Commodity Traffic Cameras as Cost-Effective Alternative to Traditional Sensing Hardware

Presenter Introduction

- **Dan Rossiter**
  - dan.rossiter@swri.org
  - (210) 522-3541

- **Enabling ITS innovation since 2013**
  - From California to Florida and many states in between
  - Traditional ATMS systems
  - Computer vision systems
  - High volume, high velocity cloud hosted data processing systems

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Agenda

- SwRI Background
- Recent Technological Advances
- Transportation Applicability
- Conclusion

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SwRI Background

Applied Research from Deep Sea to Deep Space

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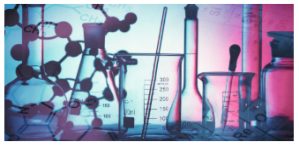
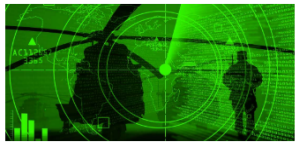
SwRI Overview

AUTOMOTIVE & TRANSPORTATION

BIOMEDICAL & HEALTH



CHEMISTRY & MATERIALS

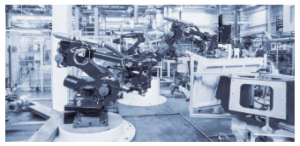


DEFENSE & SECURITY

EARTH & SPACE

ELECTRONICS & AUTOMATION

ENERGY & ENVIRONMENT



MANUFACTURING & CONSTRUCTION

SwRI is a financially stable company with broad technological capabilities and has grown consistently every year since inception.

- Established in 1947
- Independent research organization
- 501(c)(3) nonprofit organization
- $10M internal research funding to refine our technology offerings in FY20
- Dunn & Bradberry 5A-1 Credit Rating

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Broad ITS Expertise

SwRI's fleet of Autonomous Vehicles used to test Innovative Features and Technologies.

Over 70 ITS Staff with Expertise in the Following Areas:

- Advanced Traffic Management Systems
- Autonomous and Connected Vehicle Technologies
- High Volume/Velocity Data Fusion/Analysis
- Integrated Corridor Management Systems
- Transportation Cyber Security
- Traffic Camera Video Analysis

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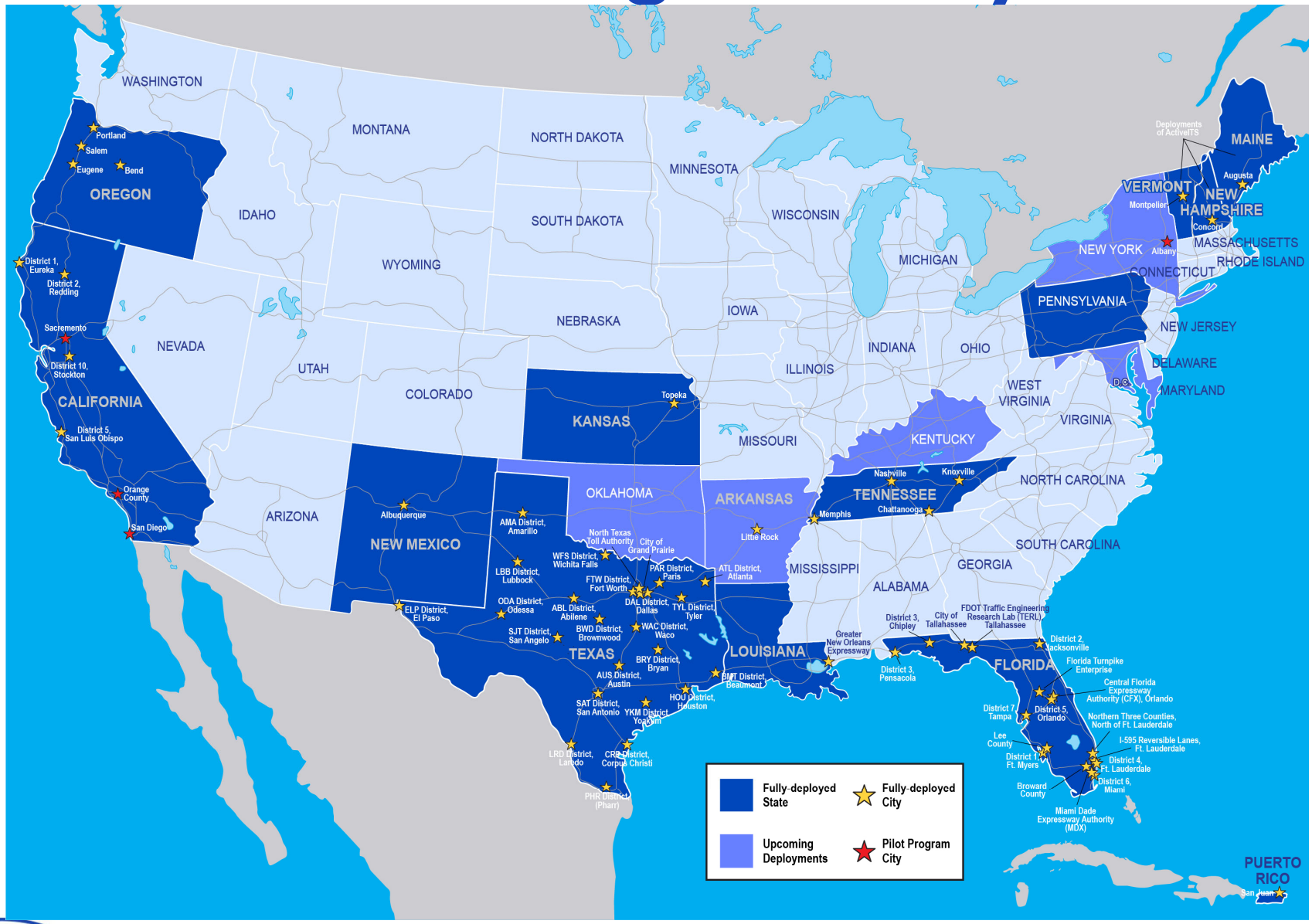
Advanced Transportation Management System



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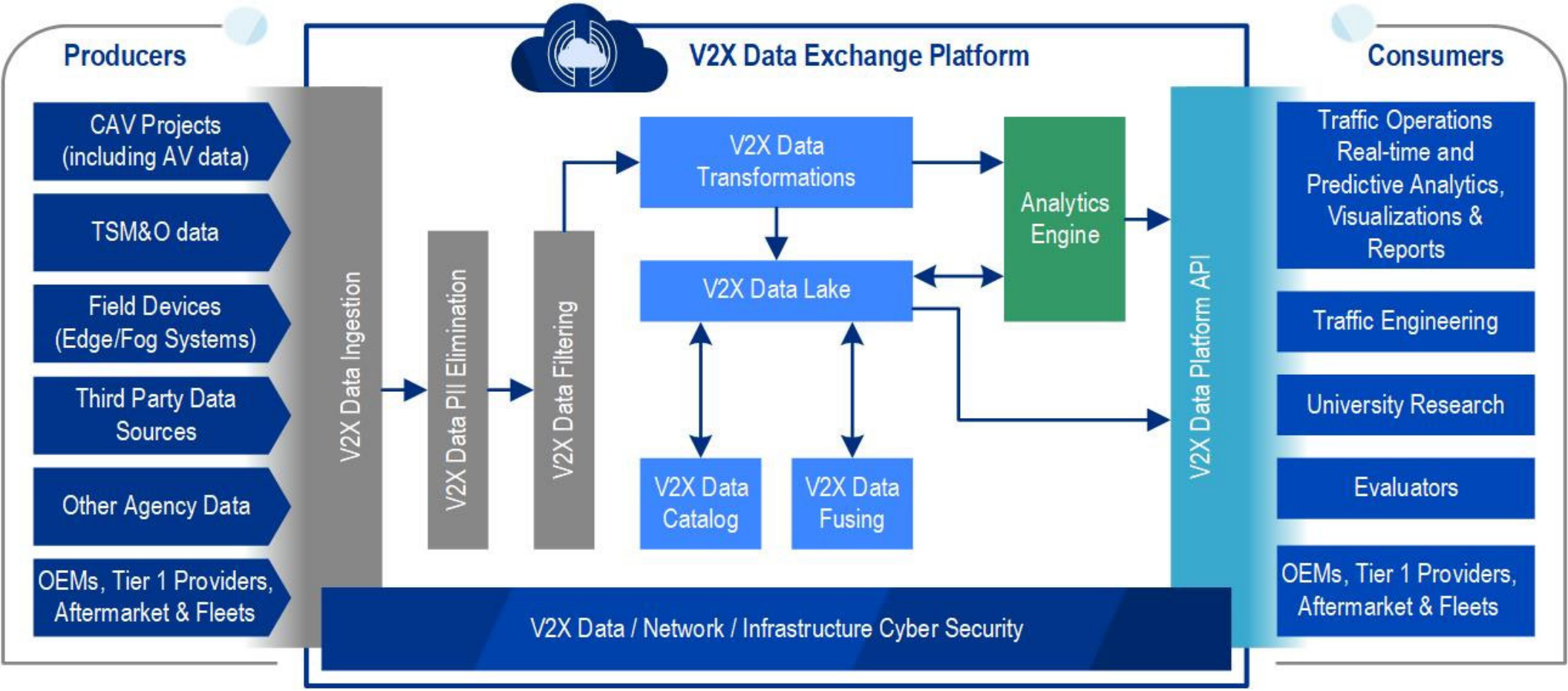
ActiveDX ITS Data Exchange Platform



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Recent Technological Advances

In other words – Why now?

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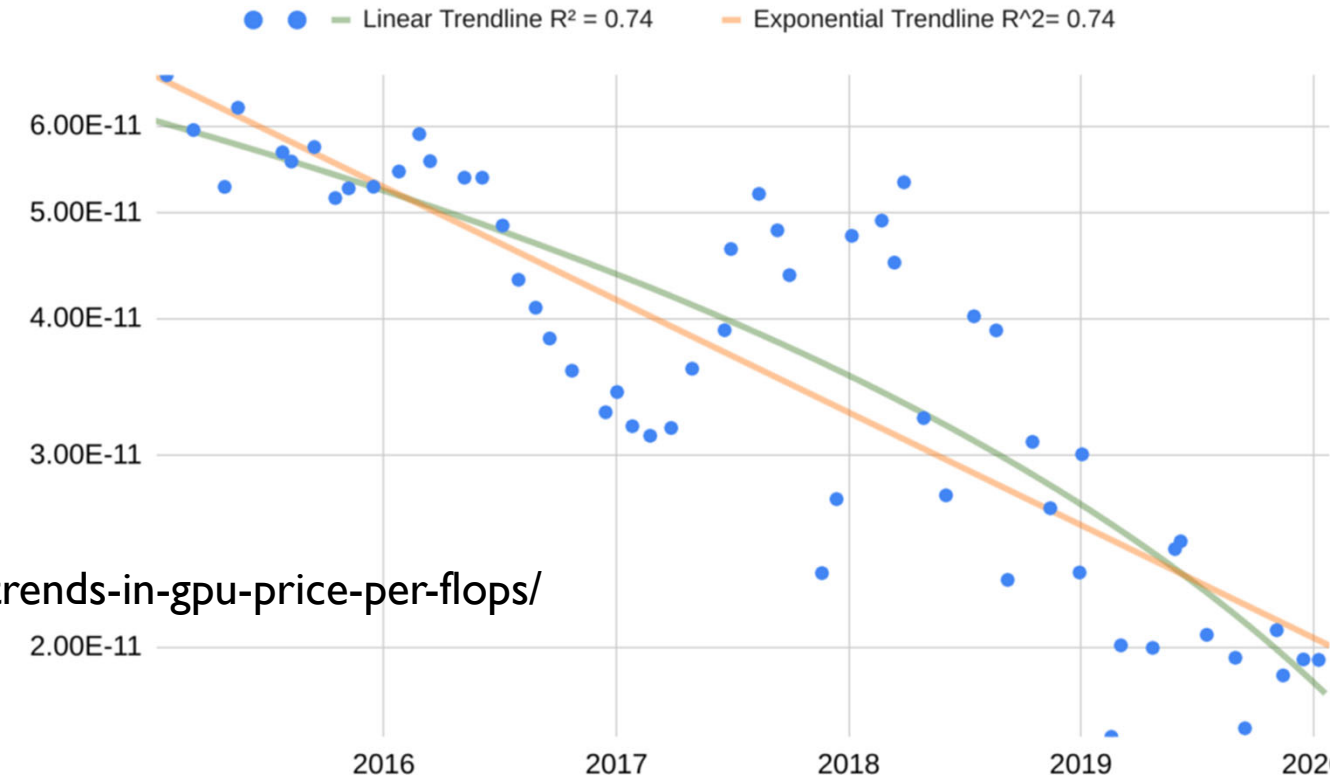
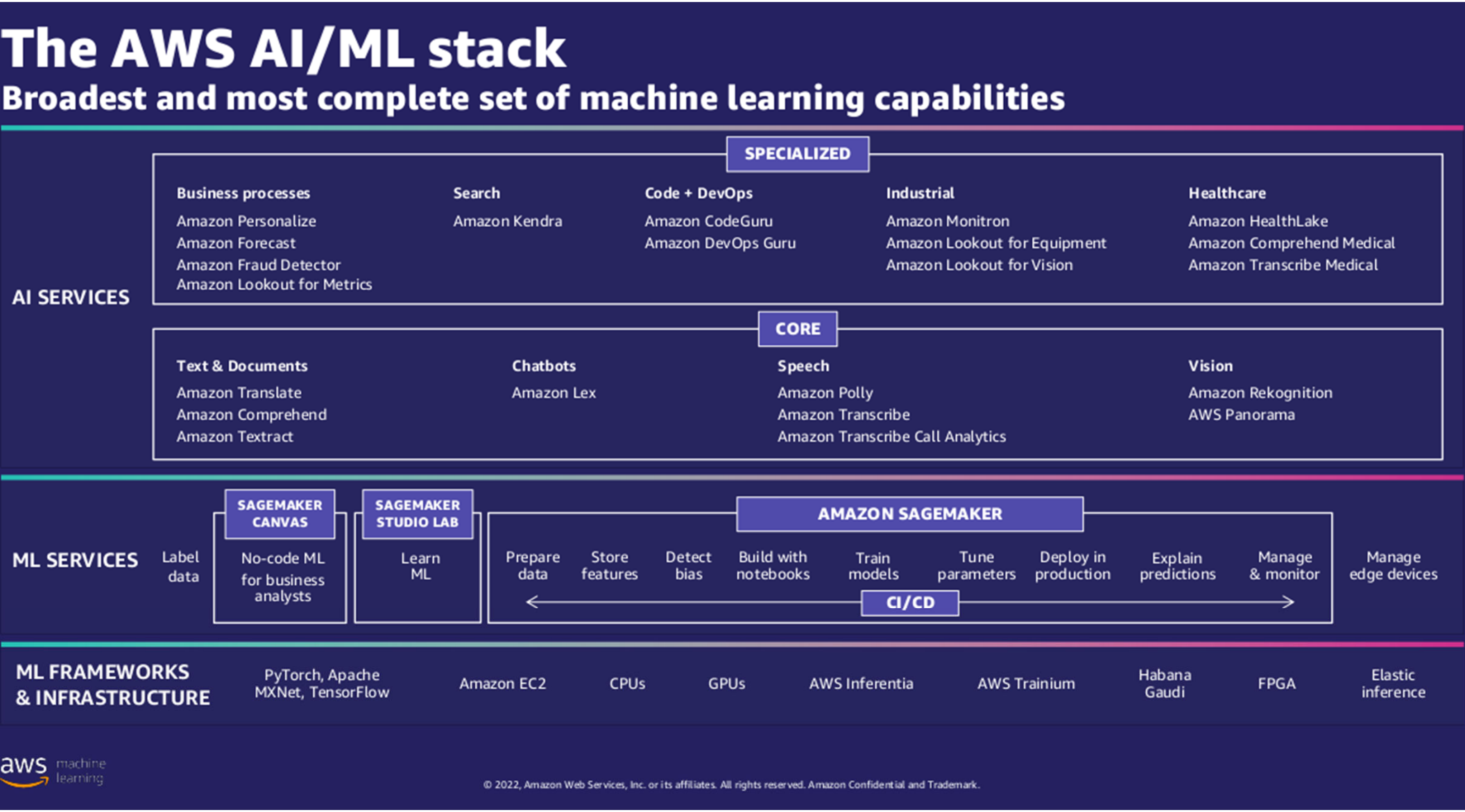
Advances Powering Computer Vision

- Cost per GPU operation capacity continues to drop significantly every year in recent history
- Machine learning frameworks have accelerated research in efficient computer vision algorithms
  - Google, Facebook, and others driving these trends through investment in open source



https://aiimpacts.org/2019-recent-trends-in-gpu-price-per-flops/

Cloud Providers Reducing Barriers to Entry



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What is Possible?

In what ways can ITS benefit?

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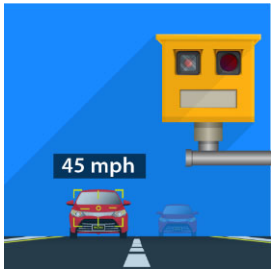
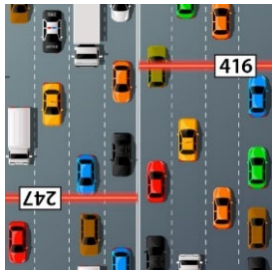
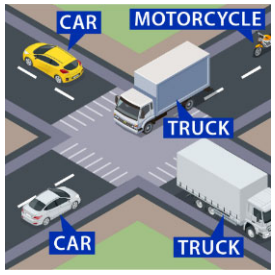
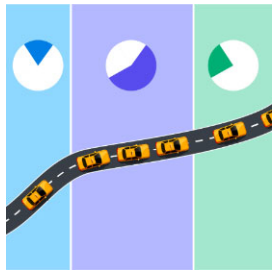
Detection Possibilities

- Vehicle Detection/Tracking







- Environmental Detection


- Pedestrian Detection/Tracking

- Advanced Detection/Tracking

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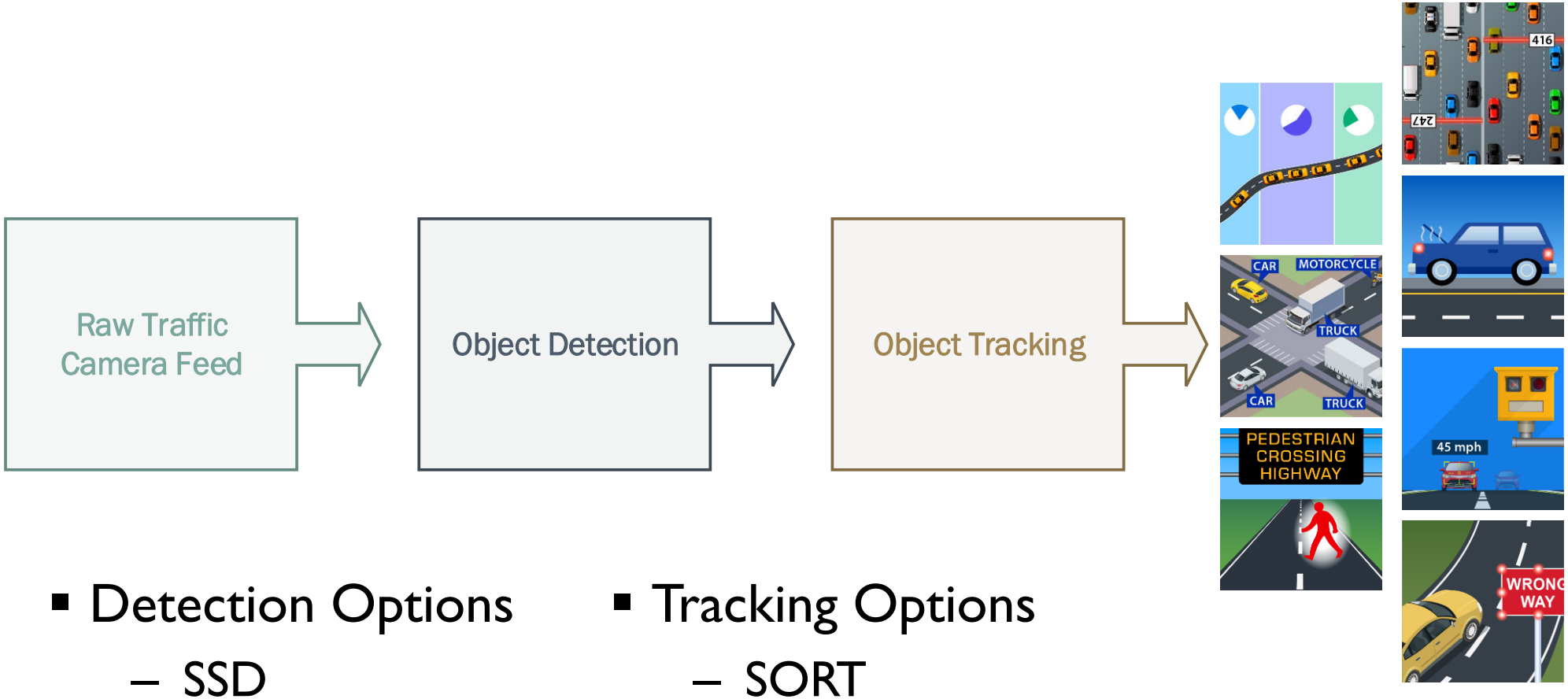
Detection/Tracking Implementation



- Detection Options
  - SSD
  - EfficientDet
  - YOLOv5
- Tracking Options
  - SORT
  - Deep SORT

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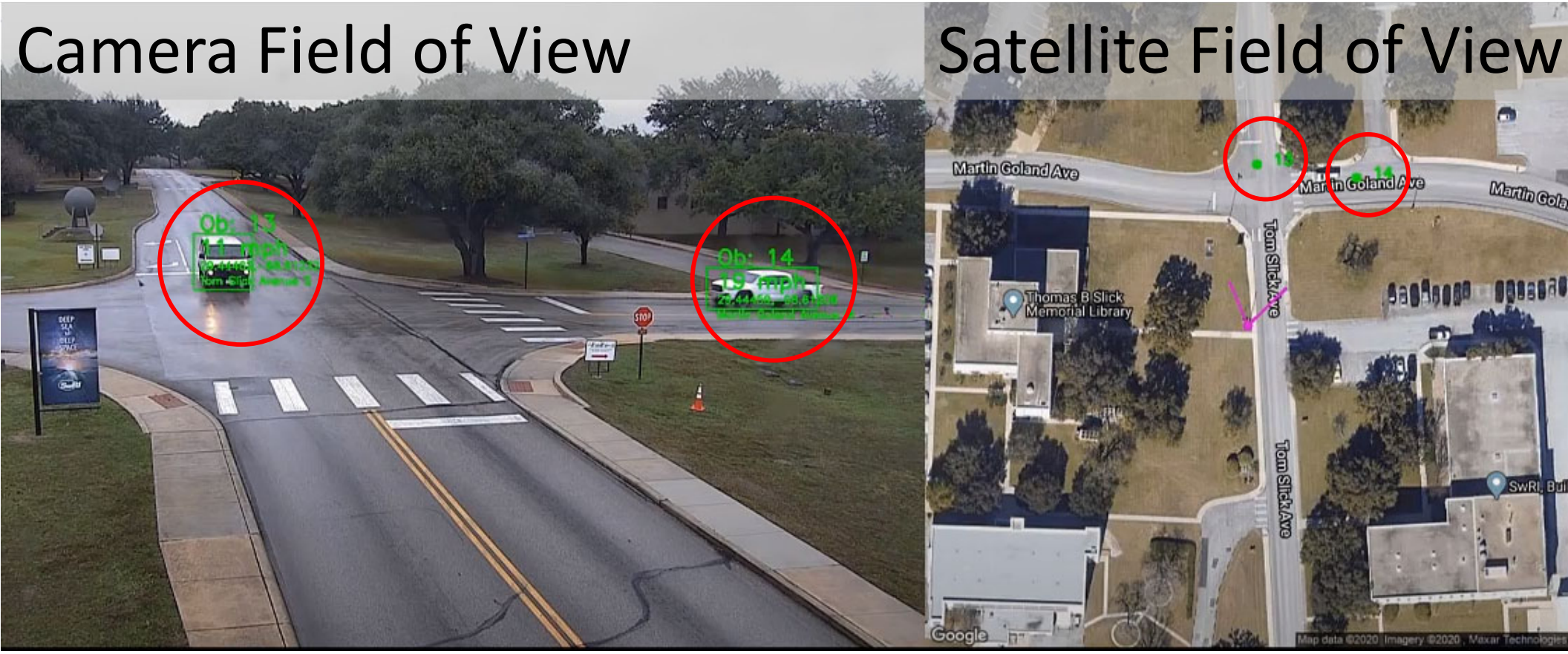
Geolocation



- Road Geometry (Esri, Open Street Map, etc)
- Camera Latitude/Longitude
- Field of View
- Homography Keypoint Map

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Geolocation Demonstration – Speed

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Weather Detection – Data Curation

- Initial approach – co-located RWIS stations + CCTVs
- When RWIS data quality was insufficient, custom tools and heuristics were used to try and narrow down where notable weather events might exist within broader dataset

Geography	Cameras	Snapshots	Weather Sensors	Sensor Readings
coastal south, plains	924	669,912	22	2,331,383
arid, desert, mountains, plains	155	5,755,019	6	207,746
central, coastal	3341	92,143,525	0	0
coastal north, hills, mountains, forest	39	712,492	52	6,656,522

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Weather Detection – Data Curation (cont)

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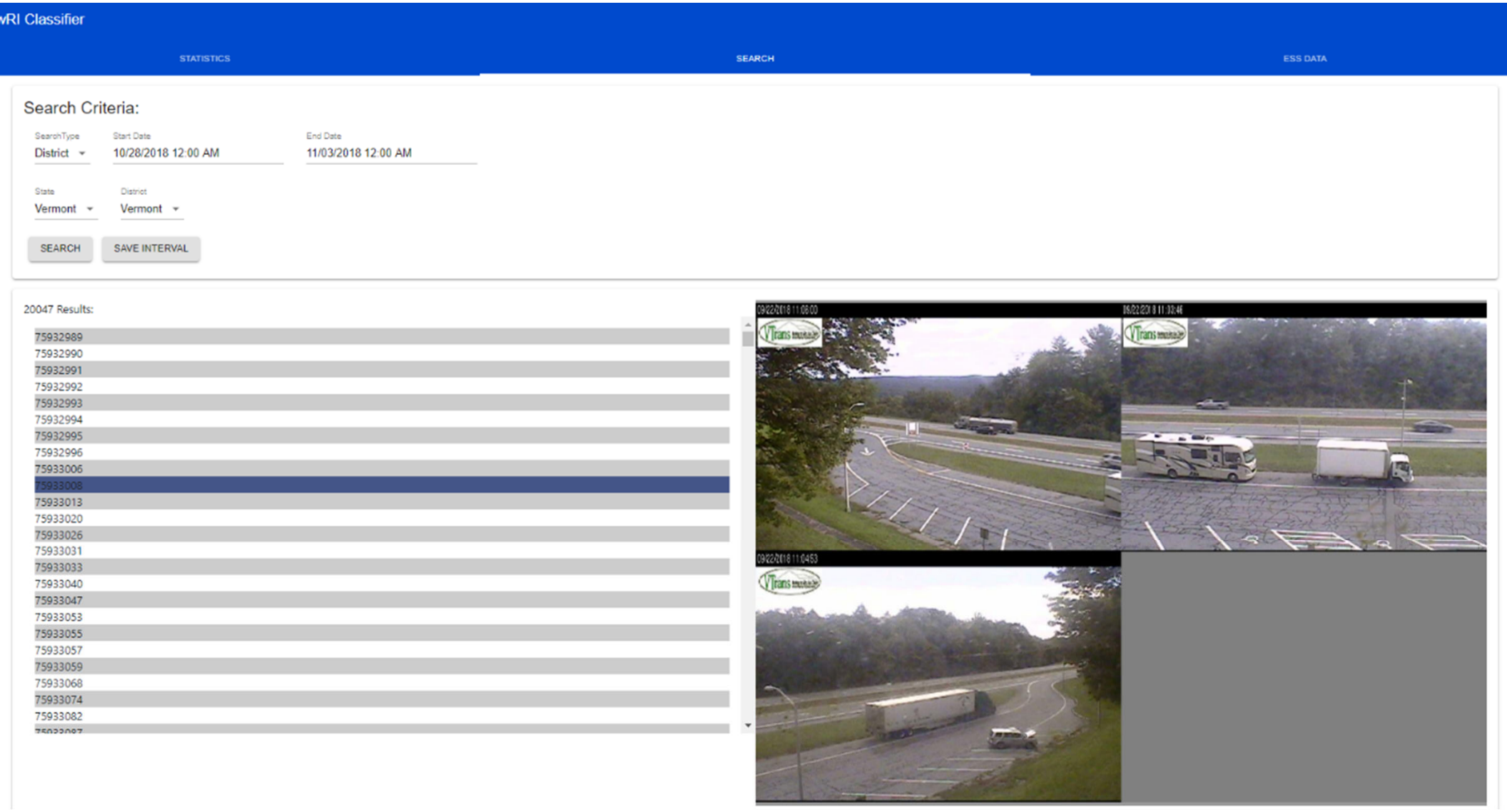
Weather Detection – Data Curation (cont)



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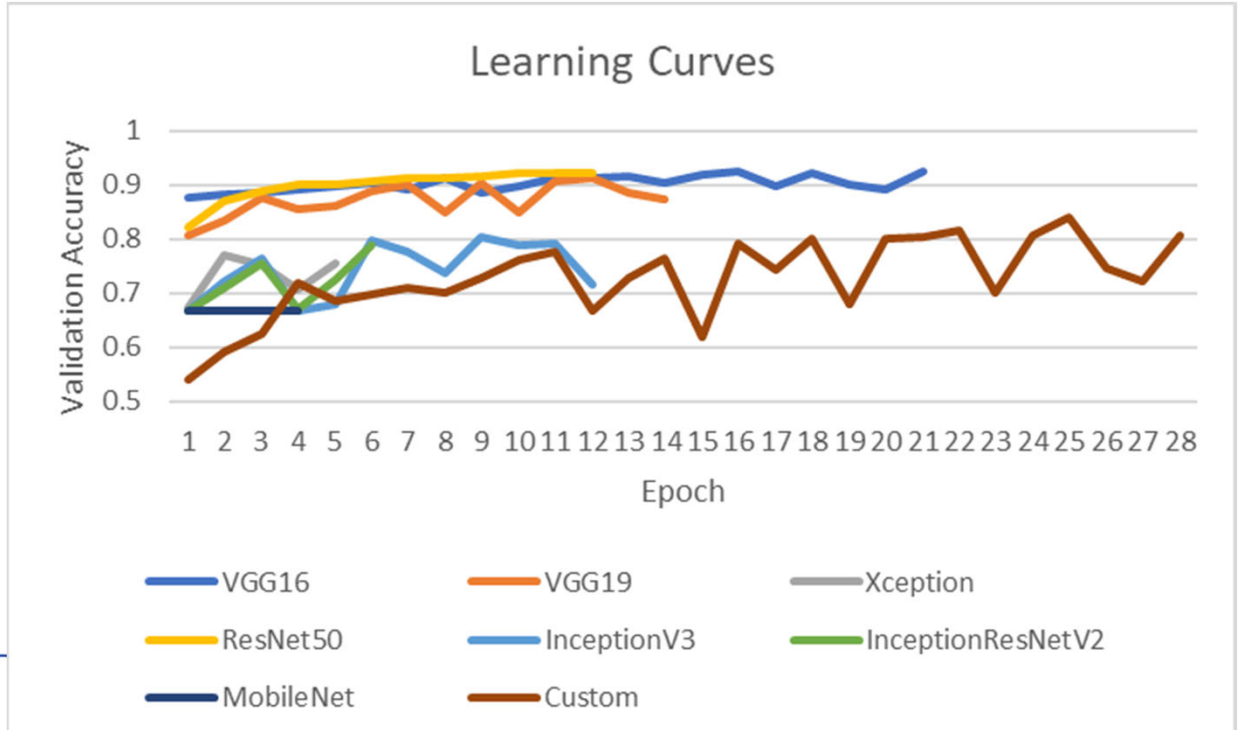
Weather Detection – Evaluating Base Model

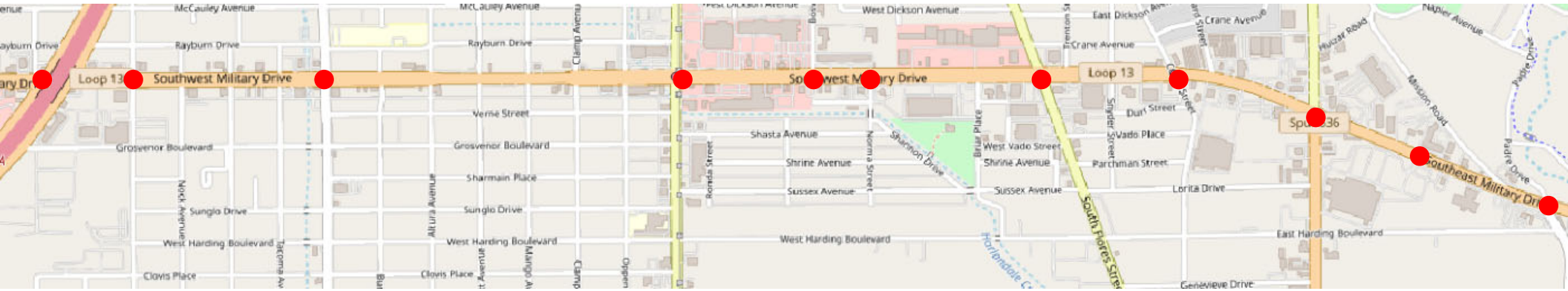
- None of the base models considered were able to perform adequately
- Some layers/weights from pre-trained models were used in our final model
- Final accuracy was able to achieve >90% classifying validation dataset

Model	Size	Top-1 Accuracy	Trainable Parameters	Depth (Layers)
Xception	88 MB	79%	22,910,480	126
VGG16	528 MB	71.3%	138,357,544	23
VGG19	549 MB	71.3%	143,667,240	26
ResNET50	98 MB	74.9%	25,636,712	-
InceptionV3	92 MB	77.9%	23,851,784	159
InceptionResNETV2	215 MB	80.3%	55,873,736	572
MobileNet	16 MB	71.3%	4,253,864	88



Case Study: City of San Antonio

- **Premise**: Monitor 11 cameras along roadway, collecting vehicle metrics. Later phase, pedestrian metrics also considered.
- **Rationale**: Stretch of road was selected due to long history of major crashes and fatalities, plus an existing high density of traffic cameras along the stretch of road in questions.



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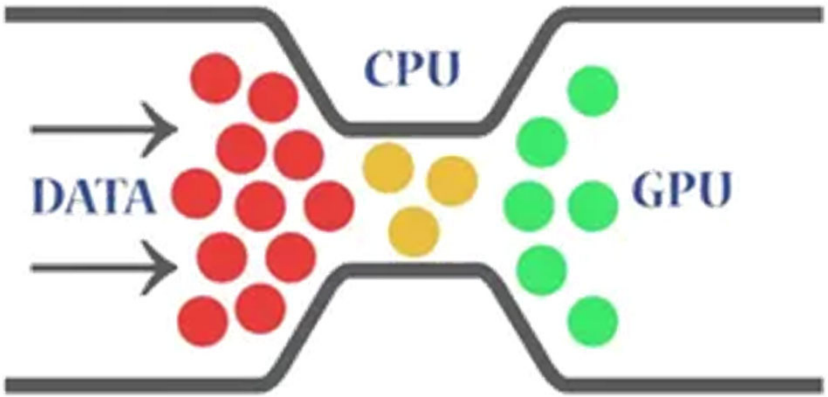
Scaling to Multiple Cameras

- Object Detection
  - Batching
- Object Tracking
  - Multiple Processes
- Geolocation
  - Multiple Processes
- Other
  - Multiple Docker Containers
  - Each Supports Batch of Camera Feeds

- GPU & CPU Bottlenecks
- Optimize Frames Per Second
  - Native 30fps
  - Necessary 5-10fps
- Eliminate Disk IO Dependencies



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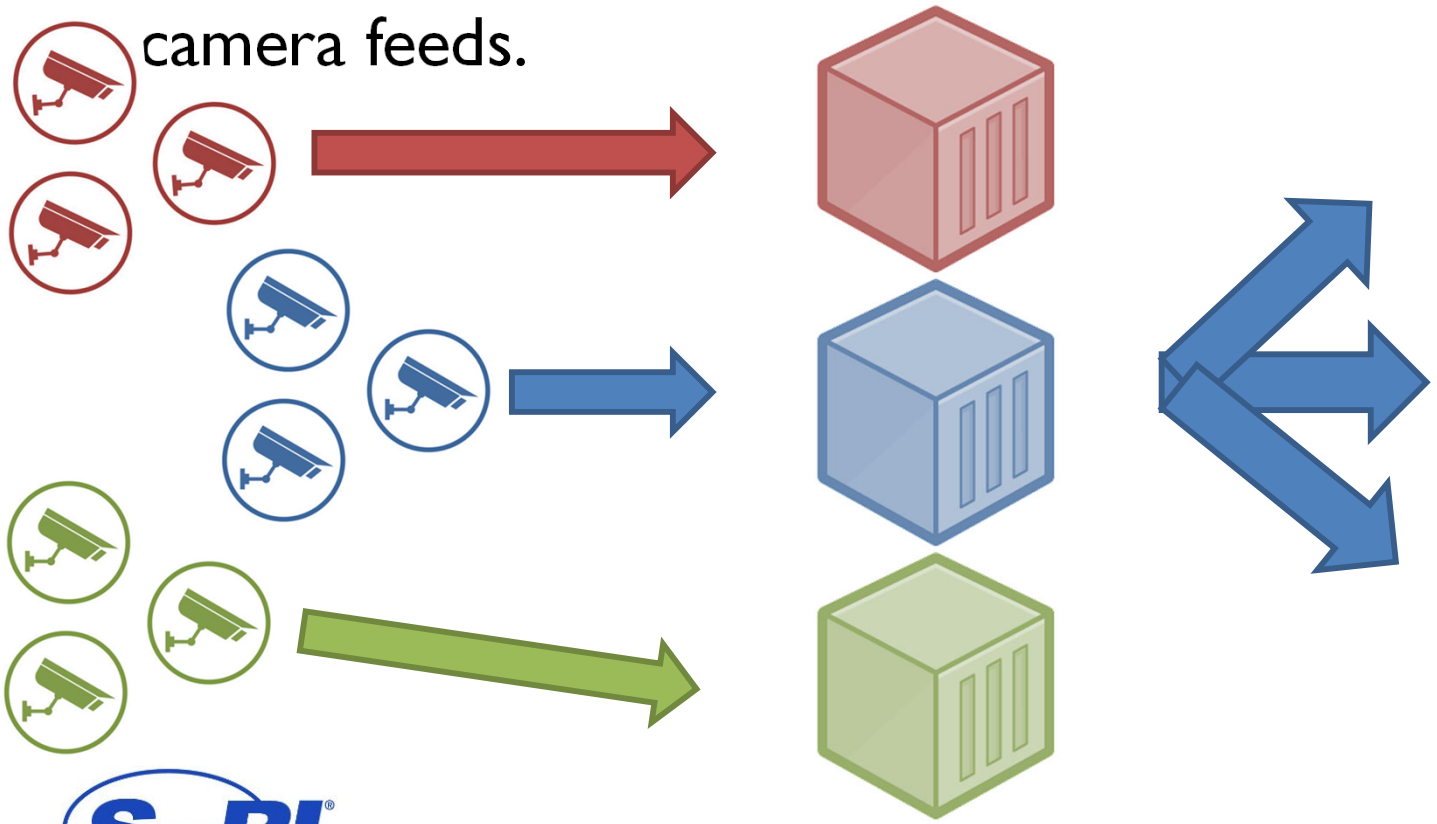
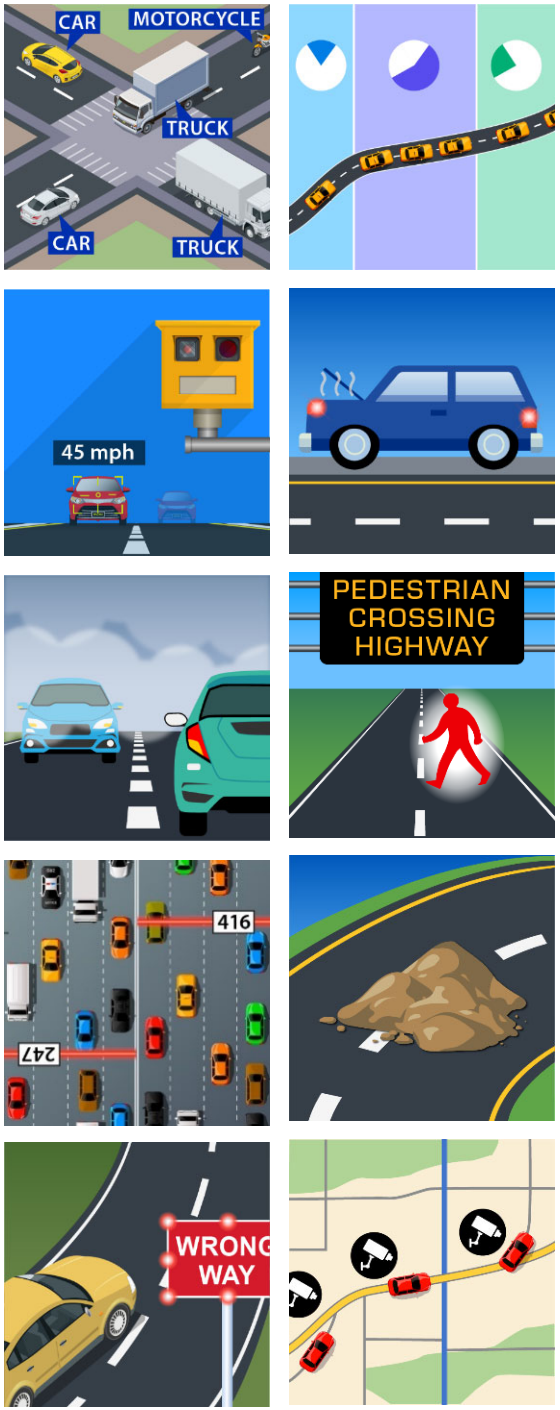
Scaling – Next Steps

- Extend batch processing beyond detection, tracking, and geolocation.
- Capabilities beyond above rely largely on serial CPU processing, forcing use of multiple docker containers to scale out number of camera feeds.





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Refining Homography Mapping

- Working with broader range of cameras, it became clear better tooling to build robust homography maps at scale was necessary.
- The number of keypoints used in building homography map had significant impact on ability to generalize across the entire field of view.

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