

# Tackling Fleet Test Data with MATLAB

*An Automotive Fleet Data Case Study*

Will Wilson

Application Engineer

# Agenda

- Motivation & Common Understanding
- Case Study: Automotive Fleet Data Analytics
- Key Takeaways

## Why Analyze Vehicle Fleet Data?

- Understand real-world behavior (spec vs. actual usage)
- Make decisions with **all** of your data
- Enable Domain Experts to validate component or system behavior ***in situ***
- Identify and open up new market / product opportunities

# BMW Uses Machine Learning to Detect Oversteering

## Challenge

Develop automated software for detecting oversteering, an unsafe condition in which rear tires lose their grip during a turn

## Solution

Use MATLAB to develop, train, and evaluate a variety of supervised machine learning classifier types, including KNN, SVM, and decision trees

## Results

- Oversteering identified with greater than 98% accuracy
- Multiple machine learning classifiers trained automatically
- Code generated and deployed to an ECU for real-time, in-vehicle testing



A BMW M4 oversteering on a test track.

*“Working in MATLAB, we developed a supervised machine learning model as a proof of concept. Despite having little previous experience with machine learning, in just three weeks we completed a working ECU prototype capable of detecting oversteering with over 98% accuracy.”*

*- Tobias Freudling, BMW Group*

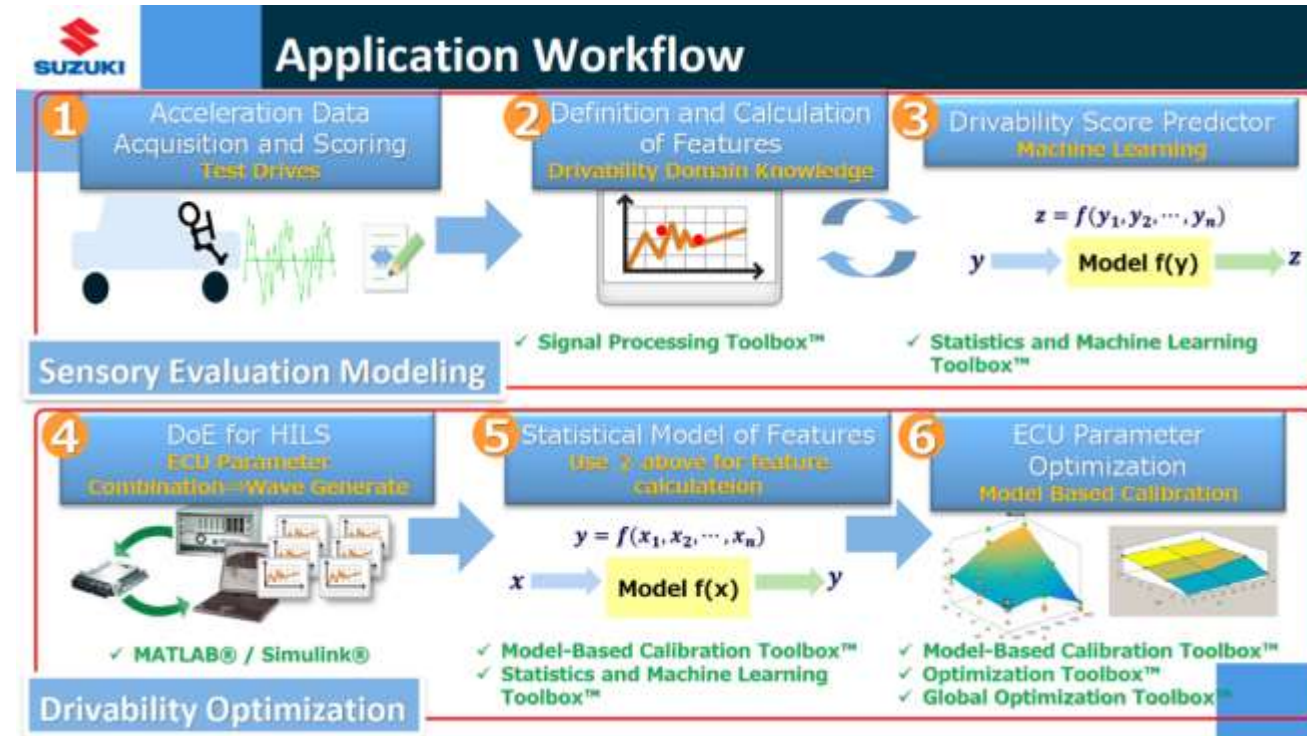
# Suzuki Motor Corporation leverages Machine Learning as part of a MATLAB based workflow to optimize control parameters

## Optimize control parameters to achieve “Drivability feel”

- Need to standardize

## Challenges

- Drivability was quantified based on individual experience and sensory feel
- Model creation required lots of trial and error, need to iterate quickly was important
- Computing time



Source: „Machine Learning Based Sensory Evaluation Modeling for Vehicle Driveability Optimization“  
 Yoshinao Okajima, Suzuki Motor Corporation  
 MATLAB EXPO Japan, 2017



# Workflows Enable Domain Experts to Develop Fleet Analytics

## Complete Workflows

Data Access

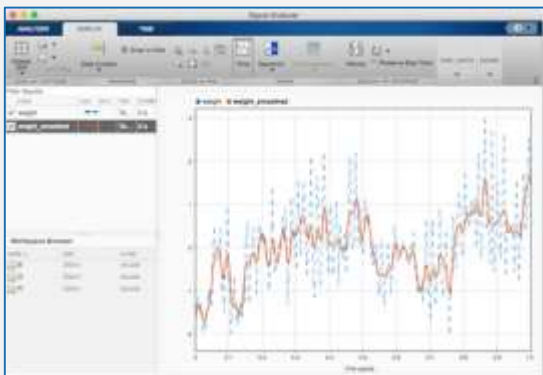
Preprocessing

Feature Engineering

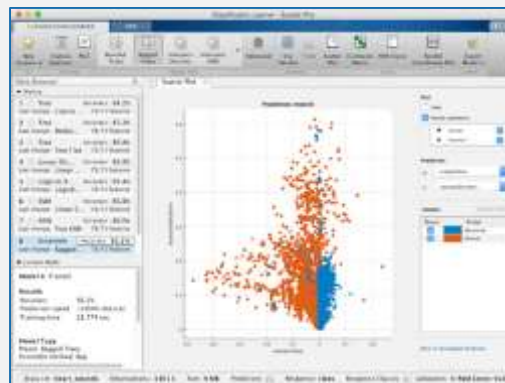
Model Training

Model Tuning

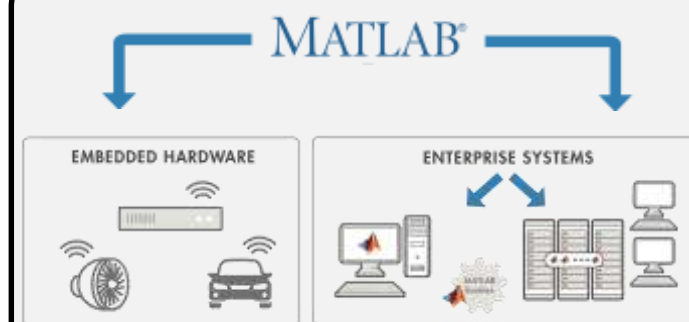
Deployment



Datatypes and tools for missing data, outliers, time-alignment, etc.



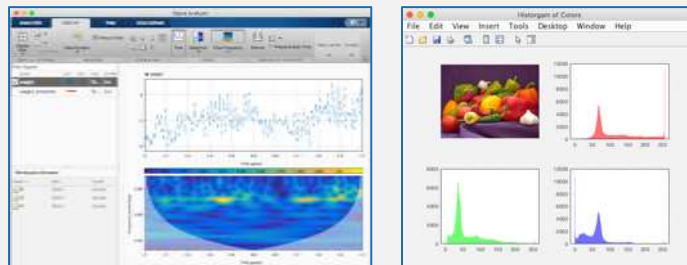
Machine Learning apps



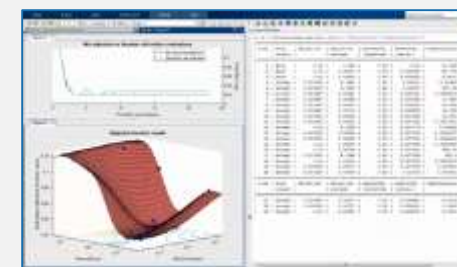
C/C++ Code Generation and Enterprise IT Integration



Text files, spreadsheets, databases, binary files, data feeds, web, cloud storage

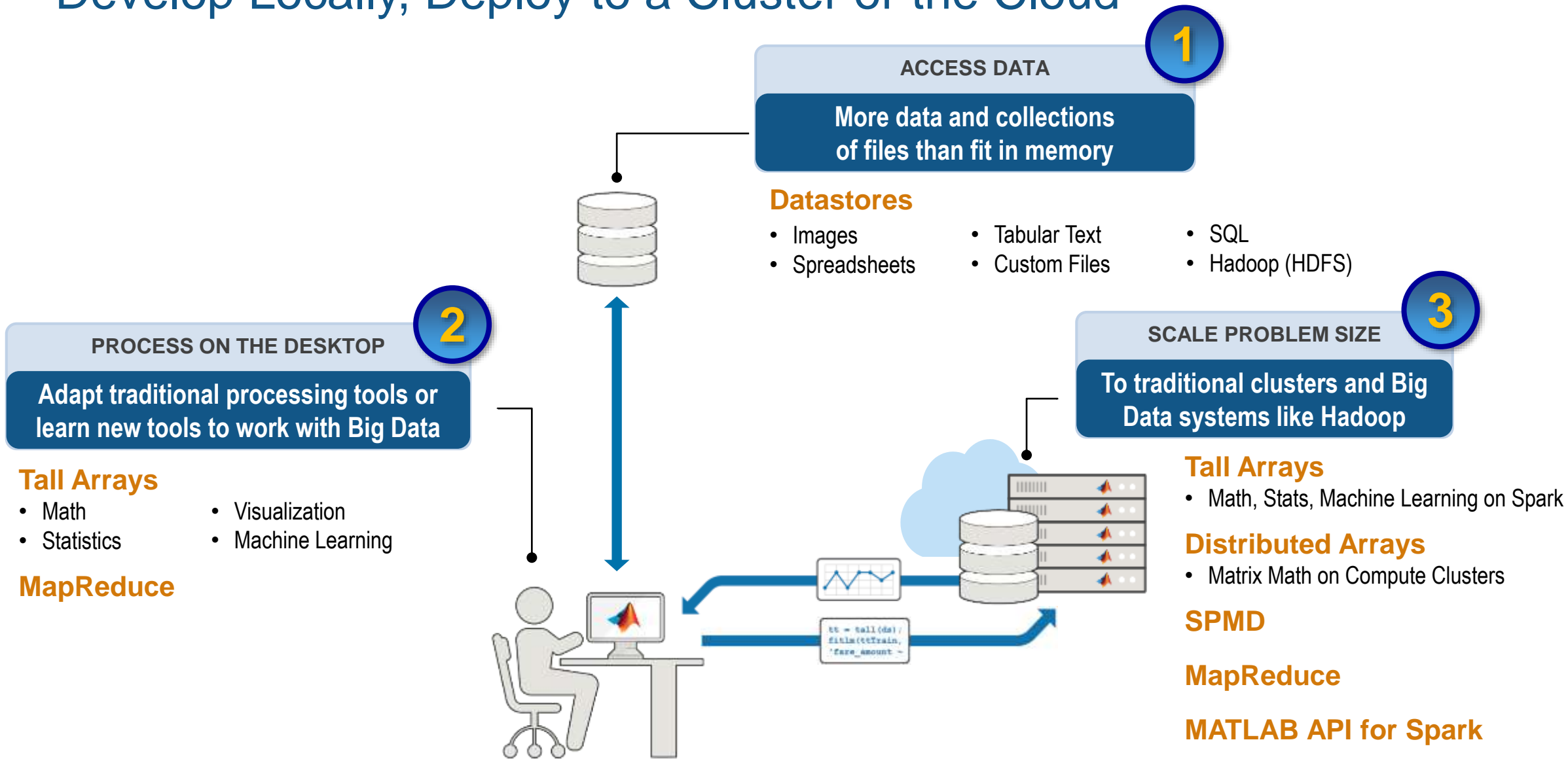


Domain-specific techniques for Signals, Images, Video, Audio, and Text







Automated Parameter Tuning

# Develop Locally, Deploy to a Cluster or the Cloud

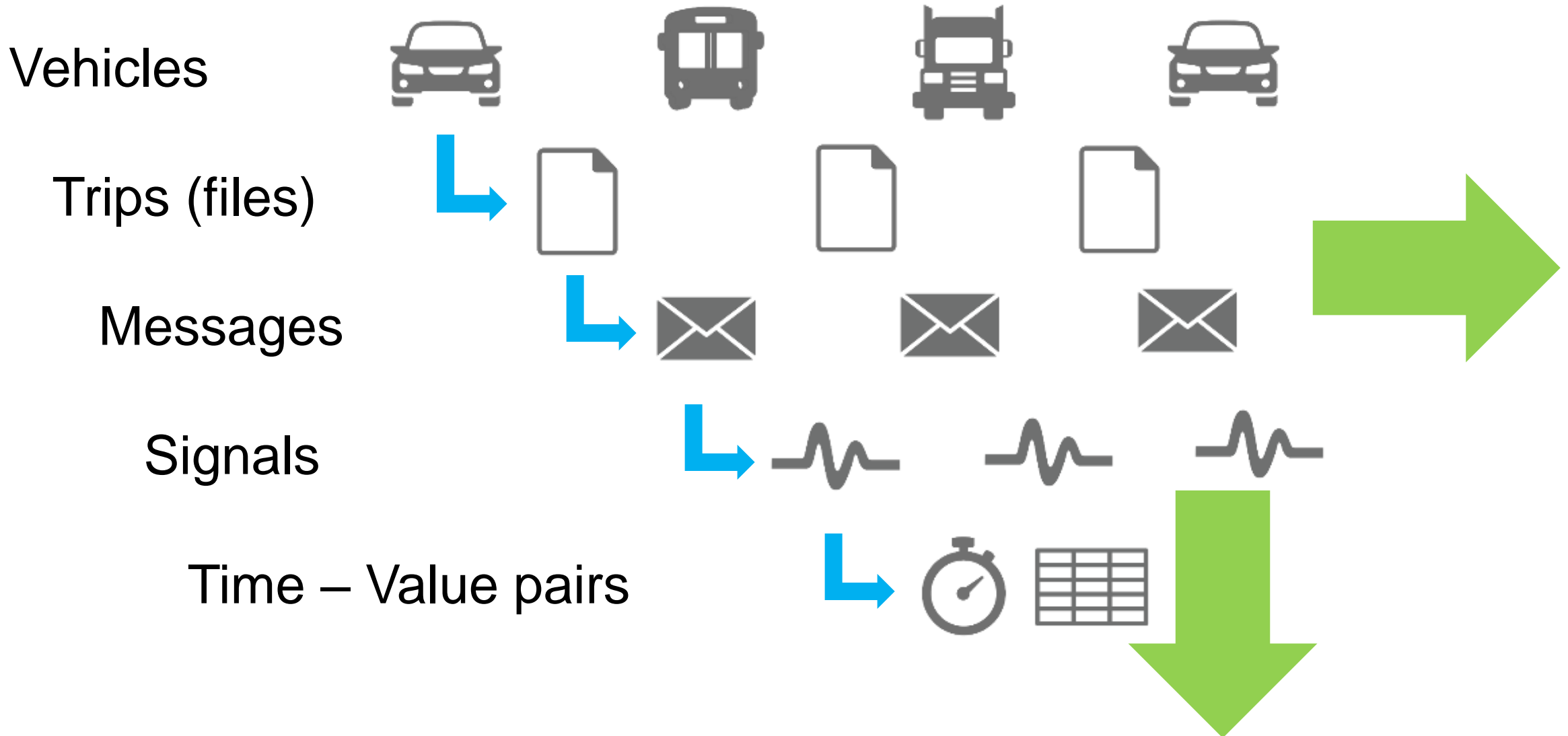


# Challenges with Analyzing Automotive Fleet Data

Challenge	How does MATLAB Help?
Time    	Out of the box, MATLAB R2018a is 2x faster than MATLAB R2015a (or older)
Too much data / very large individual files	datastores, tall Arrays, MATLAB MapReduce, Parallel Computing
Time Series Data ( <i>with different sample rates</i> )	timetable, retime, synchronize
Messy / Missing / Incomplete Data	Extensive <a href="#">pre-processing</a> functionality
File Formats	Native support for parquet and MDF file formats, custom datastores
Integrate data-oriented algorithms with classical controls	MATLAB & Simulink in a single platform



# Lesson's Learned About Automotive Vehicle Test Fleets



# Agenda

- Motivation & Common Understanding
- **Case Study: Automotive Fleet Data Analytics**
- Key Takeaways

# Case Study: MathWorks Vehicle Fleet

## Challenge

- Given a large set of vehicle fleet data:
  - Efficiently explore all of the available data to deepen our understanding
  - Develop and implement “event detection” functionality
  - Develop a Machine Learning model to classify driving behavior

## Results

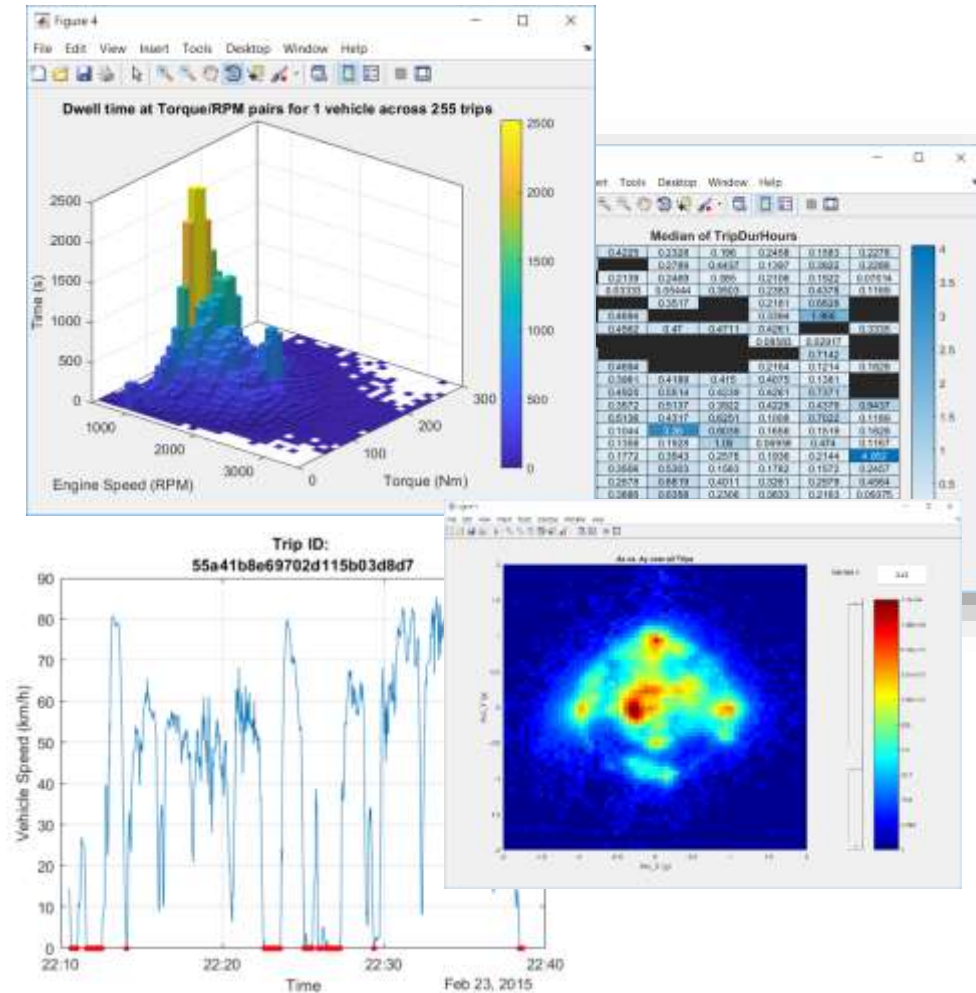
- Utilizing the MATLAB platform and `tall` arrays, each of the challenge requirements above were delivered on in a flexible, scalable way.

# Demo

## *Parts 1 & 2*

# Case Study Results – Exploration & Discovery

- Worked with all of our data with `cell` arrays
  - Trip based analytics (“for Each”)
  - Fleet based analytics (“for All”)
- Extracted performance metrics & created summary visualizations
- Applied an "Event Detection" function to all of our data to find specific information



# Case Study: MathWorks Vehicle Fleet

## Challenge

- Given a large set of vehicle fleet data:
  - Efficiently explore all of the available data to deepen our understanding
  - Develop and implement “event detection” functionality
  - Develop a Machine Learning model to classify driving behavior

## Results

- Utilizing the MATLAB platform and `tall` arrays, each of the challenge requirements above were delivered on in a flexible, scalable way.

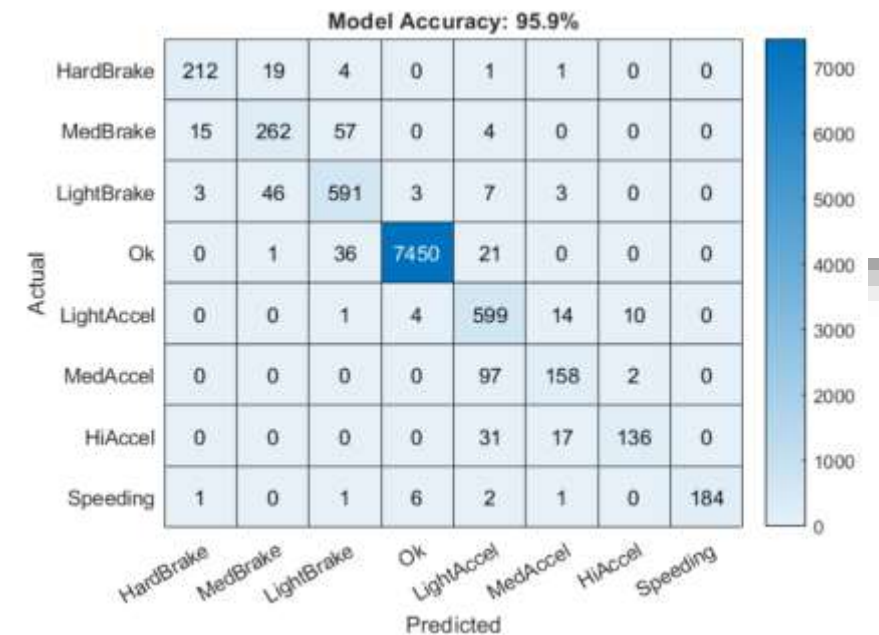
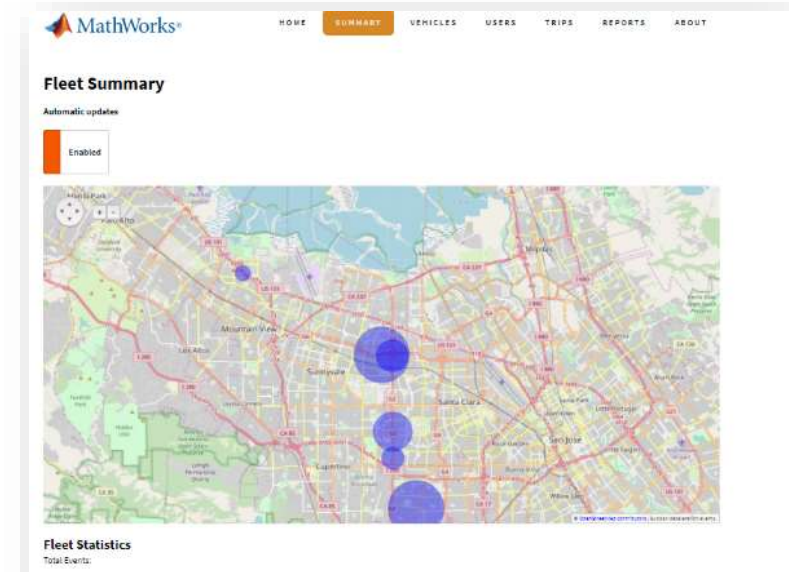


# Demo

## *Part 3*

# Case Study Results – Model & Predict

- Interactively explored classification algorithms with the Classification Learner App
- Investigated ways to incrementally improve model performance
- Generated c-code from our MATLAB based Machine Learning model to enable faster prediction time



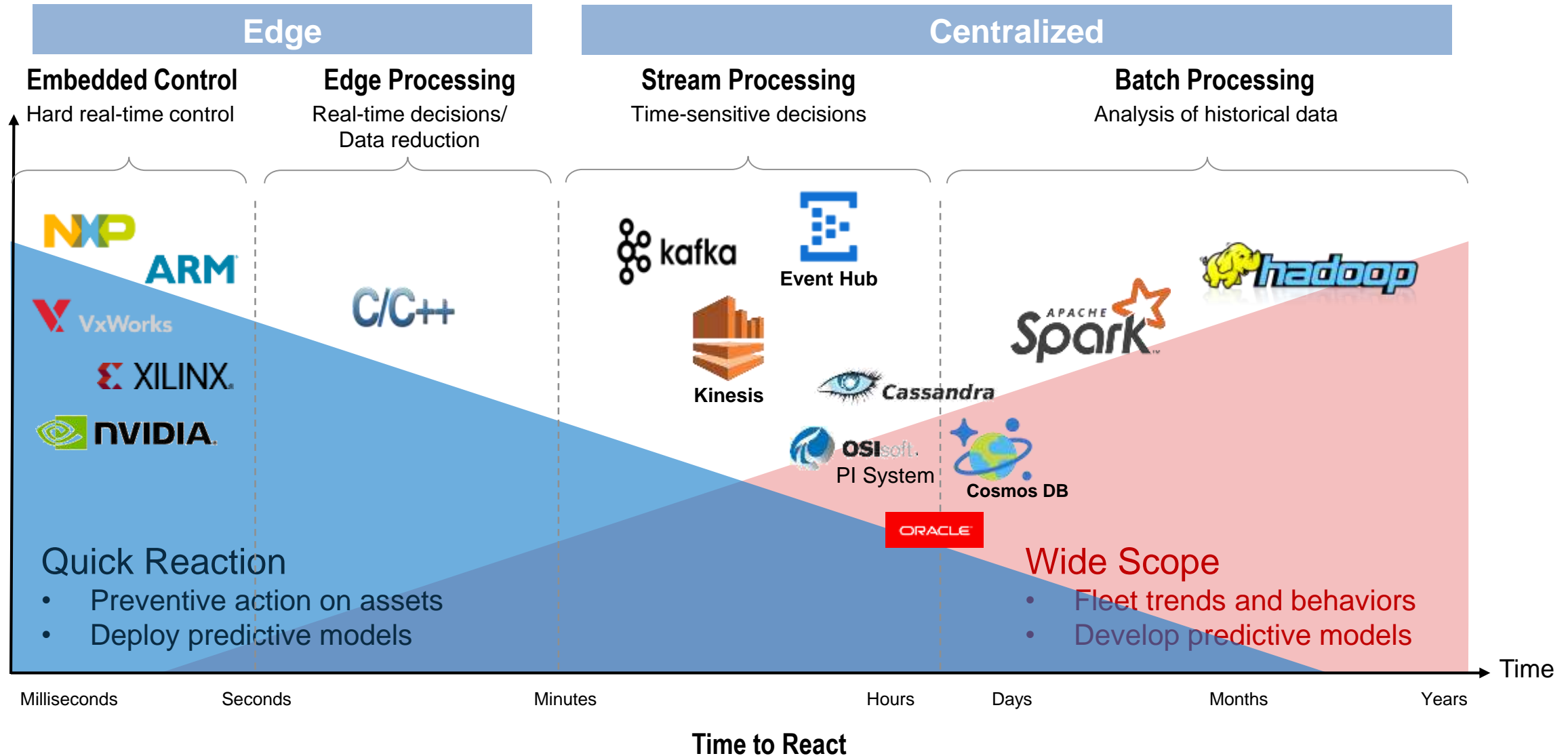
## Workflow Pattern / Recipe

- Access out of memory data
  - Aggregate, summarize, & visualize
  - Develop functions for event detection and calculation
  - Leverage table & timetable functions
  - Apply functions to all of your data
- `datastore & tall`
  - `table, histogram, heatmap, boxplot, binscatter`
  - Normal MATLAB code
  - `fillmissing, filloutliers, synchronize, retime, etc`
  - `matlab.tall.transform & matlab.tall.reduce`

# Agenda

- Motivation & Common Understanding
- Case Study: Automotive Fleet Data Analytics
- **Key Takeaways**

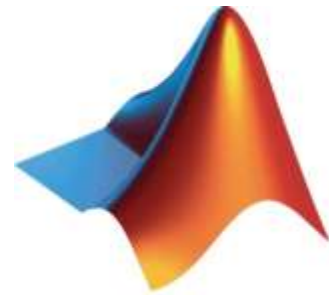
# MATLAB Integrates Across the Spectrum of Processing Needs



## Key Takeaways / Call To Action

- Working with fleet test data is hard. The MATLAB platform enables **Domain Experts** to implement efficient **Data Analytics** ranging from simple exploratory work to deployment of full featured **Machine Learning Models**.
- Make sure you are thinking about the “**Everything Else**” required to achieve your goals. Data ingestion, cleanup, and deployment are just as important as the modeling / Machine Learning step in the process.
- Connect with me to discuss fleet analytics: [wwilson@mathworks.com](mailto:wwilson@mathworks.com)





# MathWorks®

*Accelerating the pace of engineering and science*

© 2019 The MathWorks, Inc. MATLAB and Simulink are registered trademarks of The MathWorks, Inc. See [www.mathworks.com/trademarks](http://www.mathworks.com/trademarks) for a list of additional trademarks. Other product or brand names may be trademarks or registered trademarks of their respective holders.