Award* (2005-08)
  - *Robust Matched Field Processing*, Lockheed Martin (2001-02)

Group website: http://ece.gmu.edu/~kwage/research/oasp

Tire Data Analysis -- Conceptual Overview



Could be replaced by alternative transforms, e.g. wavelet, DCT, etc.

Tentative approach: Form features based on statistics of contourlet coefficients.

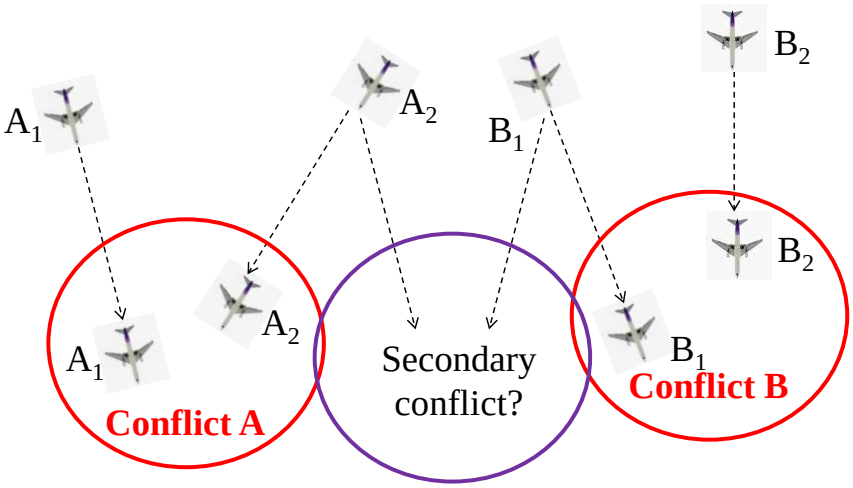
Apply “kinematic” model and tracking/prediction techniques.

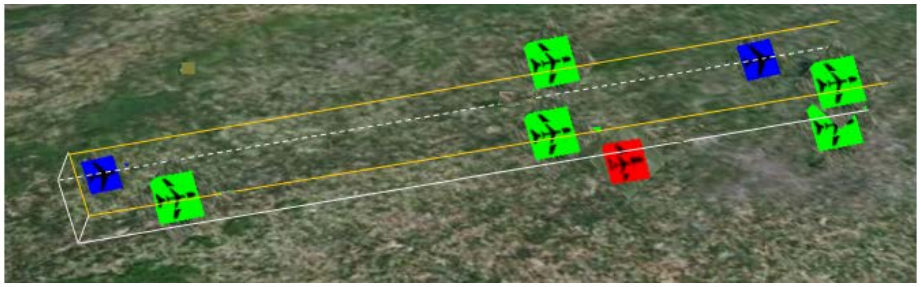
John Shortle, Ph.D.
Professor, Systems Engineering & Operations Research

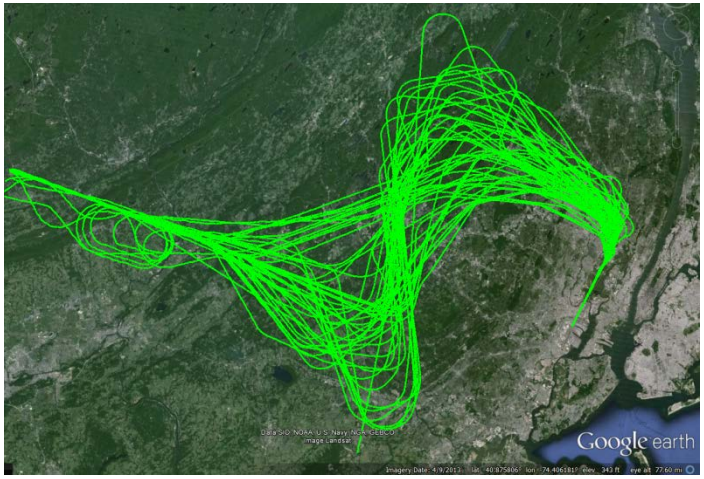
Related Expertise

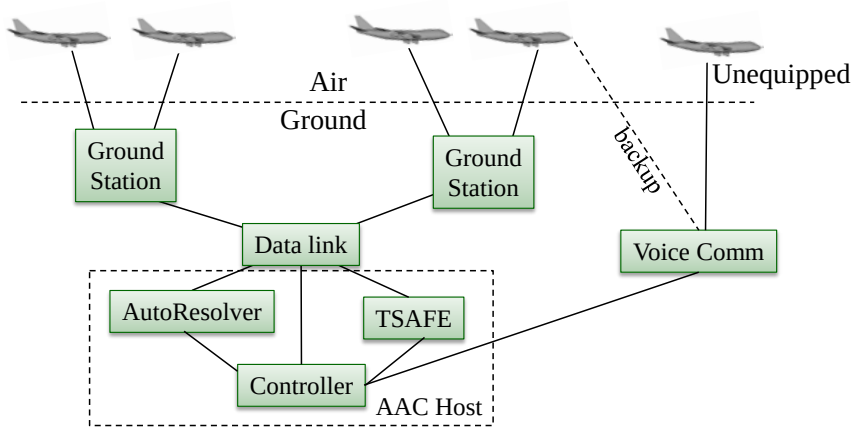
- Aviation safety
- Automated separation
- Reliability
- Rare-event simulation

Automated Separation Assurance





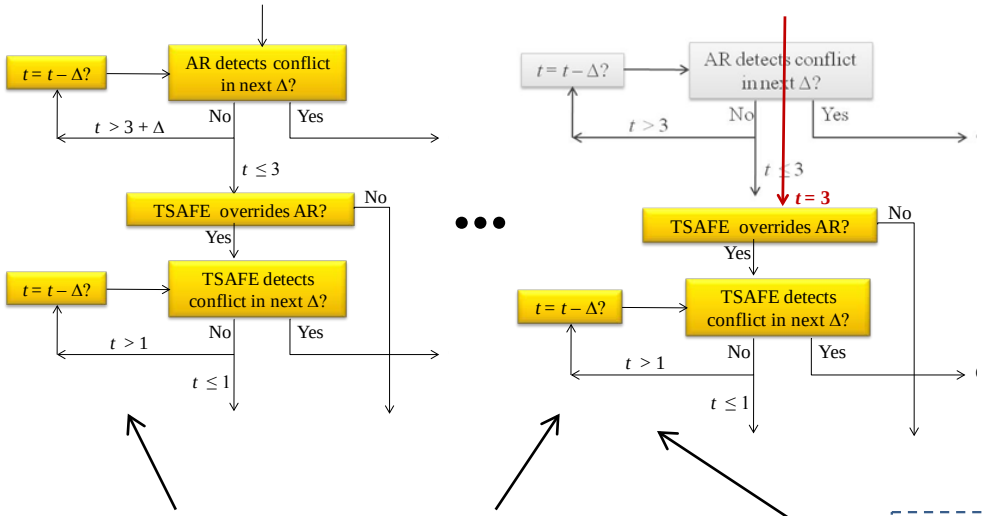




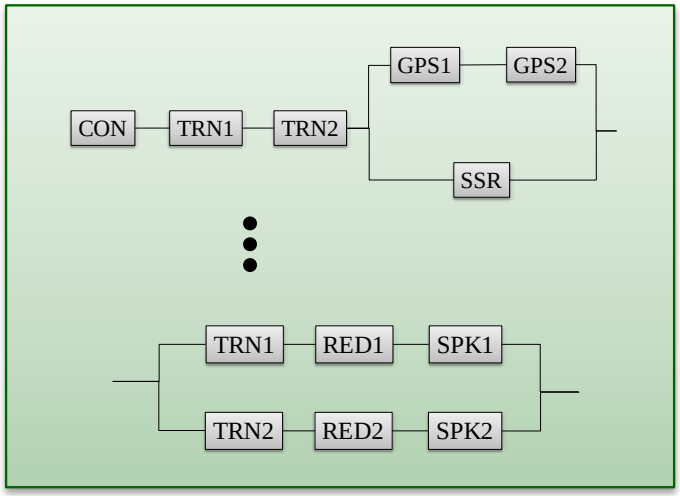
Goal: Increase role of automation in safely separating aircraft while maximizing throughput

Safety Evaluation and Rare Events

Dynamic event trees

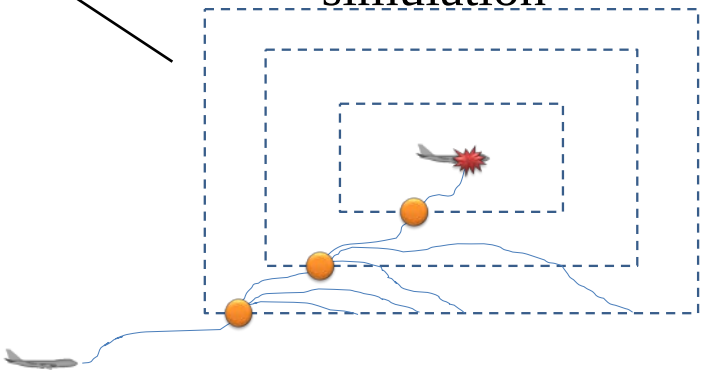


Reliability diagrams



Reliability Diagrams

Rare-event simulation



Risk events result from discrete-event failures and continuous-time state of vehicles

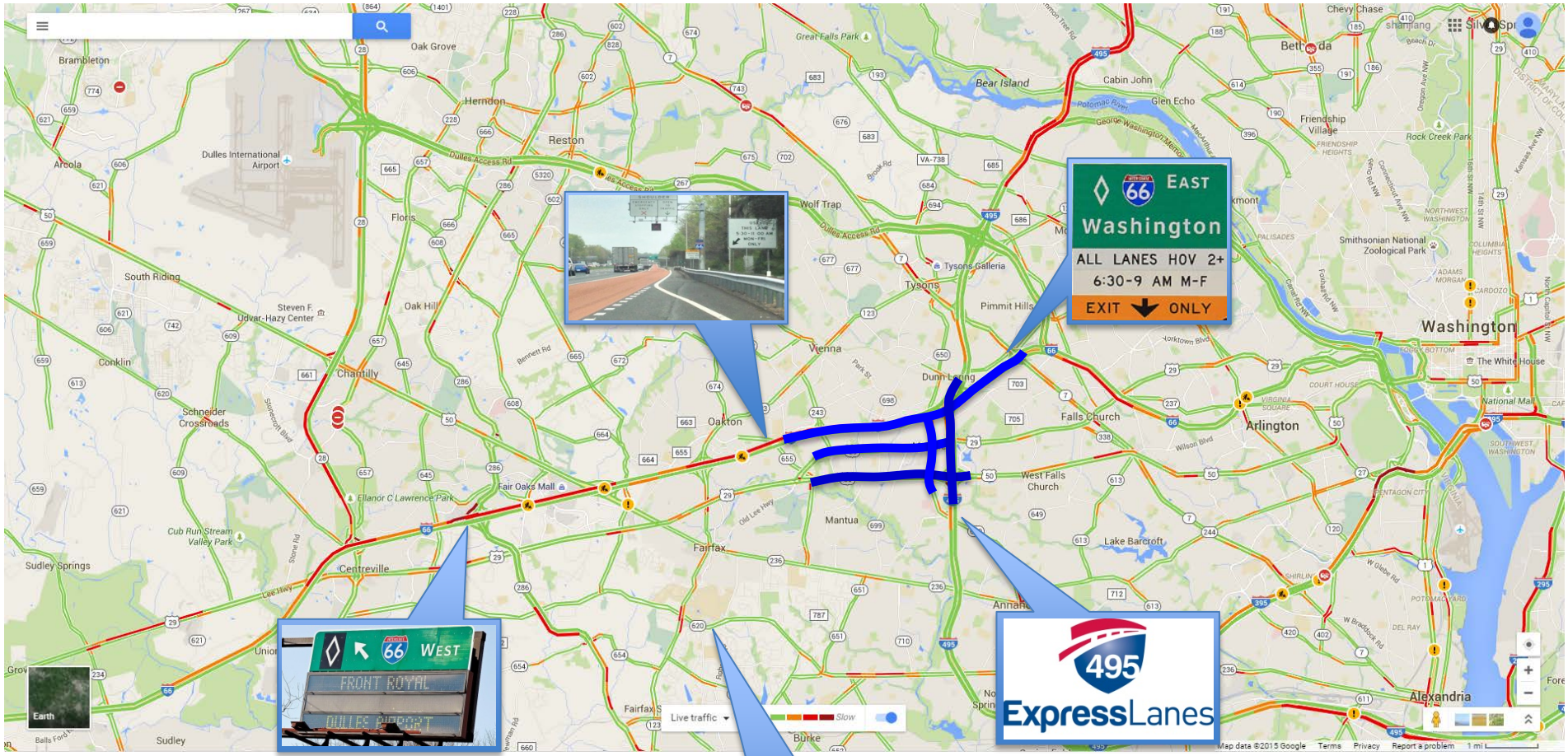
Next-Generation Automobile Research
Lance Sherry, Ph.D. Director, CATSR

- Design:
  1. Collision-Risk analysis
     - CATSR/GMU pioneered new method for collision risk analysis using *Dynamic* Event Trees and Rare Event Simulation
     - Now widely used in aviation
  2. Human Factors Design (provisional patent)
     - CATSR/GMU developed Monte Carlo simulation of Human-Computer Interaction (HCI)
     - Used for design and certification of airline flight deck procedures
  3. Design of (Semi-) Autonomous Systems
     - Combinatorial state-space approach to autonomous system design
     - Explicitly designs interventions for hazards
  4. Paranoid Driver Associate (invention disclosure submitted)
     - Joins off -vehicle data (e.g. maintenance logs, recalls, …) with on-vehicle data to identify probabilistic alerting for drivers

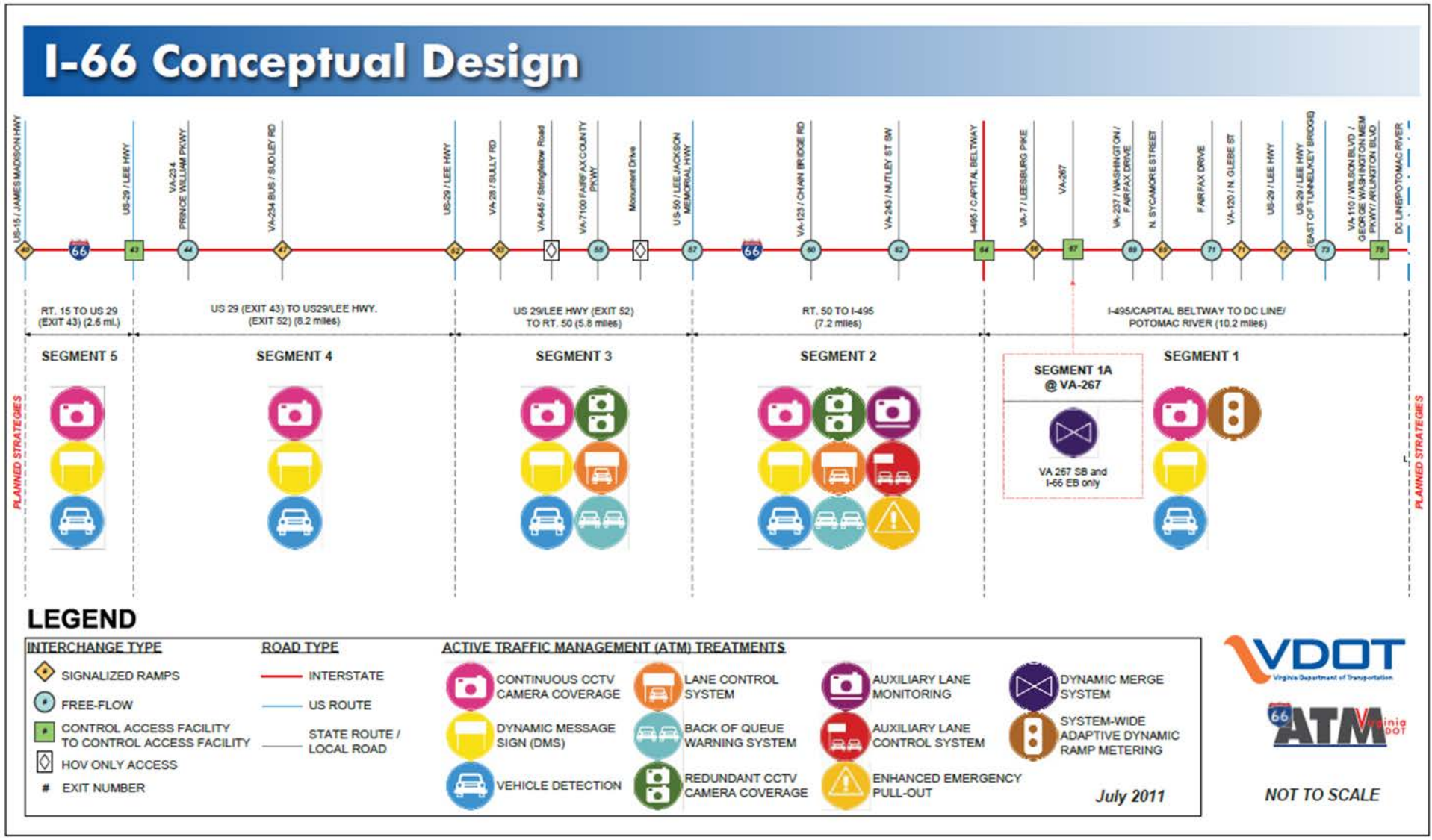
- Operation:
  1. Real-time Big Data Analytics of Vehicle Trajectory and Guidance/Control Mode data for:
     - Vehicle
       - efficiency (e.g. fuel burn, accelerations/decelerations)
       - emissions inventory analysis
       - Real-time risk factors
       - Performance Anomaly detection
       - Control Mode Anomaly detection
     - Transportation
       - flow analysis
       - real-time risk factor identification

Connected Vehicle Testbed in Northern Virginia

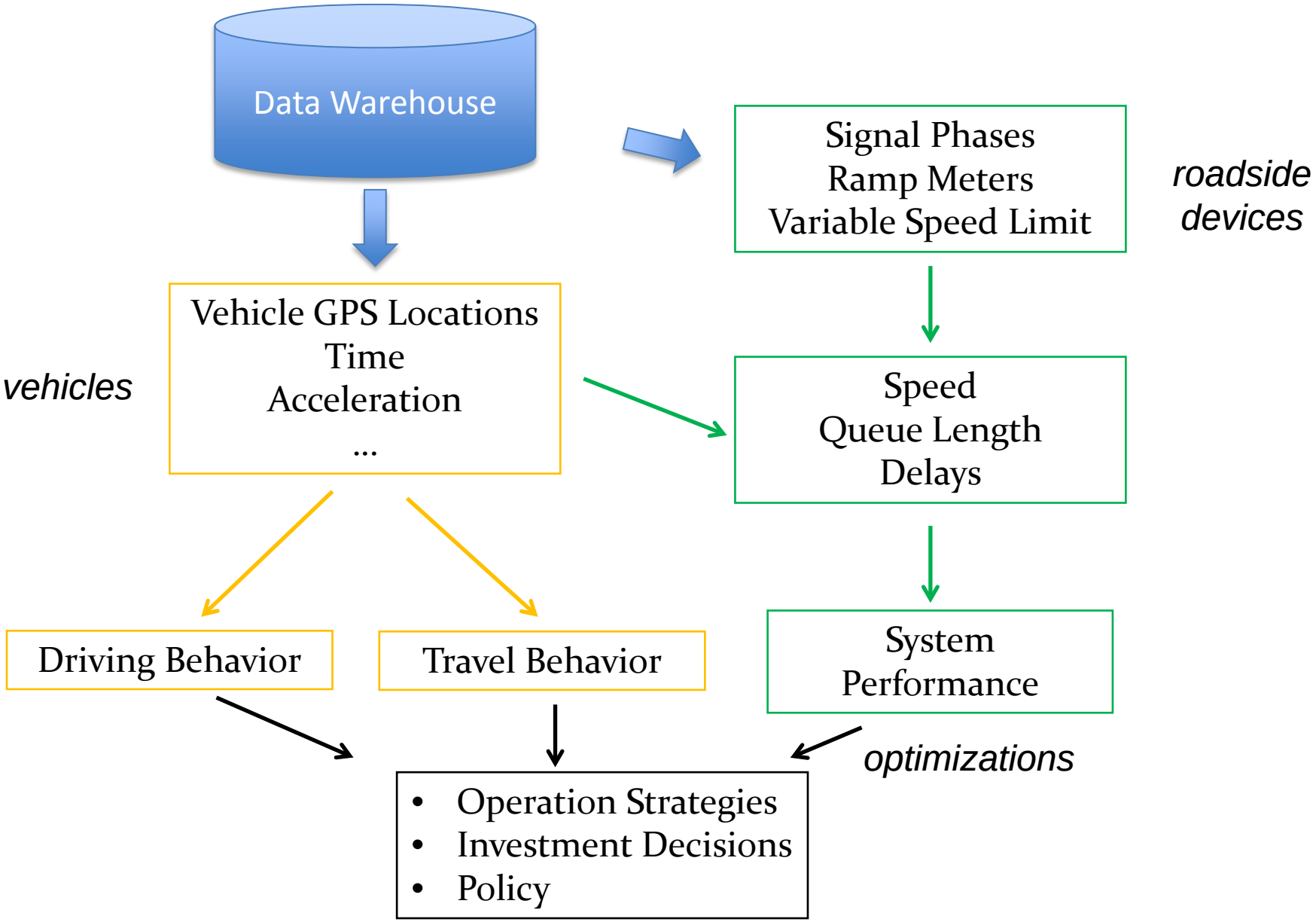
Shanjiang Zhu, Ph.D., Asst. Prof. CEIE



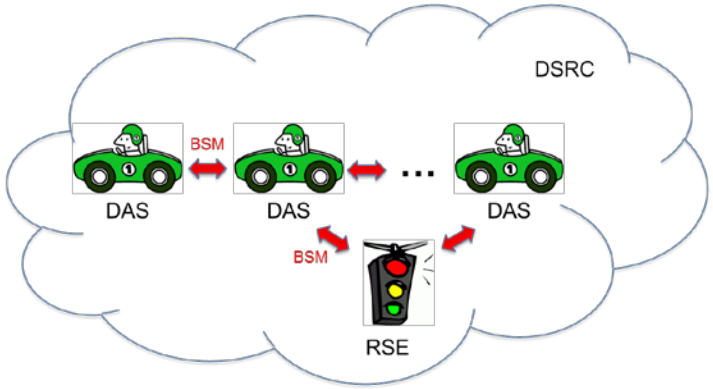
Active Traffic Management along I-66



Travel Behavior Study and System Performance Evaluation



Resilience Strategies



Vulnerability Analysis

Device Failure
Communication Failure
Extreme Weather
Cyber Attack
…

Demand Management Strategies
Reserved Capacity

Local Failure

cascading effect

activation of intervention strategies

System Failure

System Recovery

Distributed Traffic Light Coordination

Prof. Sean Luke
Department of Computer Science

- **No** centralization
- **No** communication among traffic lights
- Highly **efficient** in terms of total system throughput
- Highly **fair** in treatment of vehicles
- Good handling of **emergency events**
- Good handling of **sudden high traffic events**
  (everyone leaving a rock concert at the same time)
- **Green waves** should appear naturally
- **Simple**

Connected Vehicle Research at Mason

Mohan Venigalla, Ph.D., Assoc. Prof. CEIE

- Hardware
  - sensor technologies, hardware units
- Communication
  - protocols, security, data collection and transfer
- Data processing, analysis and solutions
  - dynamic routing, traffic management, driver behavior

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Kenneth S. Ball, Ph.D., P.E.

If interested in discussing research or academic partnerships or collaborations, please contact me at:

ball@gmu.edu

http://volgenau.gmu.edu

THANK YOU FOR YOUR ATTENTION