
MATLAB EXPO 2018
KOREA

MATLAB EXPO 2018

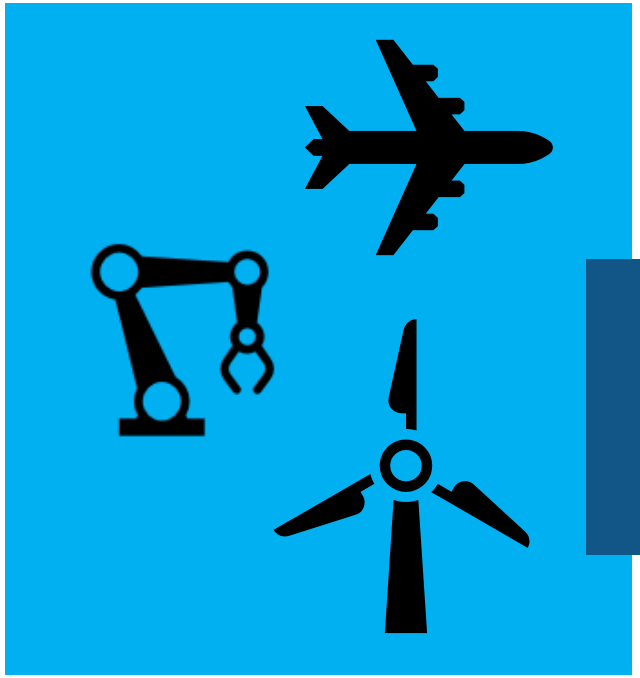
엔터프라이즈, 빅 데이터 및 애널리틱 솔루션 활용을 위한 MATLAB 적용기술 소개

성 호 현 부장

Agenda

1. Access and Explore Data
   - Files
   - Databases
   - Sensors
2. Preprocess Data
   - Working with Messy Data
   - Data Reduction/ Transformation
   - Feature Extraction
3. Develop Predictive Models
   - Model Creation e.g. Machine Learning
   - Parameter Optimization
   - Model Validation
4. Integrate with Production Systems
   - Desktop Apps
   - Enterprise Scale Systems
   - Embedded Devices and Hardware
5. Visualize Results
   - 3rd party dashboards
   - Web apps

The Need for Large-Scale Streaming



Jet engine: ~800TB per day
Turbine: ~ 2 TB per day

Predictive Maintenance

Increase Operational Efficiency

Reduce Unplanned Downtime

More applications require near real-time analytics

Medical Devices

Patient Safety

Better Treatment Outcomes

Connected Cars

Safety, Maintenance

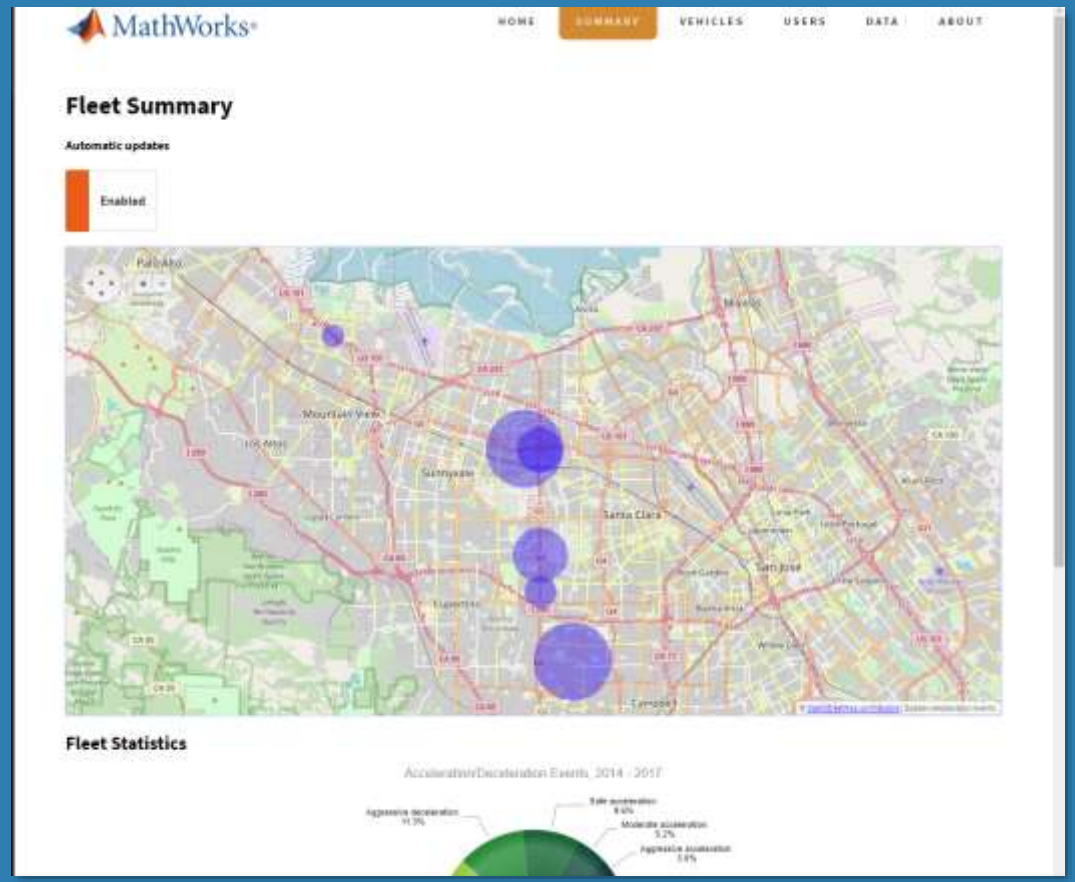
Advanced Driving Features

Car: ~25 GB per hour

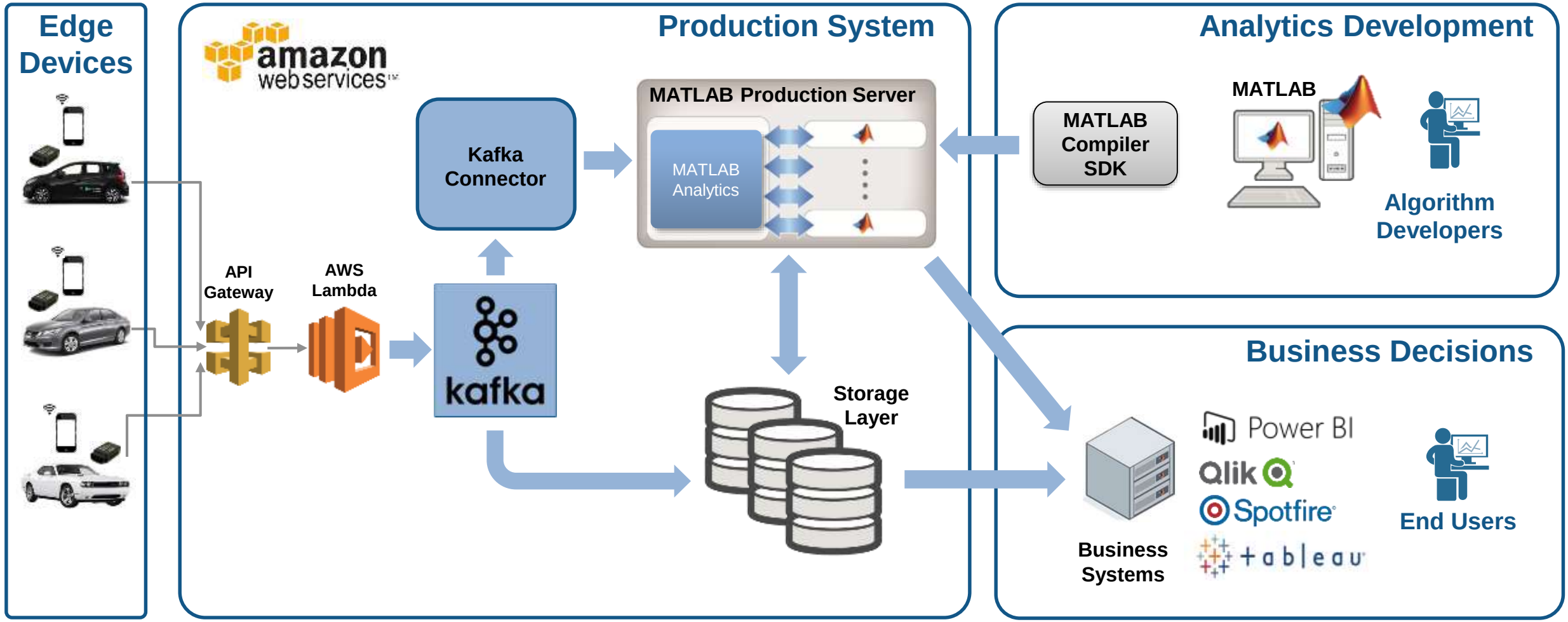
Example Problem – How's my driving?

- A group of MathWorks employees installed an OBD dongle in their car that monitors the on-board systems
- Data is streamed to the cloud where it is aggregated and stored
- We would like to use this data to score the driving habits of participants

Example: Fleet Analytics with MATLAB

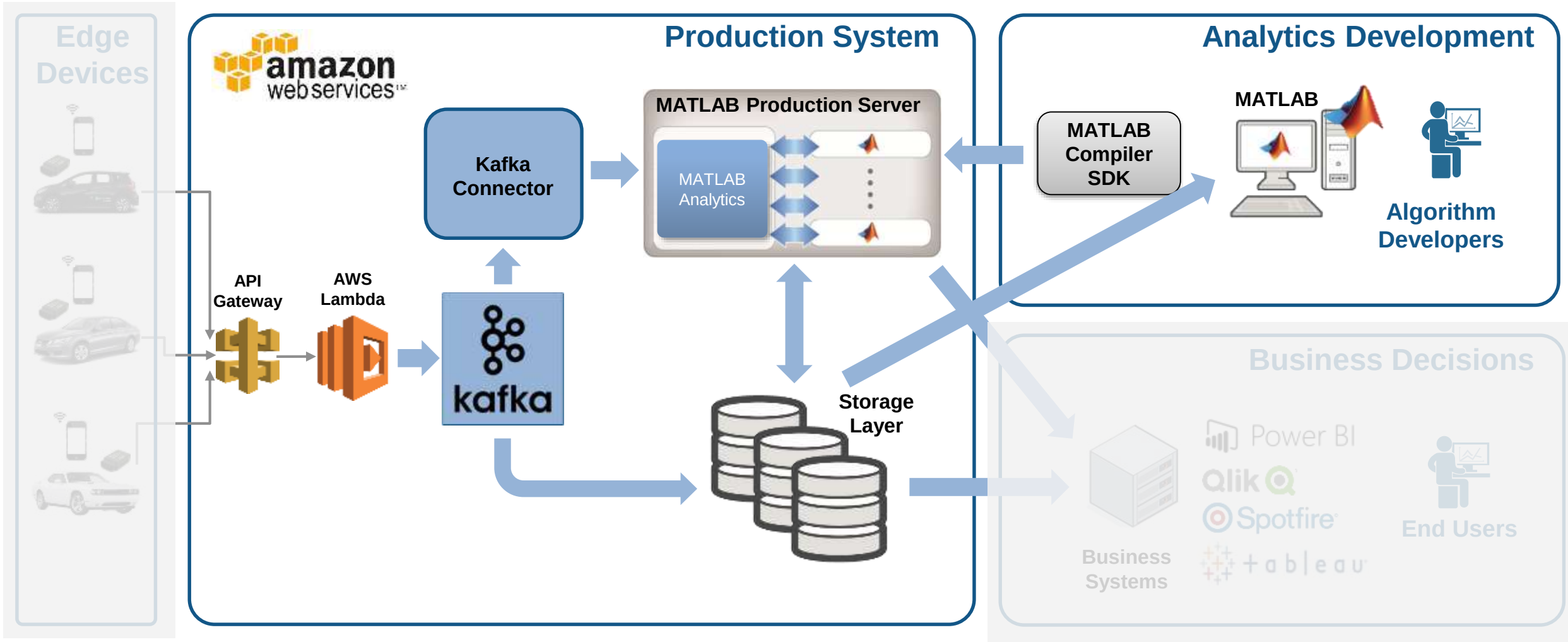


Fleet Analytics Architecture



1 Access and Explore Data

The first step is to clean up the incoming data



The Data: Timestamped messages with JSON encoding

```
{
    "vehicles_id": {"$oid":"55a3fd0069702d5b41000000"},
    "time" : {"$date":"2015-07-13T18:01:35.000Z"},
    "kc" : 1975.0, "kff1225" : 100.65293, "kff125a" : 110.36619, …
}
```

Key

Timestamp

Values

```
{
    "vehicles_id": {"$oid":"55a3fe3569702d5c5c000020"}
    "time":{"$date":"2015-07-13T18:01:53.000Z"},
    "kc" : 2000.0, "kff1225" : 109.65293, "kff125a" : 115.36619,
      …
}
```

```
{
    "vehicles_id": {"$oid":"55a4193569702d115b000001"}
    "time":{"$date":"2015-07-12T19:04:04.000Z"}
    "kc":2200.0, "kff1225" : 112.65293, "kff125a" : 112.36619,
      …
}
```

Access a Sample of Data

Raw Data

	timestamp	1 value	2 key
1	15-Jan-2015 22:12:23	'{ "_id" : { "$oid" : "55a41cb069702d115b059ee0" }, "trip_id" : { "$oid"...	'55a41cb069702d115b059ede'
2	15-Jan-2015 22:12:24	'{ "_id" : { "$oid" : "55a41cb069702d115b059ee1" }, "trip_id" : { "$oid"...	'55a41cb069702d115b059ede'
3	15-Jan-2015 22:12:25	'{ "_id" : { "$oid" : "55a41cb069702d115b059ee2" }, "trip_id" : { "$oid"...	'55a41cb069702d115b059ede'
4	15-Jan-2015 22:12:26	'{ "_id" : { "$oid" : "55a41cb069702d115b059ee3" }, "trip_id" : { "$oid"...	'55a41cb069702d115b059ede'

- ✓ Decode JSON data
- ✓ Create Timetable

Timetable

t = 4647×40 timetable

	trip_id	VIN	kff1001	kff1005	kff1006	kff1220	kff1221	kff1222	kff1223	kff125a
1 Sun Jul 12 16:18:41 UTC 2015	55a3fe356...	55a3fe356...	17.1000	-84.9323	45.4704	NaN	NaN	NaN	NaN	59.0434
2 Sun Jul 12 16:18:42 UTC 2015	55a3fe356...	55a3fe356...	17.1000	-84.9322	45.4704	NaN	NaN	NaN	NaN	57.8609
3 Sun Jul 12 16:18:43 UTC 2015	55a3fe356...	55a3fe356...	18.9000	-84.9322	45.4705	NaN	NaN	NaN	NaN	52.7147
4 Sun Jul 12 16:18:44 UTC 2015	55a3fe356...	55a3fe356...	18.9000	-84.9322	45.4705	NaN	NaN	NaN	NaN	51.1983
5 Sun Jul 12 16:18:45 UTC 2015	55a3fe356...	55a3fe356...	18.0000	-84.9321	45.4706	NaN	NaN	NaN	NaN	49.1095
6 Sun Jul 12 16:19:13 UTC 2015	55a3fe356...	55a3fe356...	58.5000	-84.9305	45.4686	NaN	NaN	NaN	NaN	73.2005
7 Sun Jul 12 16:19:14 UTC 2015	55a3fe356...	55a3fe356...	56.7000	-84.9304	45.4685	NaN	NaN	NaN	NaN	75.3612
8 Sun Jul 12 16:19:15 UTC 2015	55a3fe356...	55a3fe356...	57.6000	-84.9304	45.4683	NaN	NaN	NaN	NaN	70.7542
9 Sun Jul 12 16:19:16 UTC 2015	55a3fe356...	55a3fe356...	56.7000	-84.9303	45.4682	NaN	NaN	NaN	NaN	62.8340

Develop a Preprocessing Function

Timetable

t = 4647×40 timetable

	trip_id	VIN	kff1001	kff1005	kff1006	kff1220	kff1221	kff1222	kff1223	kff125a
1 Sun Jul 12 16:18:41 UTC 2015	55a3fe356...	55a3fe356...	17.1000	-84.9323	45.4704	NaN	NaN	NaN	NaN	59.0434
2 Sun Jul 12 16:18:42 UTC 2015	55a3fe356...	55a3fe356...	17.1000	-84.9322	45.4704	NaN	NaN	NaN	NaN	57.8609
3 Sun Jul 12 16:18:43 UTC 2015	55a3fe356...	55a3fe356...	18.9000	-84.9322	45.4705	NaN	NaN	NaN	NaN	52.7147
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5 Sun Jul 12 16:18:45 UTC 2015	55a3fe356...	55a3fe356...	18.0000	-84.9321	45.4706	NaN	NaN	NaN	NaN	49.1095
6 Sun Jul 12 16:19:13 UTC 2015	55a3fe356...	55a3fe356...	58.5000	-84.9305	45.468	NaN	NaN	NaN	NaN	73.2005
7 Sun Jul 12 16:19:14 UTC 2015	55a3fe356...	55a3fe356...	56.7000	-84.9304	45.468					
8 Sun Jul 12 16:19:15 UTC 2015	55a3fe356...	55a3fe356...	57.6000	-84.9304	45.468					
9 Sun Jul 12 16:19:16 UTC 2015	55a3fe356...	55a3fe356...	56.7000	-84.9303	45.468					

- ✓ Clean up
- ✓ Enrich
- ✓ Restructure

Preprocess data

```
t = sortrows(t);
t = rmmissing(t,'MinNumMissing',width(t)-2);
```

Perform windowed calculations

```
t.Speed = movmedian(t.SpeedGPS,3);
t.D1 = [0;diff(t.SpeedGPS)];
```

```
[tmin,tmax] = bounds(t.time);
tnew = tmin:seconds(10):tmax;
countsByTime = retime(t(:,'Event'),tnew,@histcounts);
```

Ad Hoc Access to Data from MATLAB

athenaQuery.mlx

Access the data in S3

Bring up the AthenaClient

```
athenaClient = aws.athena.Client();
athenaClient.Database = 'trainingdata';
athenaClient.initialize();
```

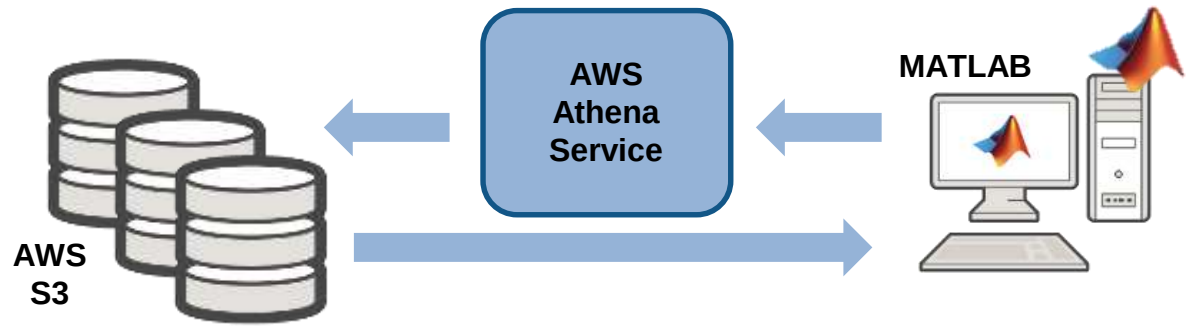
Create a query and submit

```
athenaClient.submitQuery('SELECT * FROM "trainingdata"."sampledata" limit 100','s3://fleettrainingdata')
```

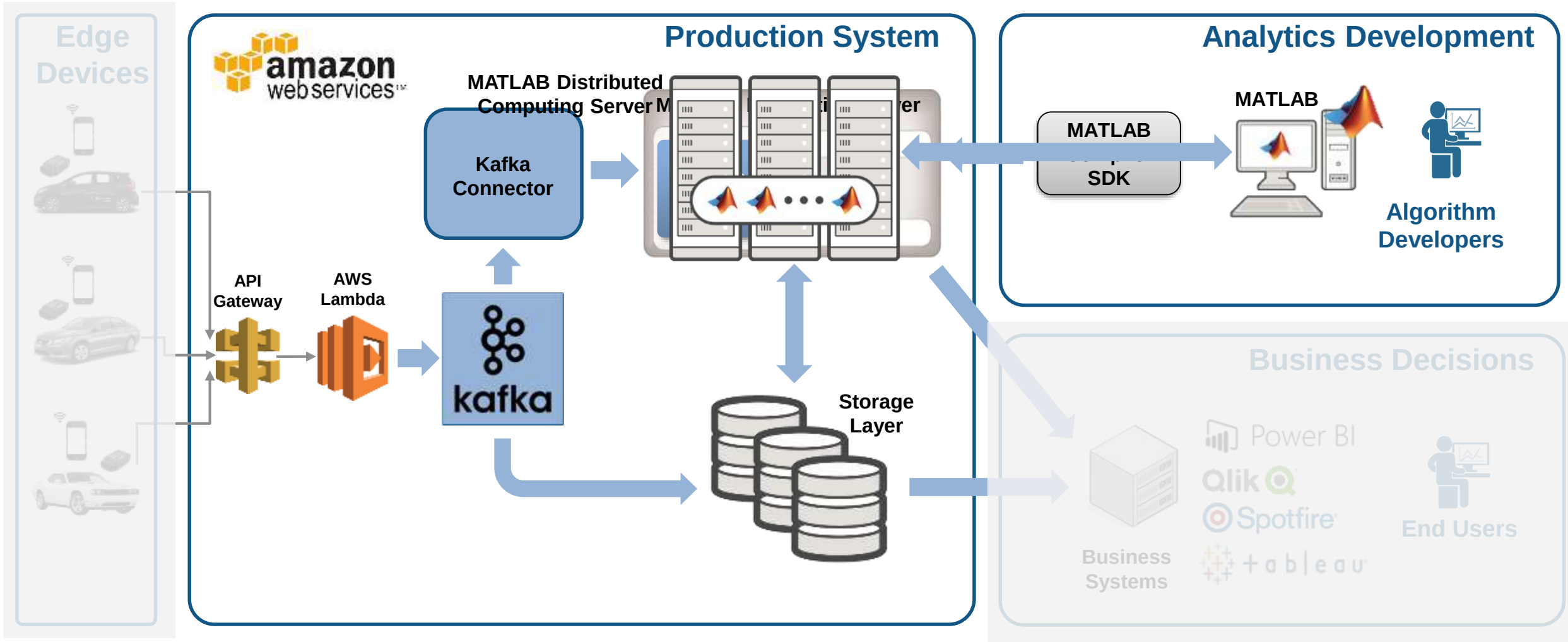
Fetch data as a table for easy analysis

```
ds = datastore('s3://fleettrainingdata/*.csv');
ds.NumHeaderLines = 2;
data = table(ds);
```

Your usual MATLAB workflow goes here



Develop a Predictive Model

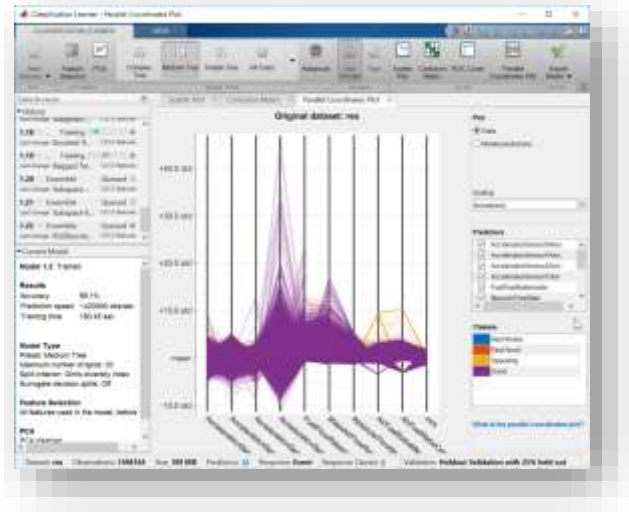


3 Develop Predictive Models

Everything you need to develop a predictive model is found in MATLAB

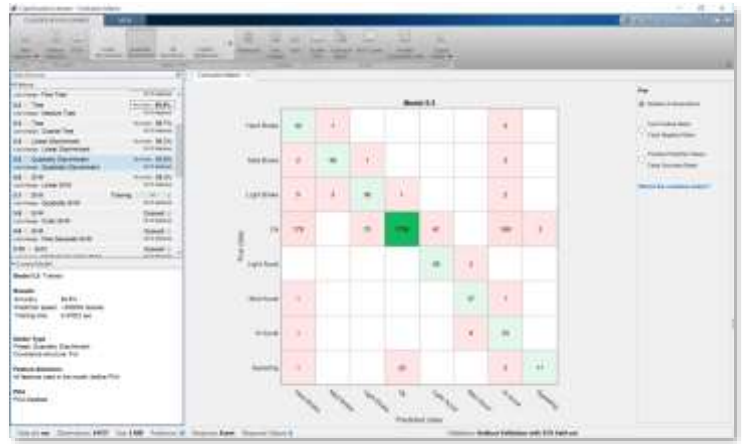
	1	2	3	4	5
time	Event	SpeedGPS	AccelerationSensorXAxis	AccelerationSensorYAxis	AccelerationSensorZAxi
Mon May 11 04:03:15 UTC 2015	Hard Brake	10.8360	-0.6996	0.6014	0.205
Wed May 06 19:09:48 UTC 2015	Hard Brake	27.8280	0.1419	0.9035	-0.526
Sun May 17 17:09:19 UTC 2015	Hard Brake	6.5520	0.9986	-0.0761	-0.004
Fri Jan 16 20:38:37 UTC 2015	Hard Brake	39.6128	0.0999	0.8000	0.367
Sat May 02 14:00:37 UTC 2015	Hard Brake	61.1280	0.4006	-0.4022	0.663
Mon Apr 27 17:54:27 UTC 2015	Fast Accel	37.7640	0.1527	0.4666	0.857
Sun May 03 21:00:42 UTC 2015	Fast Accel	17.2440	1.0235	0.0815	0.304
Mon May 04 11:30:33 UTC 2015	Fast Accel	19.6560	0.1336	0.8932	-0.578

Label Events



Represent Signals

Train Model



Validate Model

```
Evaluating tall expression using the Spark Cluster:
- Pass 1 of 2: Completed in 11 sec
- Pass 2 of 2: Completed in 2.3333 min
Evaluation completed in 2.6167 min
```

Scale up

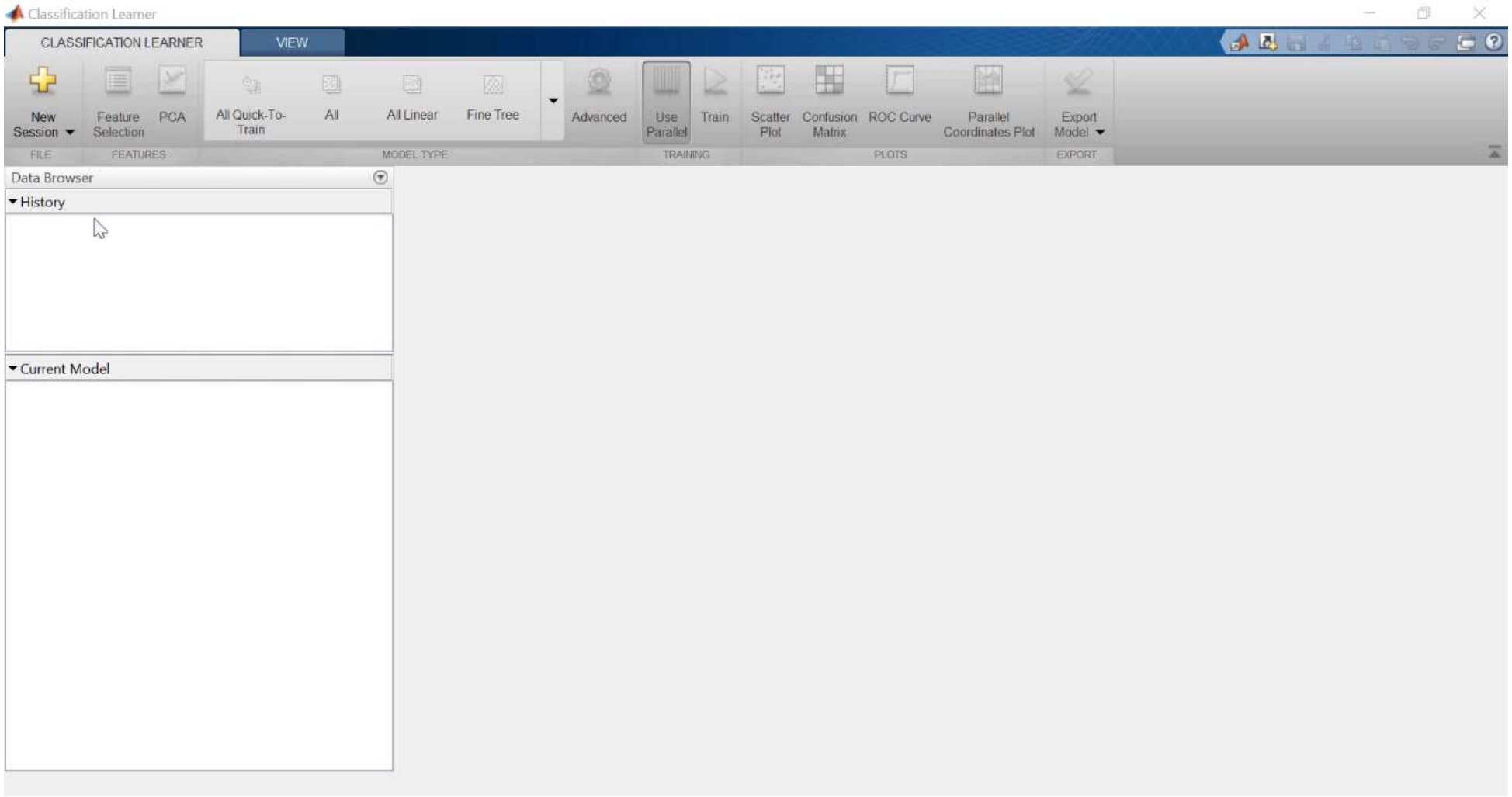
```
tt = tall(data);  % test tall array
model = TreeBagger(50,tt,'Event');
```

Scale to out of memory data

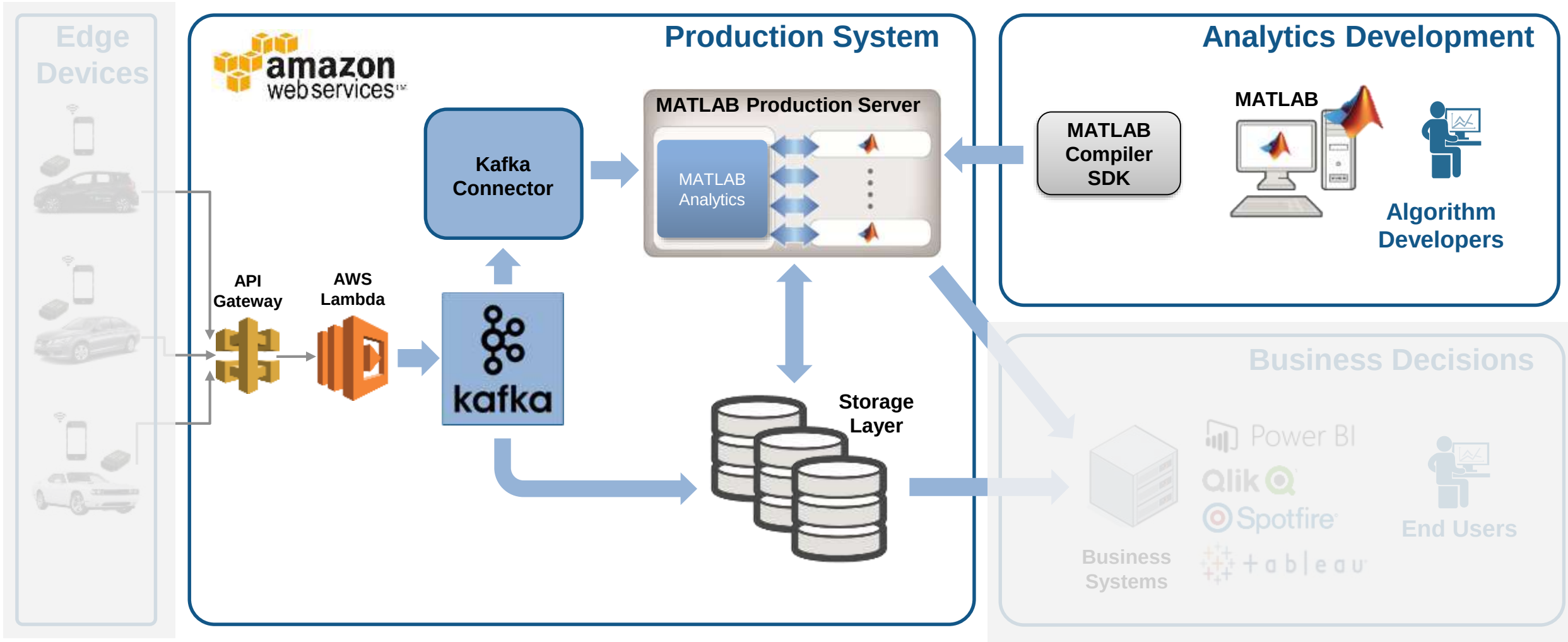
```
tt = tall(ds);
tt = preprocessData(tt);
model = TreeBagger(50,tt,'Event');
save machineLearningModel model
```

Scale Up

Develop a Predictive Model in MATLAB

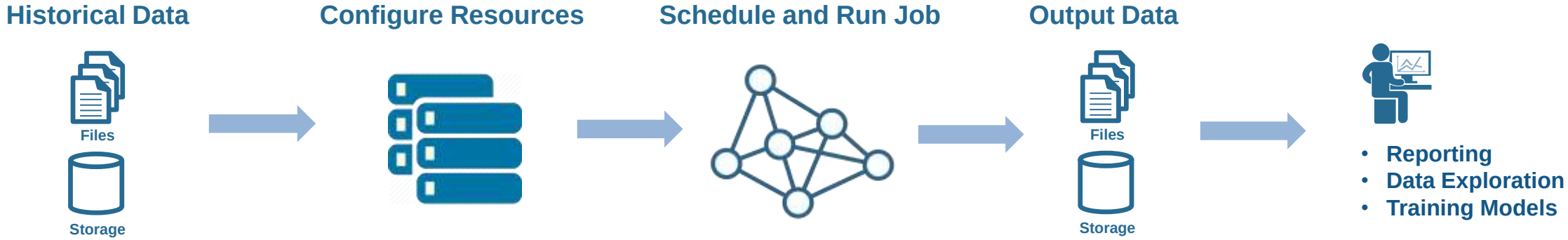


Integrate Analytics with Production Systems

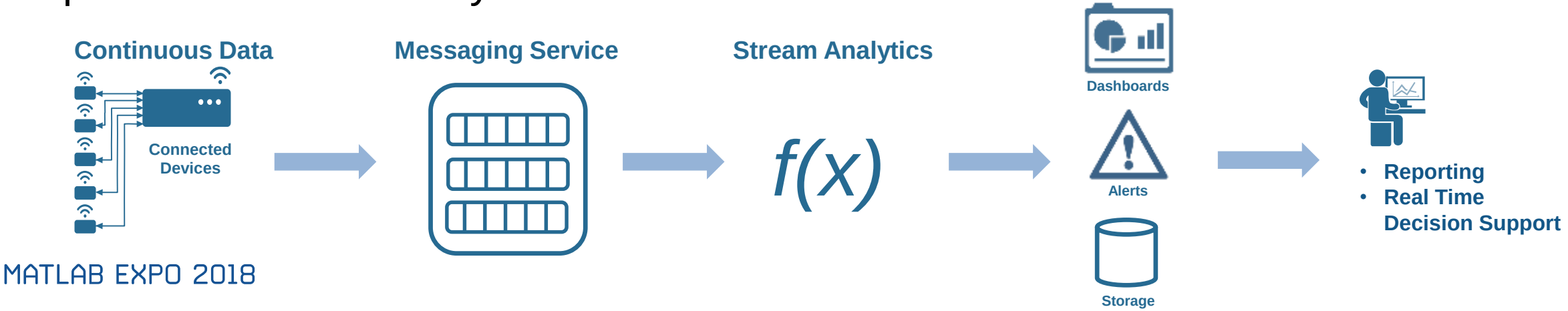


A quick Intro to Stream Processing

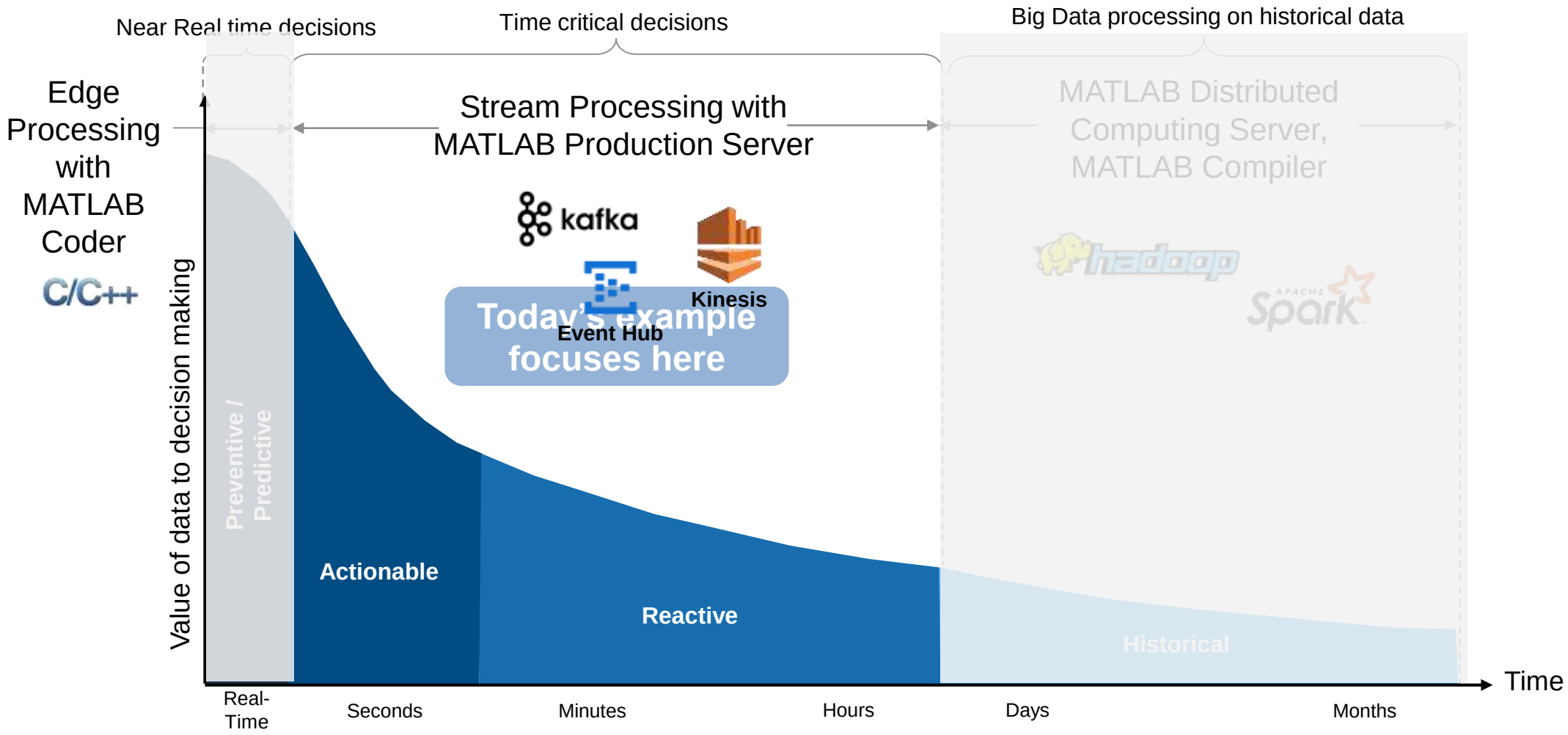
- ***Batch Processing*** applies computation to a finite sized historical data set that was acquired in the past



- ***Stream Processing*** applies computation to an unbounded data set that is produced continuously



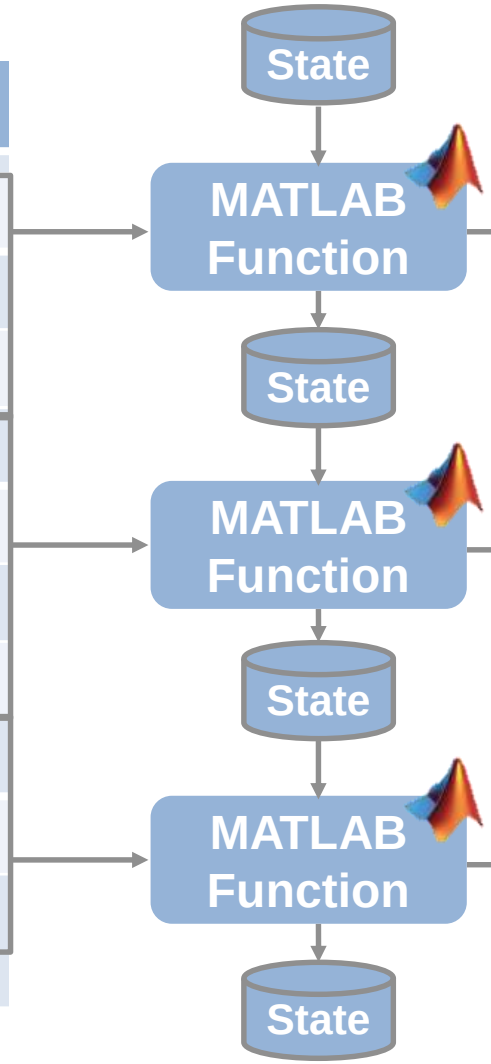
Why stream processing?



Streaming data is treated as an unbounded Timetable

Input Table

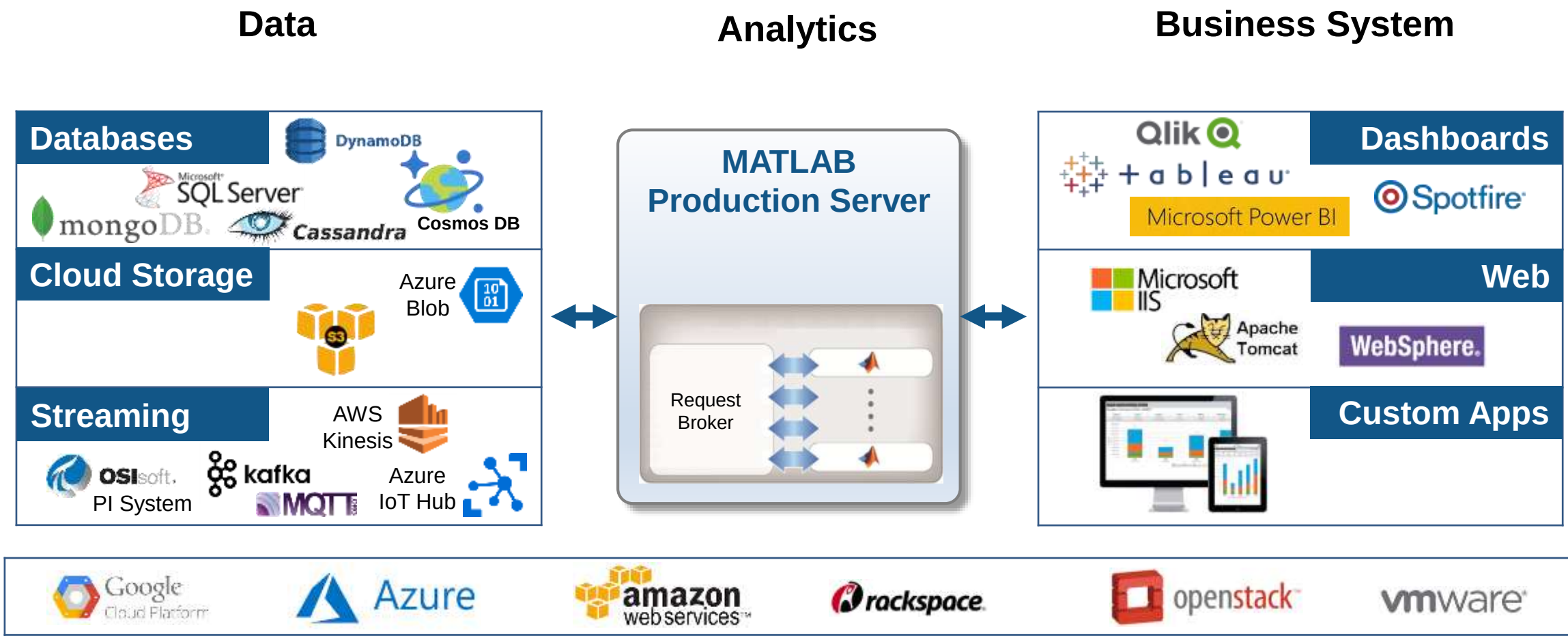
Event Time	Vehicle	RPM	Torque	Fuel Flow
18:01:10	55a3fd	1975	100	110
18:10:30	55a3fe	2000	109	115
18:05:20	55a3fd	1980	105	105
18:10:45	55a3fd	2100	110	100
18:30:10	55a419	2000	100	110
18:35:20	55a419	1960	103	105
18:20:40	55a3fe	1970	112	104
18:39:30	55a419	2100	105	110
18:30:00	55a3fe	1980	110	113
18:30:50	55a3fe	2000	100	110
…	…	…	…	…



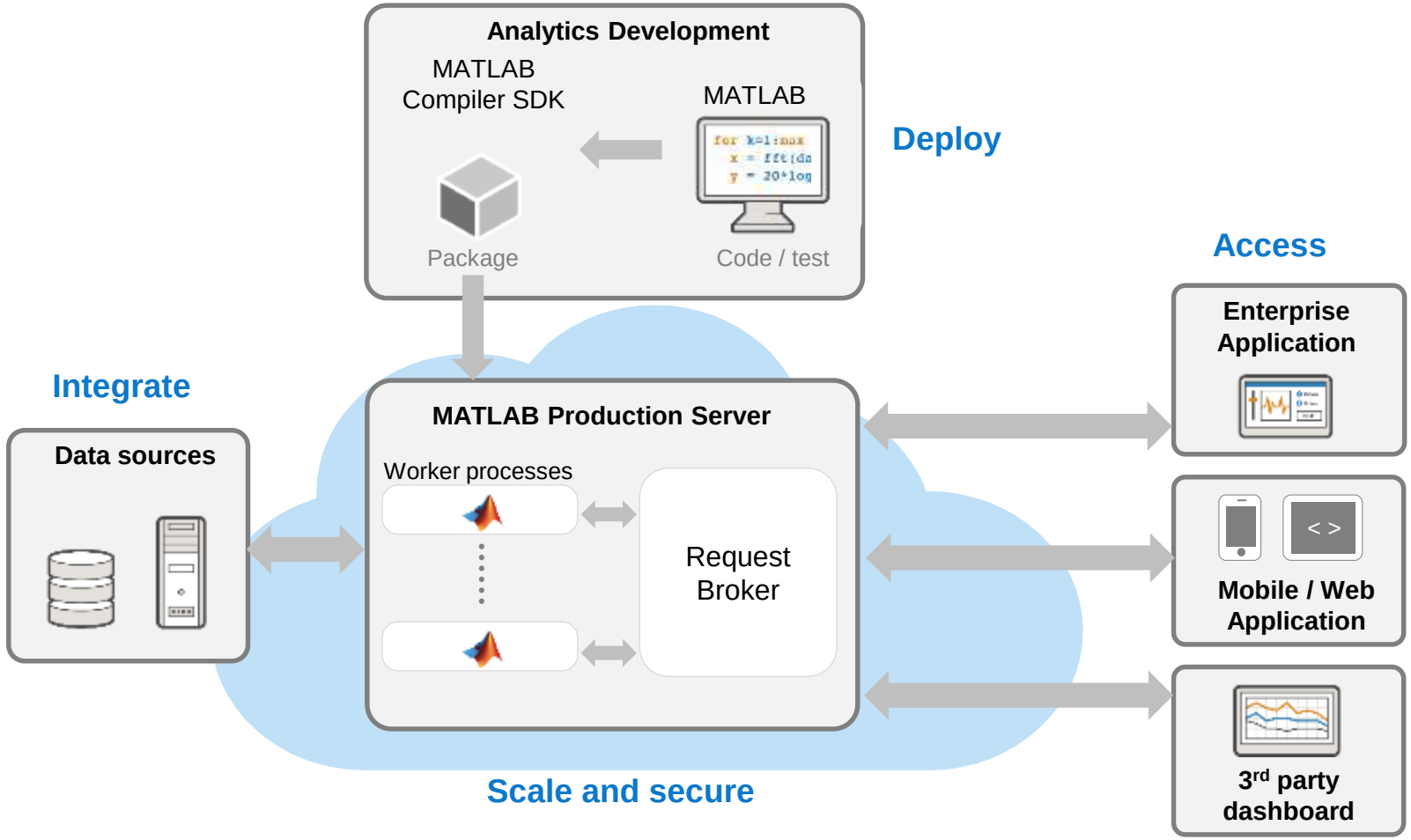
Output Table

Time window		Vehicle	Score
…		…	…
18:00:00	18:10:00	55a3fd	5
		55a3fe	…
		55a419	…
18:10:00	18:20:00	55a3fd	7
		55a3fe	3
		55a419	…
18:20:00	18:30:00	55a3fd	…
		55a3fe	4
		55a419	…
18:30:00	18:40:00	55a3fd	…
		55a3fe	5
		55a419	8

Introducing MATLAB Production Server

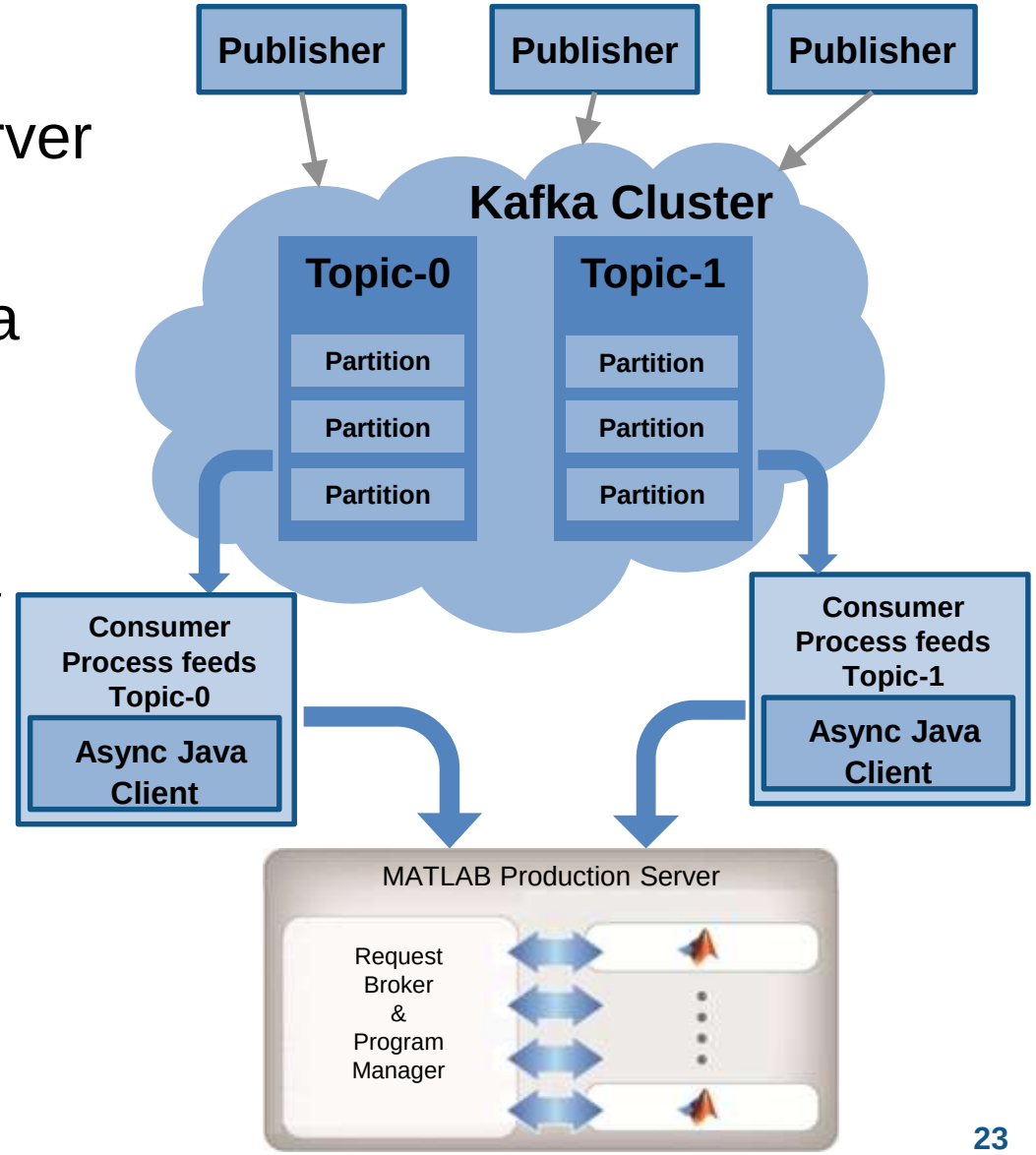


MATLAB Production Server is an application server that publishes MATLAB code as APIs



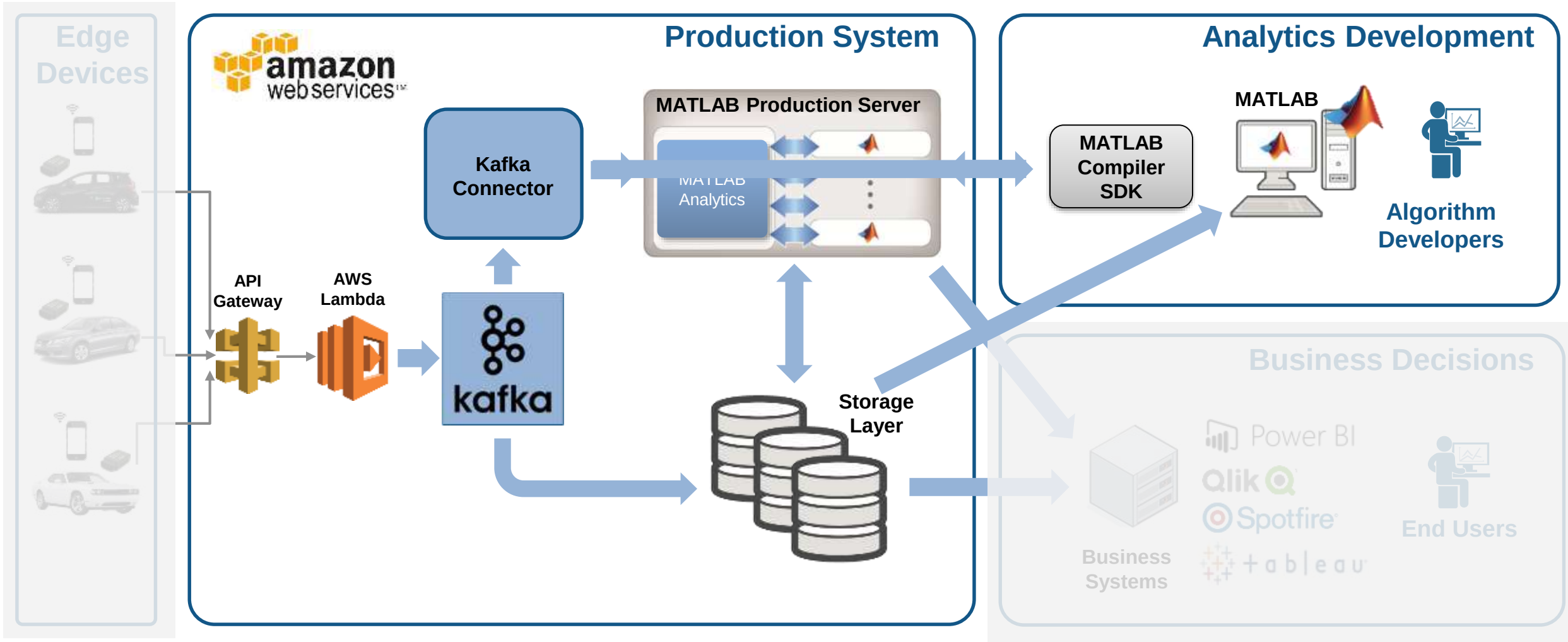
Connecting MATLAB Production Server to Kafka

- Kafka client for MATLAB Production Server feeds topics to functions deployed on the server
- Configurable batch of messages passed as a MATLAB Timetable
- Each consumer process feeds one topic to a specified function
- Drive everything from a simple config file
  - No programming outside of MATLAB!



4 Integrate with Production Systems

Develop and Deploy a Stream Processing Function



Develop a Stream Processing Function in MATLAB

calculateScores.mlx

Develop a Streaming Function

```
function new_state = calculateScores(car_id, current_data, old_state, resultsStore)
```

Preprocess and perform calculations

```
current_data = preprocessData(current_data);
```

Predict driving events

```
current_data = predictEvents(current_data);
```

Count events for each ten second window

```
countsByTime = countEvents(current_data);
```

Write discrete data to mongodb

```
updateResultsStore(car_id,countsByTime,resultsStore);
```

Update new state

```
new_state = updateState(countsByTime,old_state);
end
```

Process each window of data as it arrives

Current score

Previous state

Current window of data to be processed

Develop a Stream Processing Function in MATLAB

calculateScores.mlx

Develop a Streaming Function

```
function new_state = calculateScores(car_id, current_data
```

Preprocess and perform calculations

```
current_data = preprocessData(current_data);
```

Predict driving events

```
current_data = predictEvents(current_data);
```

Count events for each ten second window

```
countsByTime = countEvents(current_data);
```

Write discrete data to mongodb

```
updateResultsStore(car_id,countsByTime,resultsStore);
```

Update new state

```
new_state = updateState(countsByTime,old_state);
end
```

```
function current_data = preprocessData(current_data)
% Preprocess and perform calculations

% Remove records with all missing data
current_data = rmmissing(current_data,'MinNumMissing',width(current_data)-1);

% Smooth and calculate approximate gradients
current_data.Speed = movmedian(current_data.kff1001,5);
current_data.D1 = [0;diff(current_data.kff1001)];
current_data.D2 = [0;0;diff(current_data.kff1001,2)];
```

Apply your pre-processing algorithm

Develop a Stream Processing Function in MATLAB

calculateScores.mlx

Develop a Streaming Function

```
function new_state = calculateScores(car_id, current_data, old_state, resultsStore)
```

Preprocess and perform calculations

```
current_data = preprocessData(current_data);
```

Predict driving events

```
current_data = predictEvents(current_data);
```

Count events for each ten second window

```
countsByTime = countEvents(current_data);
```

Write discrete data to mongodb

```
updateResultsStore(car_id,countsByTime,resultsStore);
```

Update new state

```
new_state = updateState(countsByTime,old_state);
end
```

```
function current_data = predictEvents(current_data)
% Predict events for current data based on machine learning model
predictorNames = {'kff1005','kff1006','kff125a','k10','kff1249','Speed','D1','D2',...
    'kff1001','kff1220','kff1221','kff1222','kff1223',...
    'k47','kff124d'};
predictors = current_data{:,predictorNames};
mdl = load('machineLearningModel.mat');
current_data.Event = predict(mdl.model,predictors);

end
```

Use the model you created with Classification Learner App

Develop a Stream Processing Function in MATLAB

calculateScores.mlx

Develop a Streaming Function

```
function new_state = calculateScores(car_id, current_data, old_state, resultsStore)
```

Preprocess and perform calculations

```
current_data = preprocessData(current_data);
```

Predict driving events

```
current_data = predictEvents(current_data);
```

Count events for each ten second window

```
countsByTime = countEvents(current_data);
```

Write discrete data to mongodb

```
updateResultsStore(car_id,countsByTime,resultsStore);
```

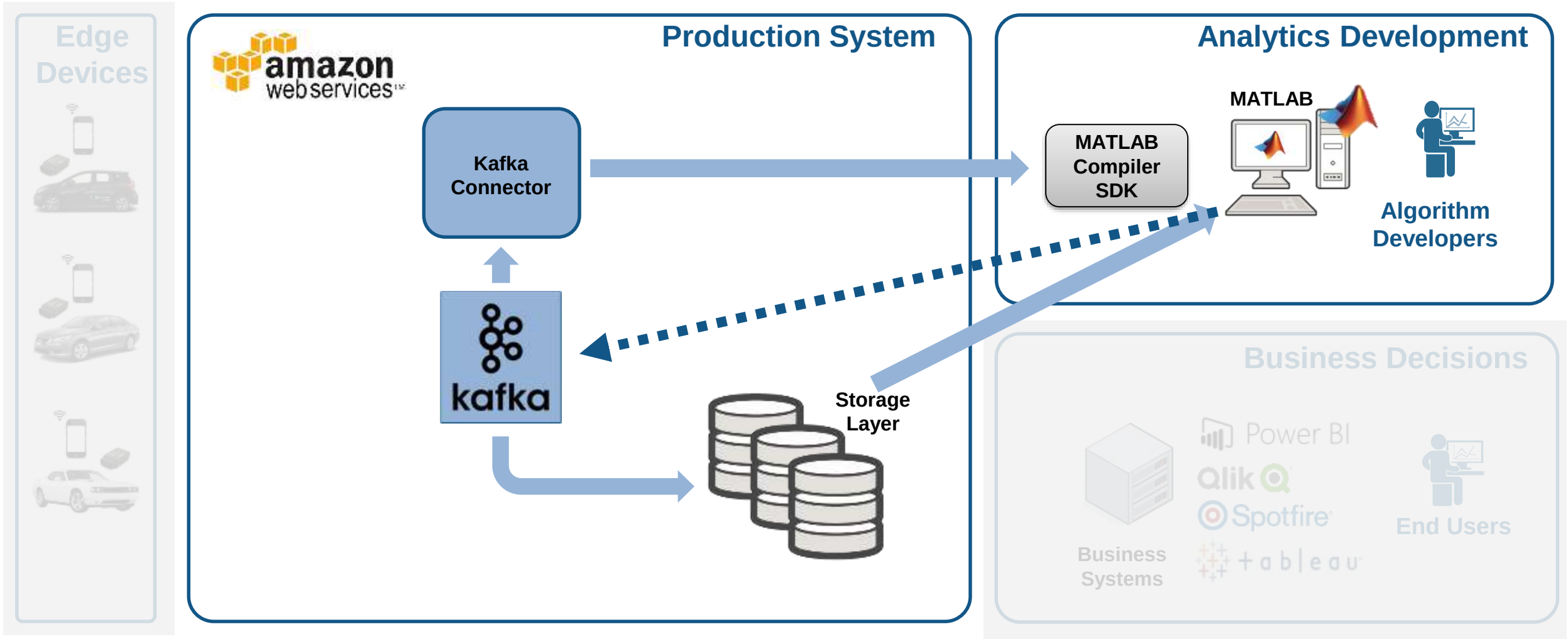
Update new state

```
new_state = updateState(countsByTime,old_state);
end
```

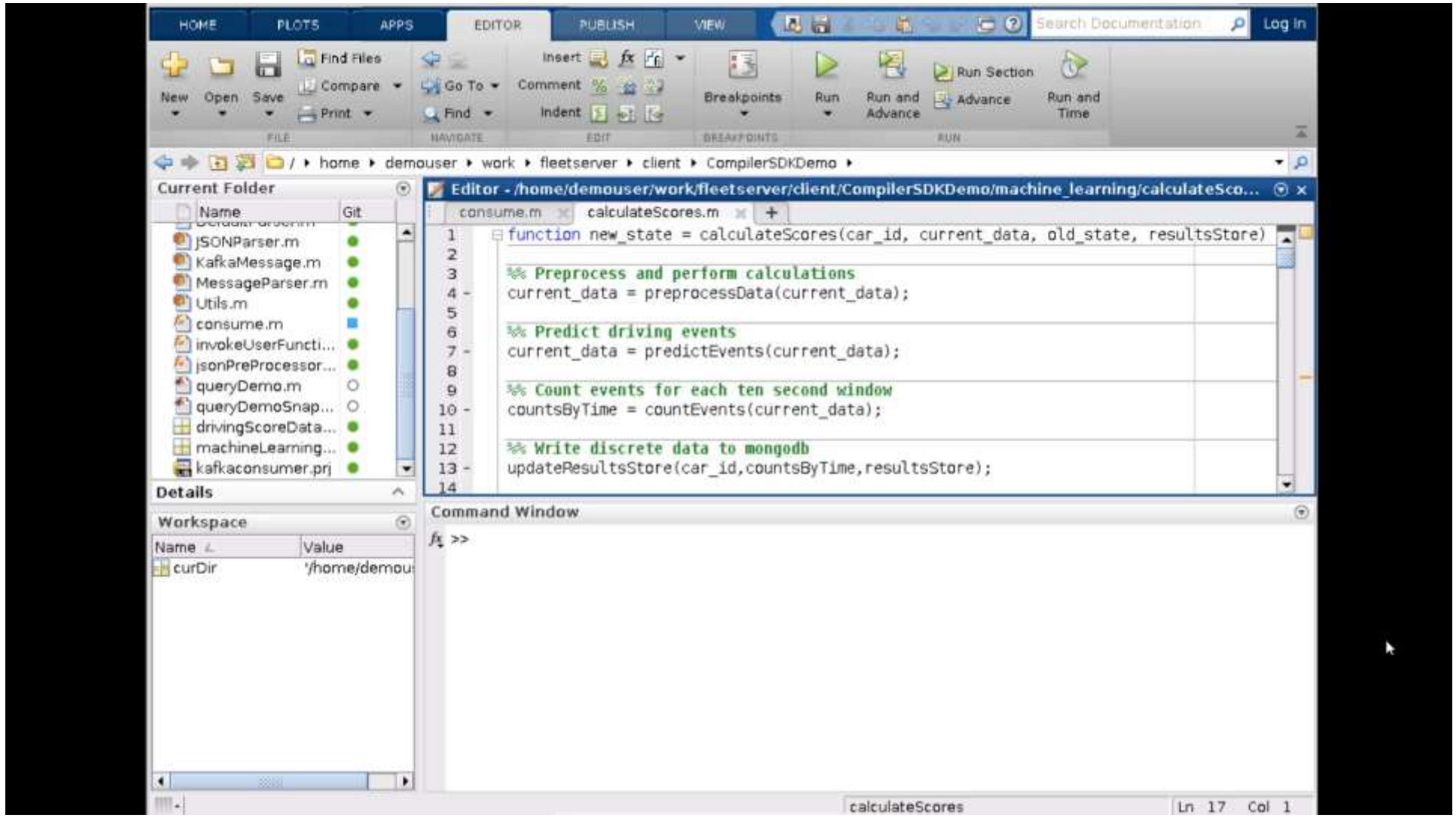
Update Mongo database

- **Count of events by type and location**
- **Results of driver scoring**

Debug a Stream Processing Function in MATLAB

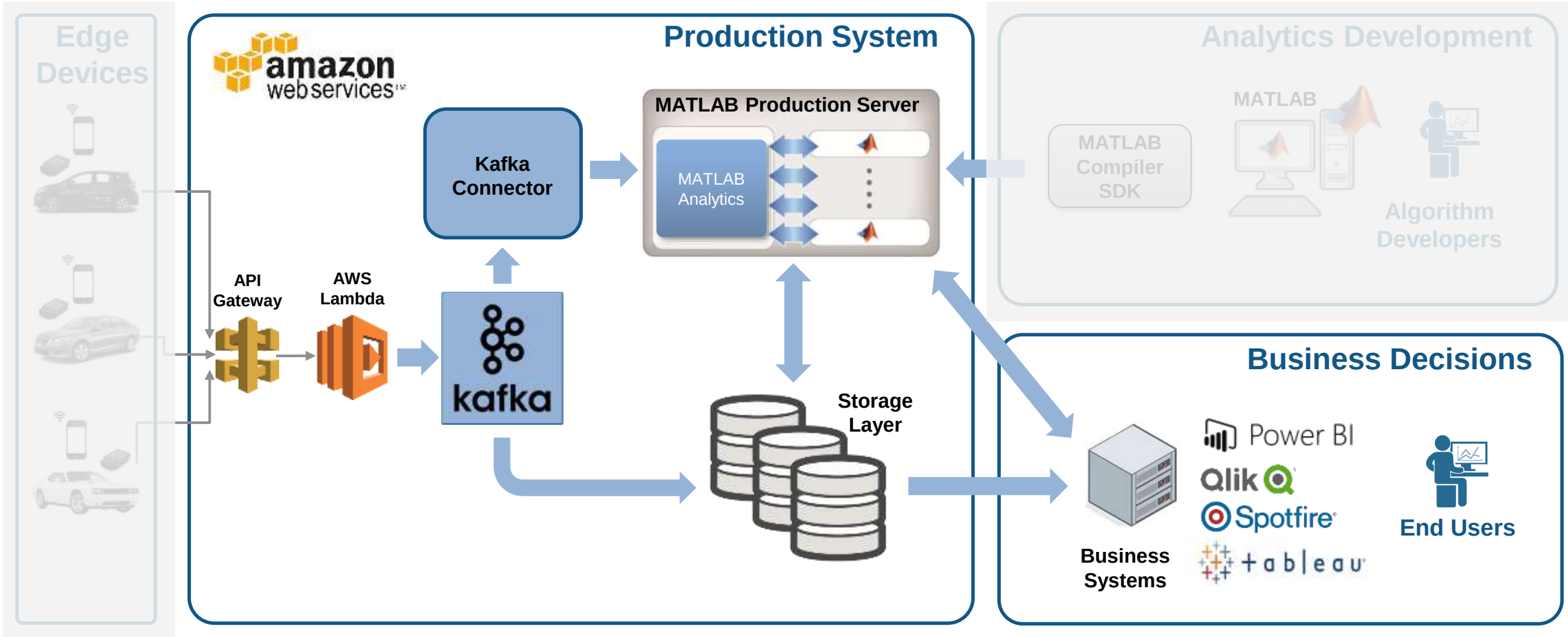


Debug a Stream Processing Function in MATLAB

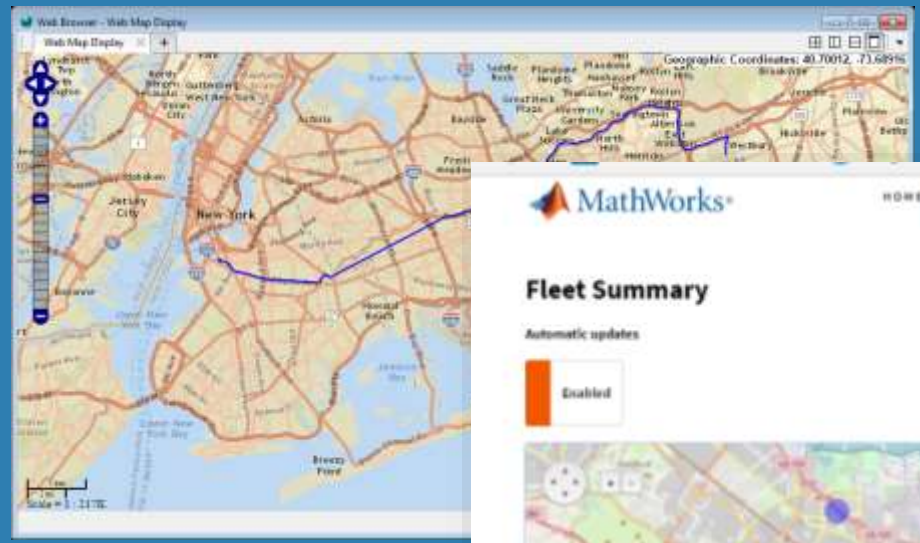


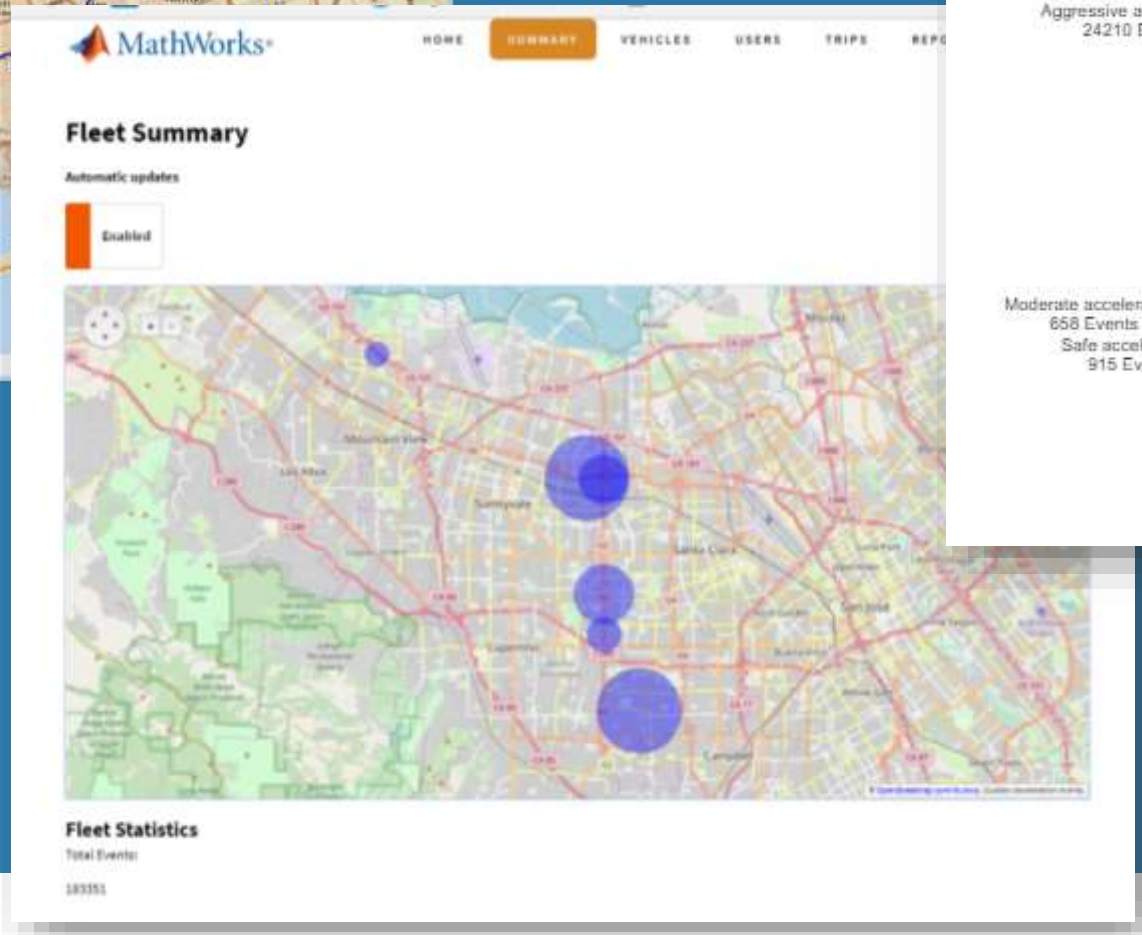
4 Integrate with Production Systems

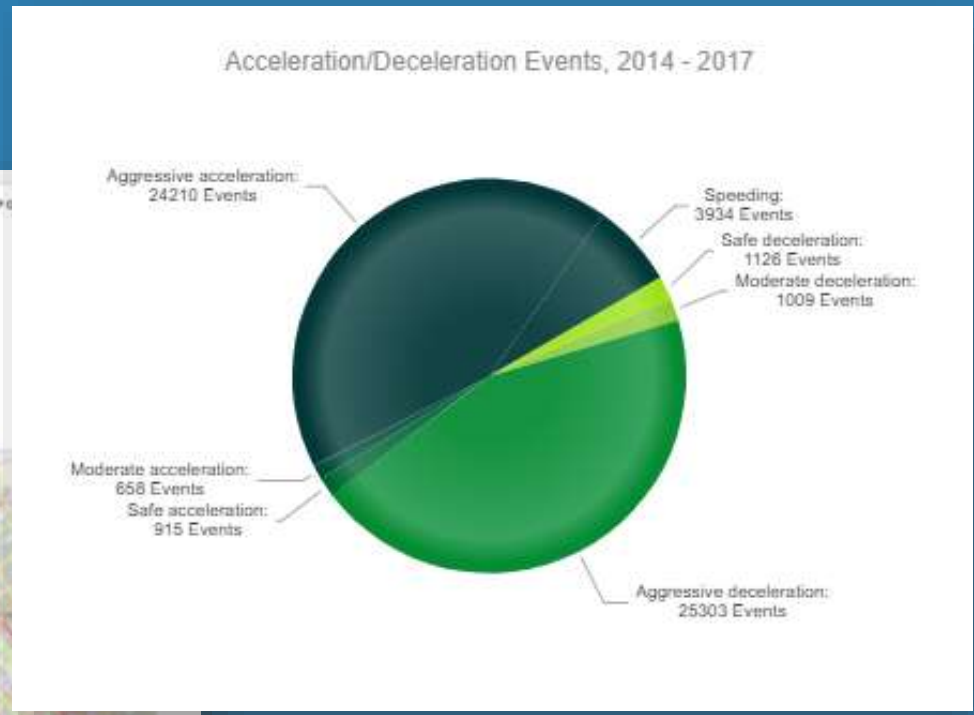
Tie in your Dashboard Application



Complete Your Application

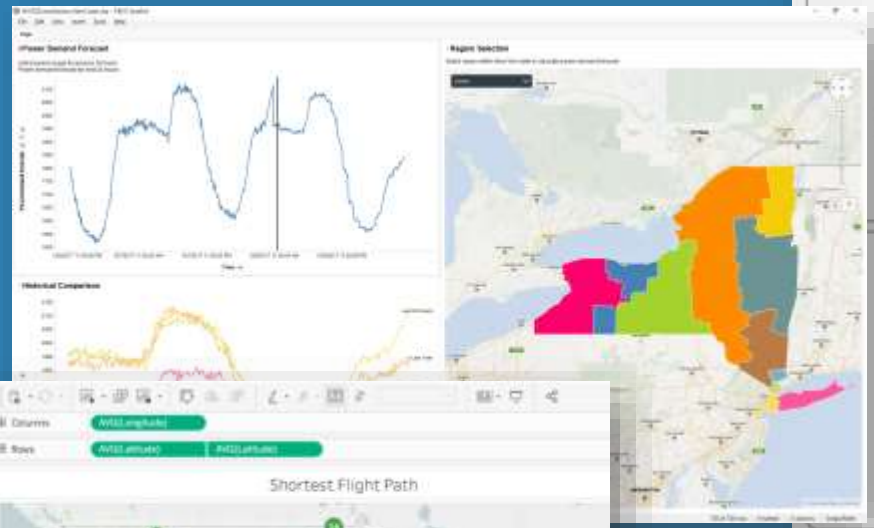




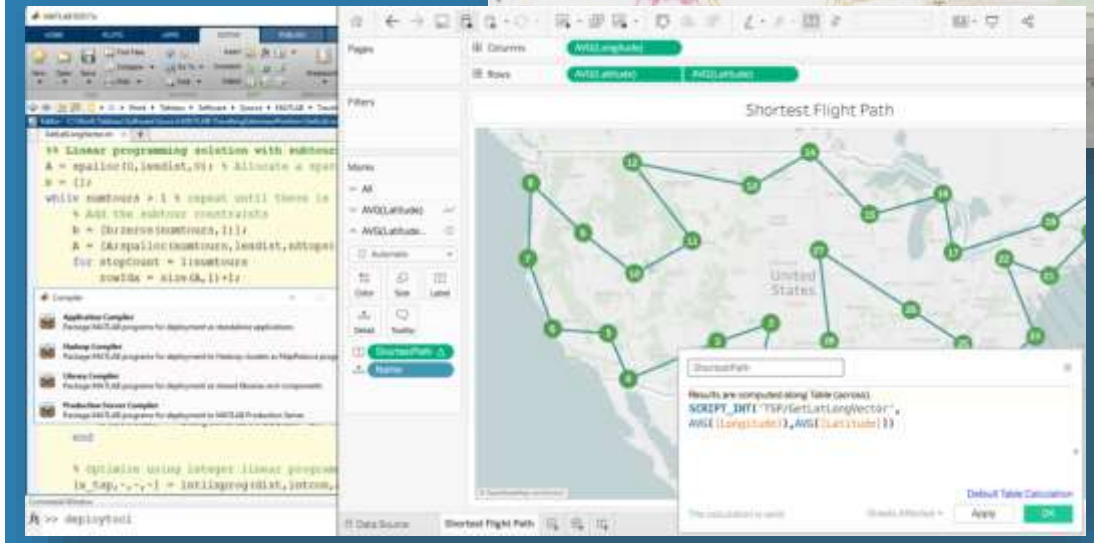


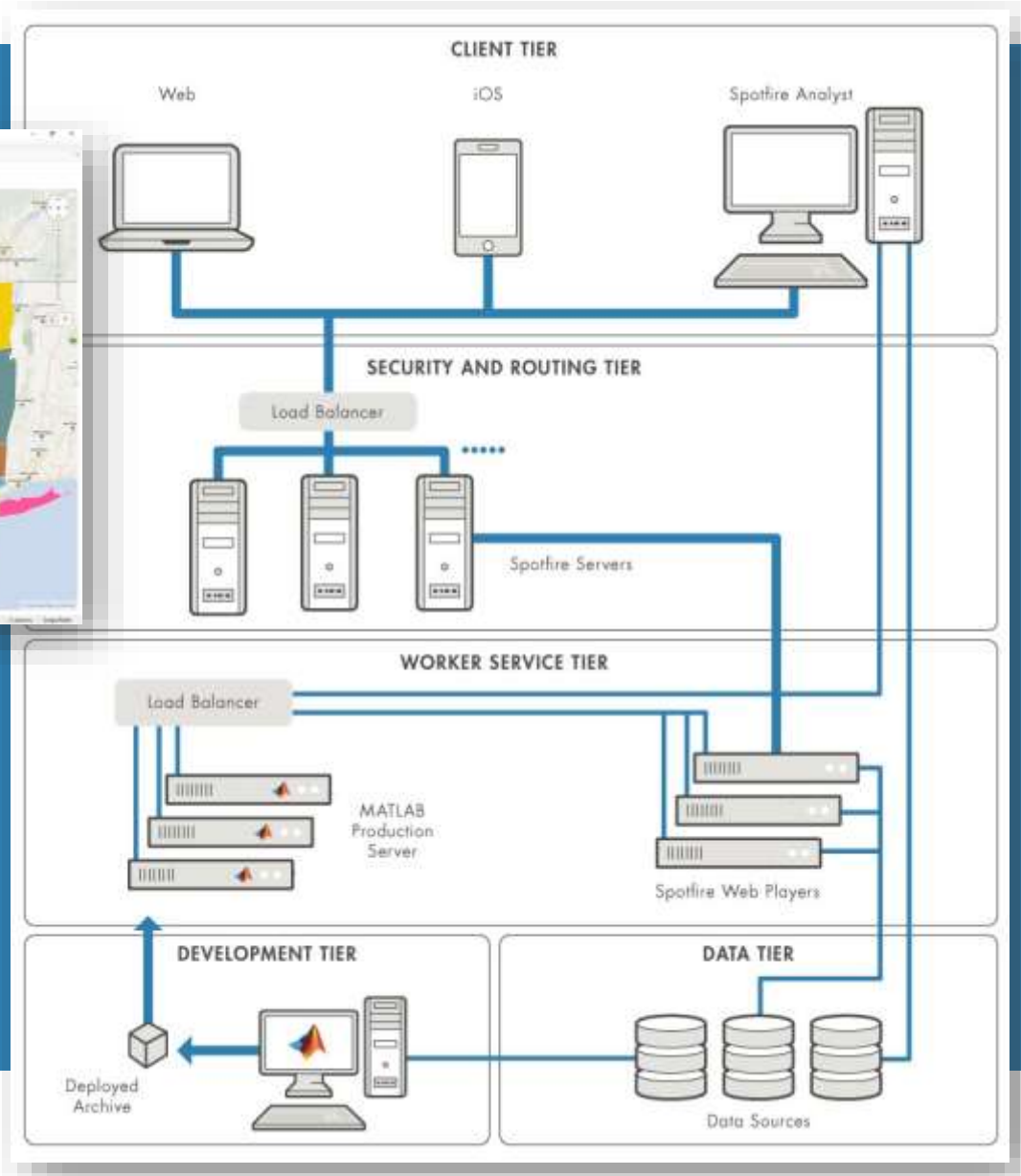
Scalable Analytics with Enterprise BI Tools

TIBCO Spotfire



Tableau





Key Takeaways

- MATLAB connects directly to your data so you can quickly design and validate algorithms
- The MATLAB language and apps enable fast design iterations
- MATLAB Production Server enables easy integration of your MATLAB algorithms with enterprise production systems
- You to spend your time understanding the data and designing algorithms

Resources to learn and get started

- Data Analytics with MATLAB
- MATLAB Production Server
- MATLAB Compiler SDK
- Statistics and Machine Learning Toolbox
- Database Toolbox
- Mapping Toolbox
- MATLAB with TIBCO Spotfire
- MATLAB with Tableau
- MATLAB with MongoDB