

MATLAB CONFERENCE 2017

Developing and Deploying Analytics for IoT Systems

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Key Takeaways

- MATLAB helps you **develop IoT algorithms**
- MATLAB and ThingSpeak helps you **collect and analyse IoT data, quickly and easily**
- MATLAB and Simulink help you **develop smart connected devices**
- MATLAB **supports cloud deployment** for small to medium scale IoT systems, up to large enterprise systems.

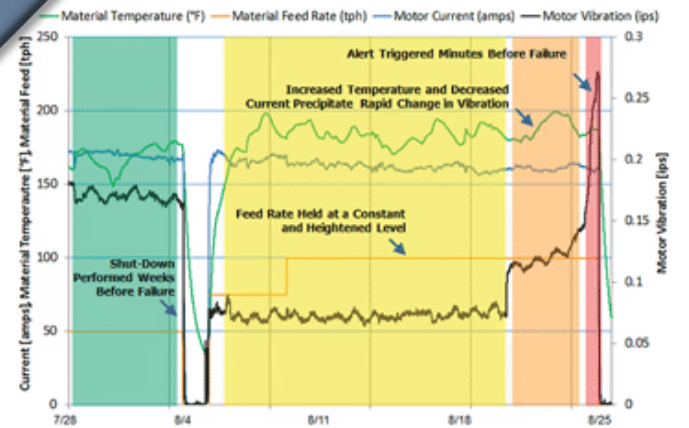
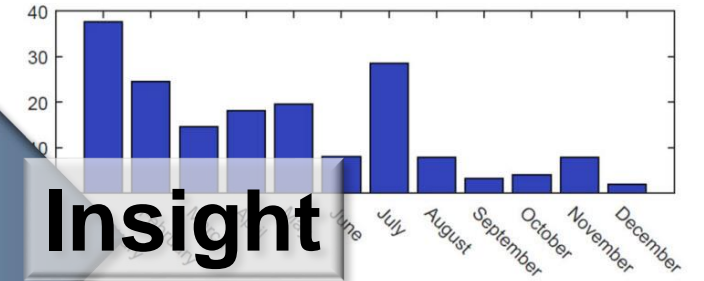
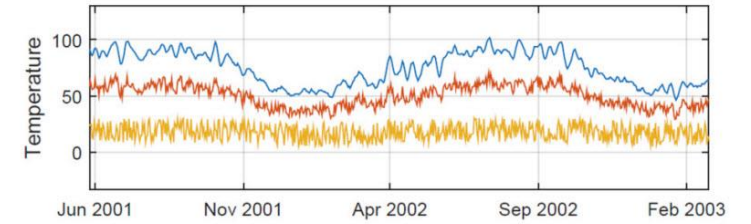
What is IoT?



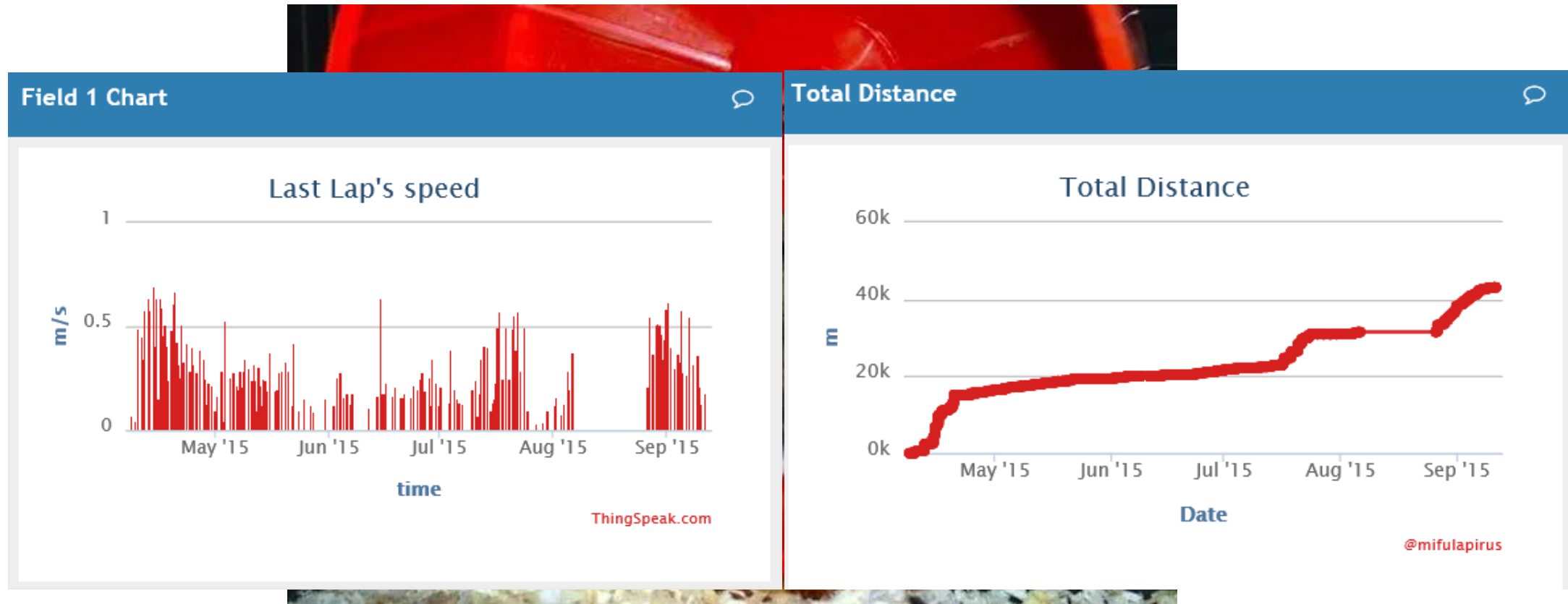
Devices

Analytics

Insight



Fun Example from Michelle Leonhart



Do hamsters run a marathon every day?

Commercial Example from Cadmus

Challenge

Measure and evaluate the energy efficiency of residential homes and businesses based on data from onsite sensors

Solution

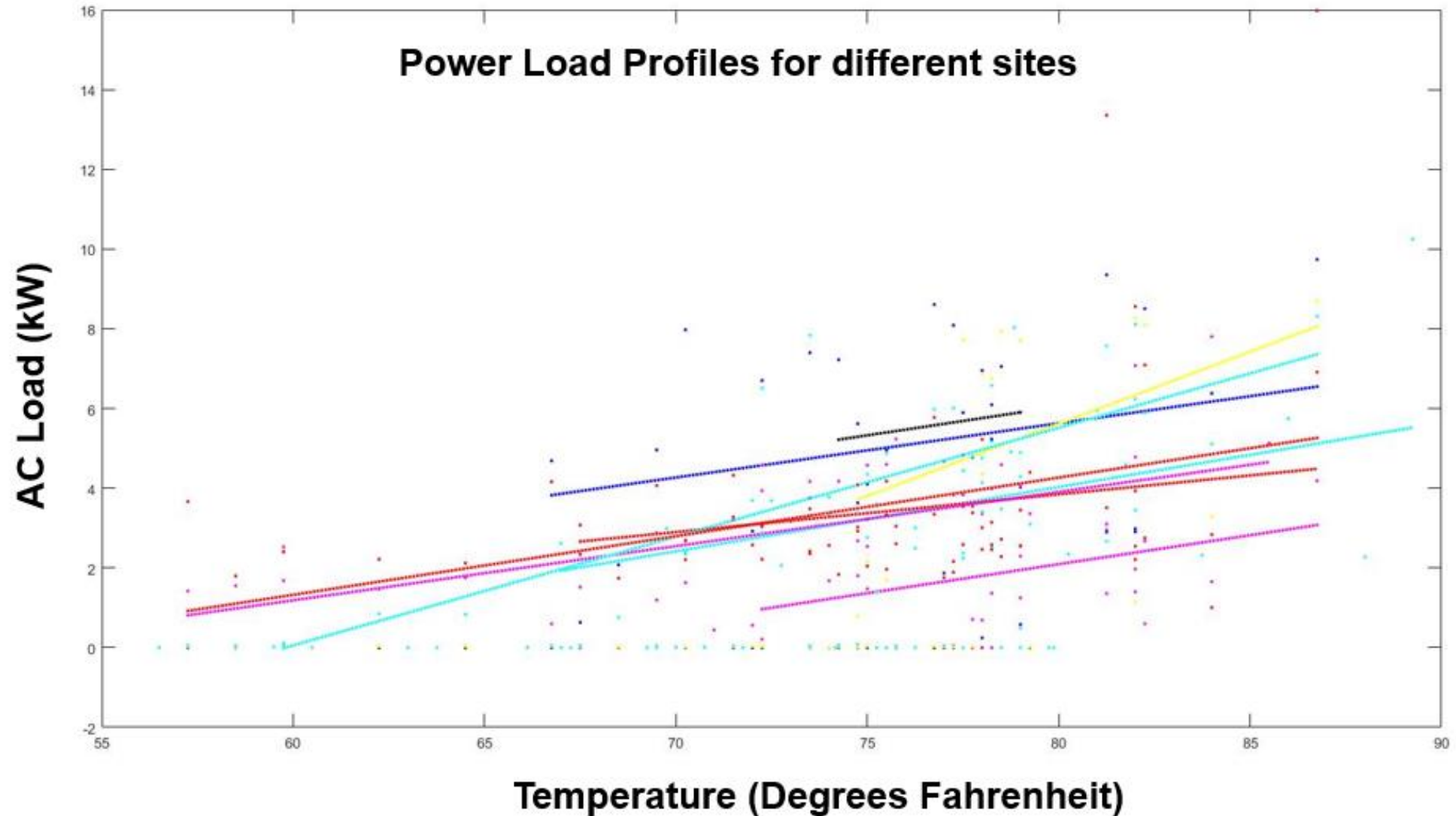
- Used **ThingSpeak** to collect up-to-the-minute temperature, humidity, and power usage data
- Used **MATLAB** to analyze and visualize the data

Results

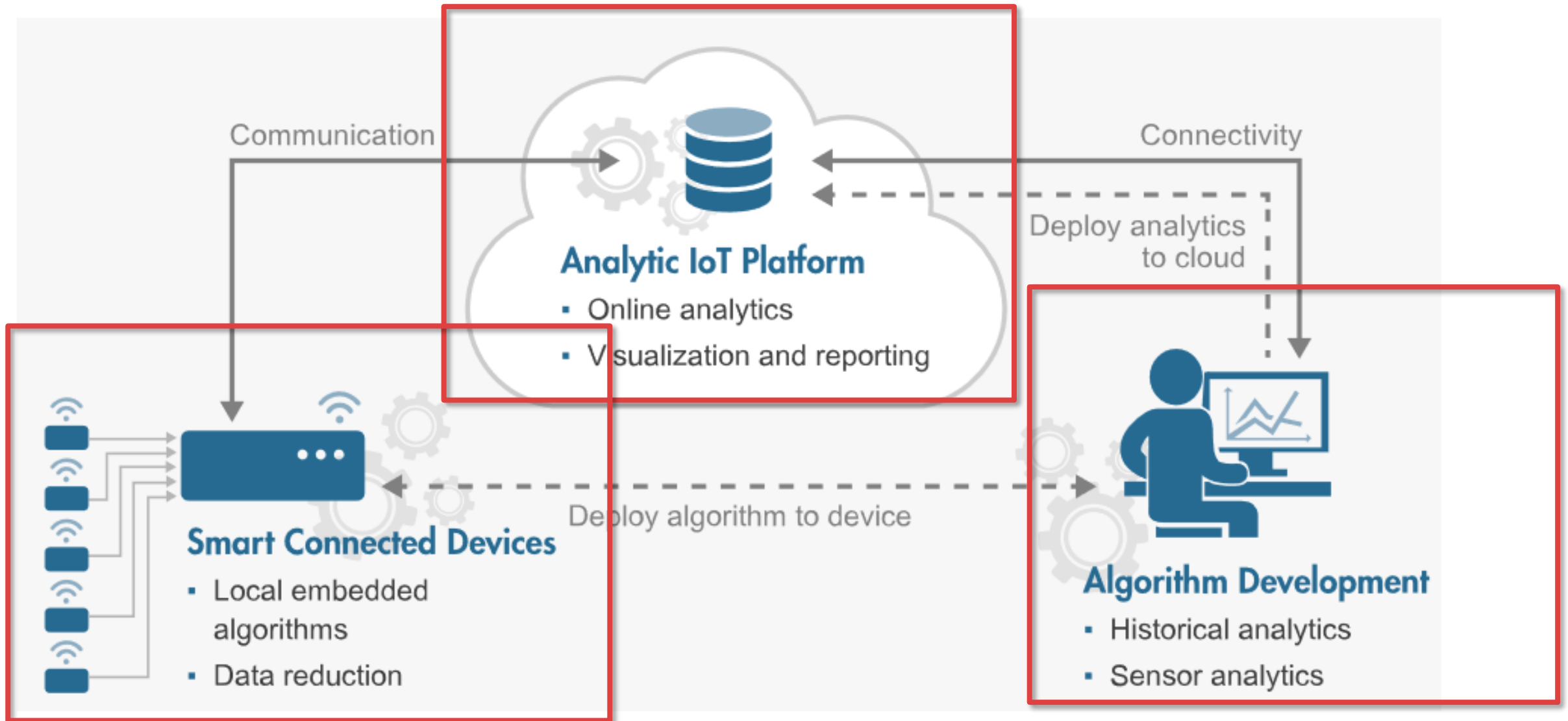
- Market opportunity seized
- Development effort cut by two-thirds
- Sensor networks quickly deployed



Commercial Example from Cadmus



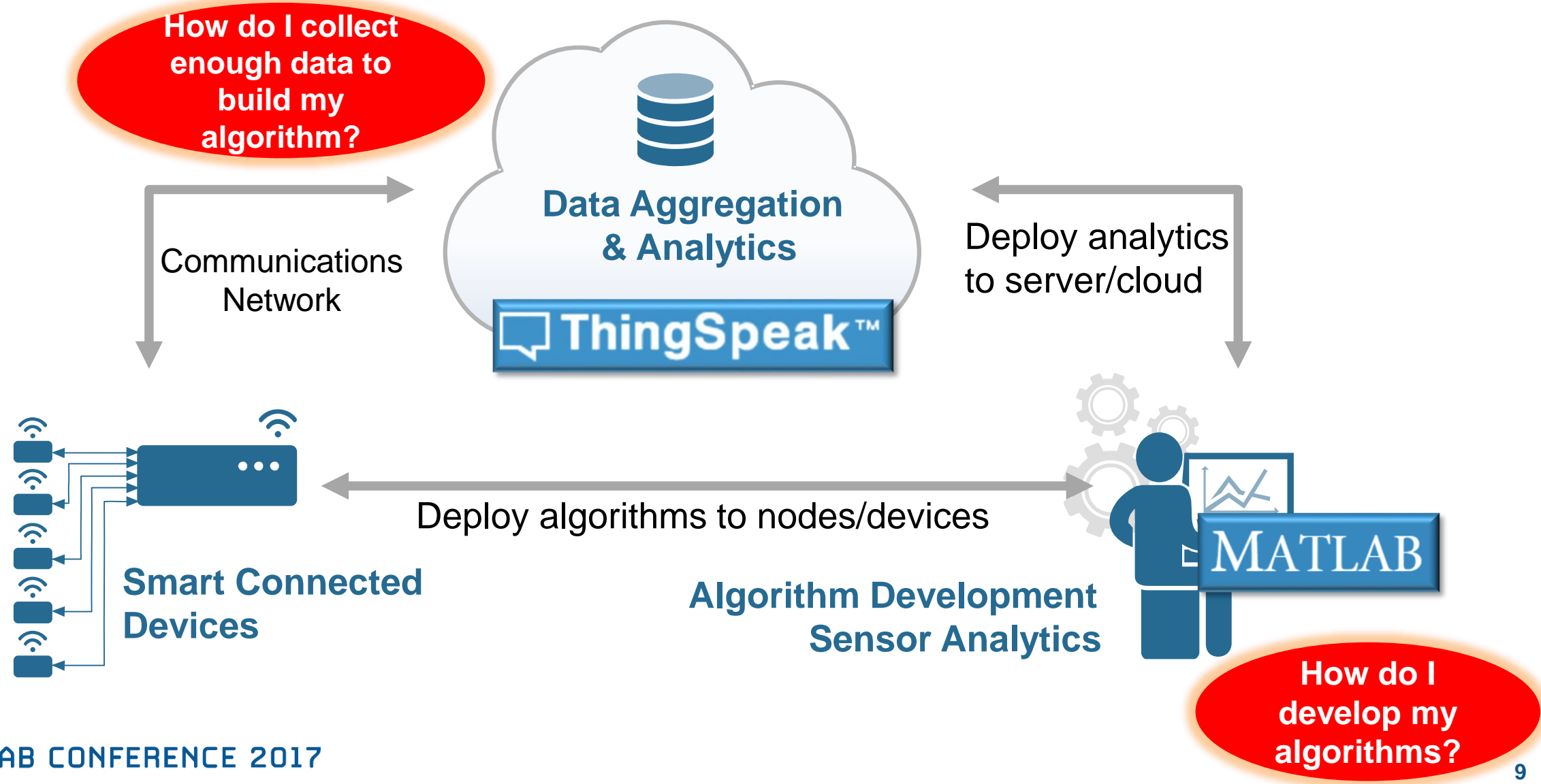
IoT Analytics Framework



IoT Analytics Challenges

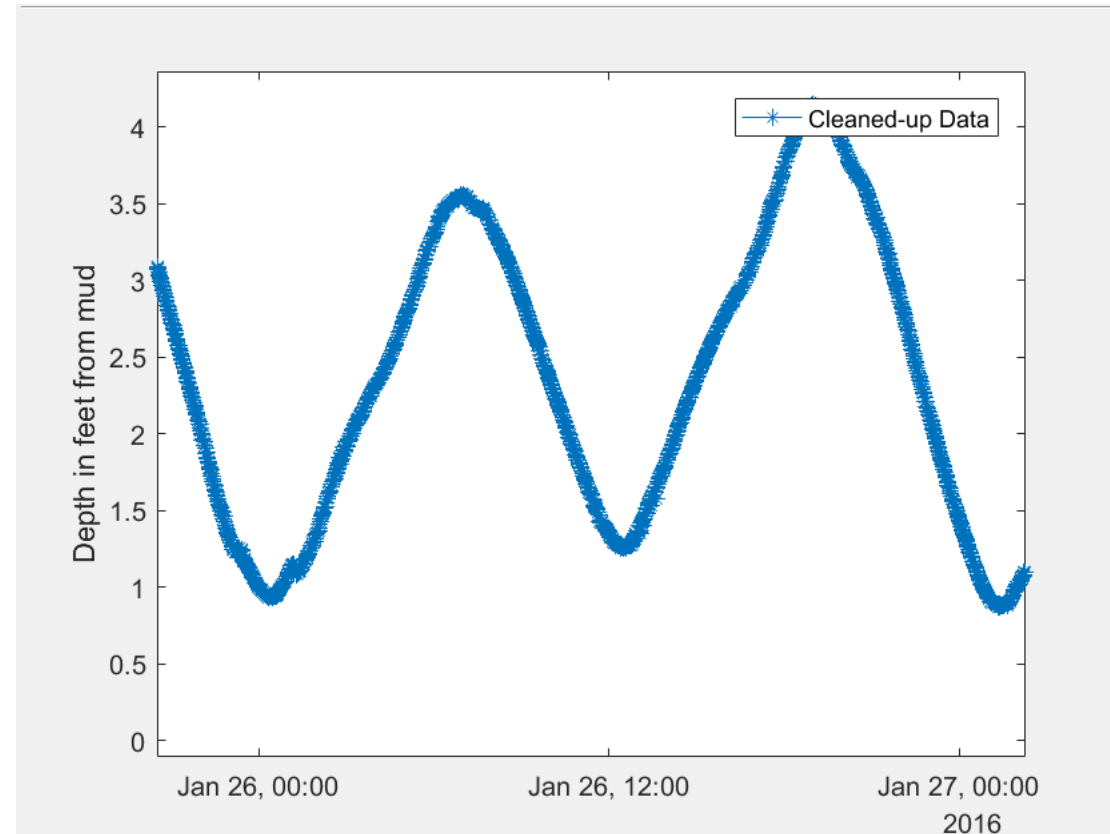
- 1. How do I develop my algorithms?**
- 2. How do I collect enough data to build my algorithm?**
- 3. How do I deploy my algorithms to the cloud?**
- 4. How do I deploy my algorithms on a smart device?**

IoT Analytics Challenges



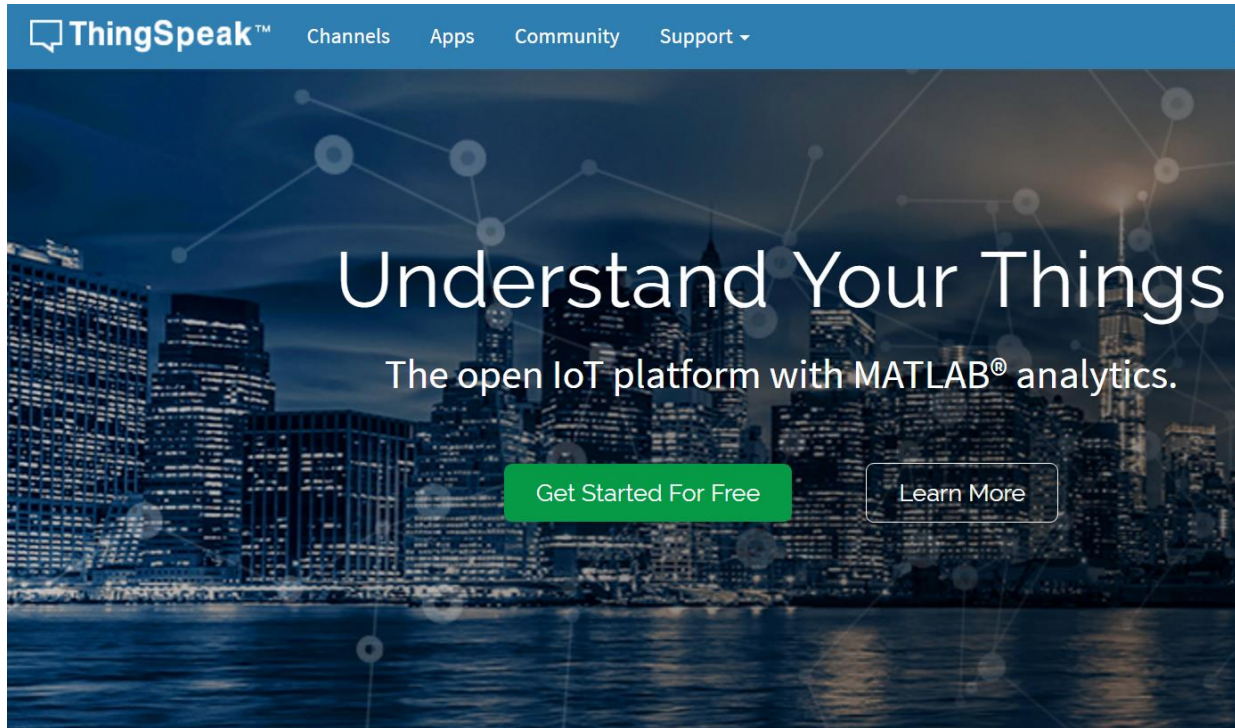
MATLAB Helps You Develop IoT Algorithms

- Real data is messy and needs to be cleaned up
- Missing data points need to be handled
- Features need to be extracted
- Predictions need to be made



What Is ThingSpeak?

Web Site For People



Web Service for Devices

```

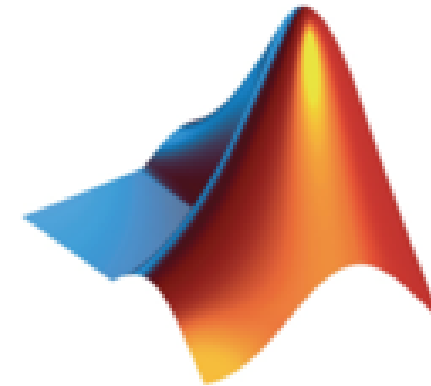
{
  - channel: {
    id: 38629,
    name: "Car Counter",
    description: "Counting number of cars passing a reference line in 15 sec interval",
    latitude: "42.28",
    longitude: "-71.35",
    field1: "Number of Westbound Cars",
    field2: "Number of Eastbound Cars",
    created_at: "2015-05-19T20:14:03Z",
    updated_at: "2016-05-19T10:36:35Z",
    last_entry_id: 1477231
  },
  - feeds: [
    - {
      created_at: "2016-05-19T10:36:20Z",
      entry_id: 1477230,
      field1: "18.000000",
      field2: "8.000000"
    },
    - {
      created_at: "2016-05-19T10:36:35Z",
      entry_id: 1477231,
      field1: "18.000000",
      field2: "14.000000"
    }
  ]
}

```

ThingSpeak Collects, Analyzes and Acts on Data

- A new MathWorks web service hosted on AWS
- Lets you collect, analyze and act on data from “things”
- Evaluates **MATLAB** code in the cloud
- Over **130,000** users worldwide
- It's **free** to get started

<https://thingspeak.com>



Collect



Analyze

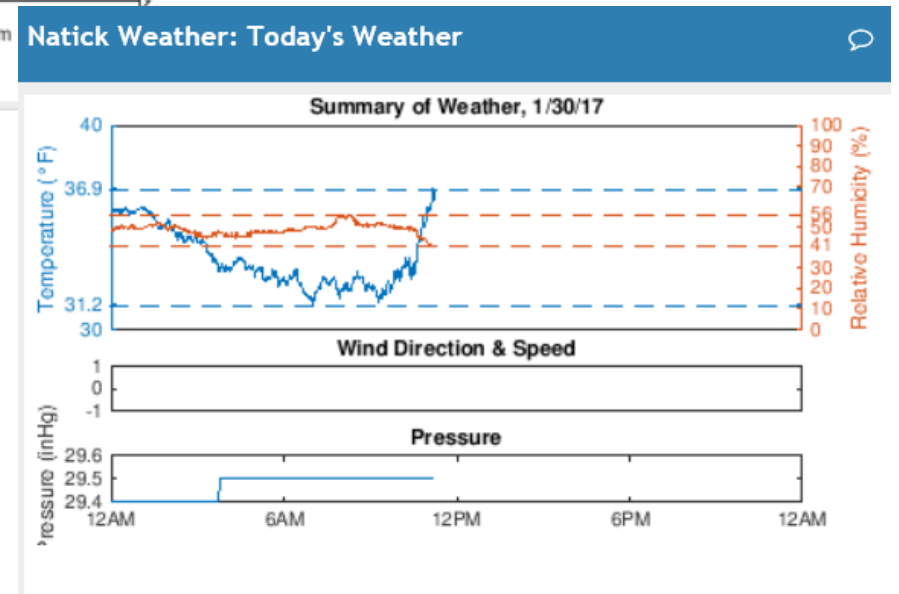
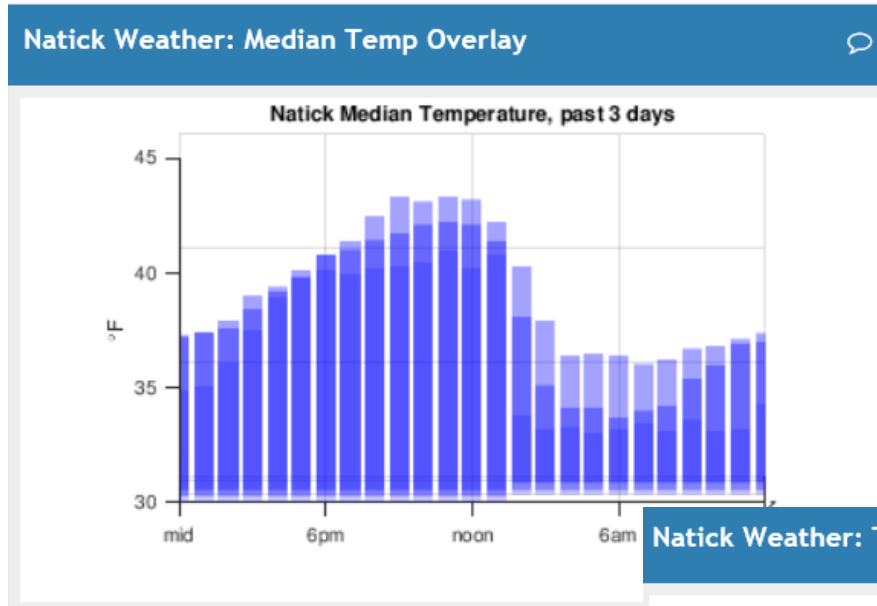


Act

MATLAB Toolbox Access from ThingSpeak

- When you are logged into ThingSpeak™ using your MathWorks® Account, you can use functions from the following toolboxes if you are licensed to use them:
 - [Statistics and Machine Learning Toolbox™](#) (Statistics and Machine Learning Toolbox)
 - [Curve Fitting Toolbox™](#) (Curve Fitting Toolbox)
 - [Control System Toolbox™](#) (Control System Toolbox)
 - [Signal Processing Toolbox™](#) (Signal Processing Toolbox)
 - [Mapping Toolbox™](#) (Mapping Toolbox)
 - [System Identification Toolbox™](#) (System Identification Toolbox)
 - [Neural Network Toolbox™](#) (Neural Network Toolbox)
 - [DSP System Toolbox™](#) (DSP System Toolbox)
 - [Datafeed Toolbox™](#) (Datafeed Toolbox)
 - [Financial Toolbox™](#) (Financial Toolbox)
- Up to date info: <https://au.mathworks.com/help/thingspeak/matlab-toolbox-access.html>

Custom Visualizations with ThingSpeak- Weather Station Example



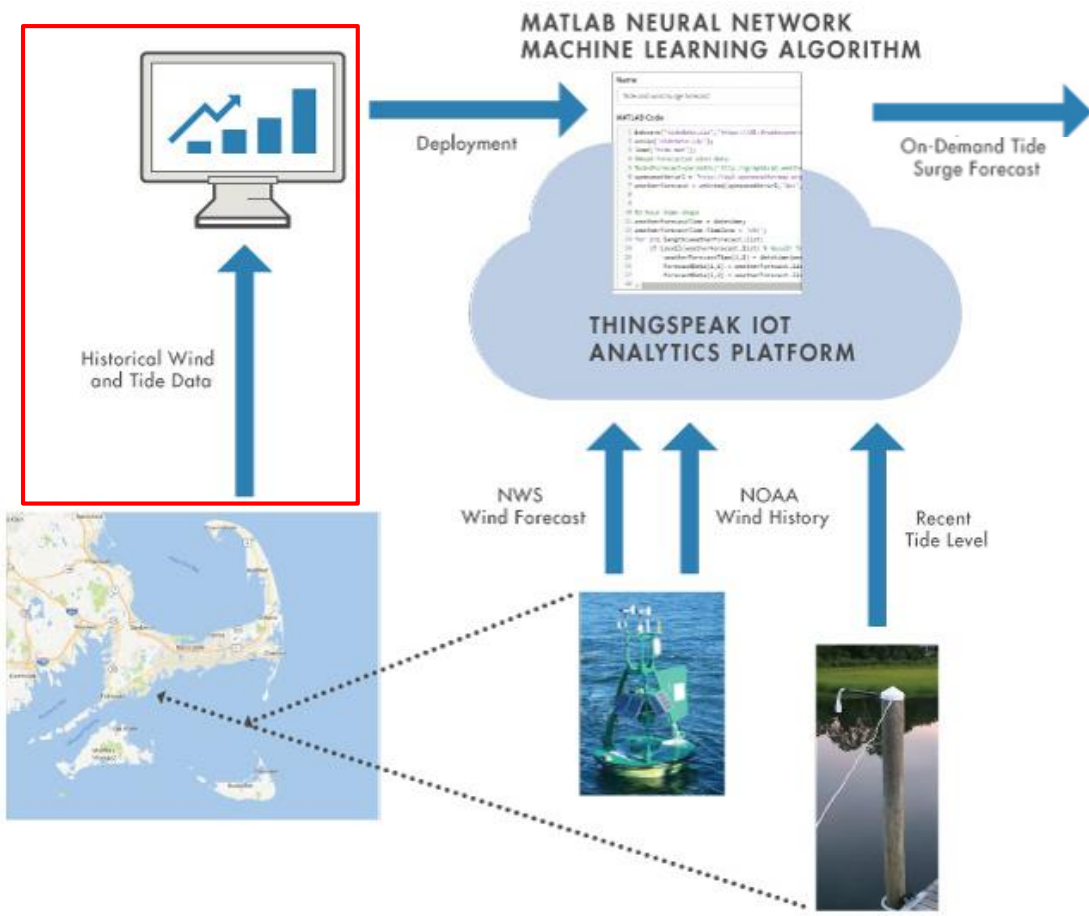
Custom Visualizations with ThingSpeak- Weather Station Example

The screenshot displays the ThingSpeak interface for a channel named "WeatherStation" (Channel ID: 12397). The channel is public and was created by "hemdanw". It is located at "MathWorks Weather Station, West Garage, Natick, MA 01760, USA".

Key features and visualizations include:

- Data Export:** A button to export the channel's data.
- MATLAB Analysis and Visualization:** Two buttons for integrating MATLAB with the channel.
- Field 1 Chart:** A line graph titled "WeatherStation" showing "Wind Direction (North = 0 degrees)" on the y-axis (ranging from -250 to 500) against "Date" on the x-axis. The data shows a steady state around 250 degrees with periodic sharp drops to 0 degrees.
- Channel Location:** A map showing the location of the weather station in Natick, Massachusetts, with a red pin.
- Field 2 Chart:** A line graph titled "WeatherStation" showing "Wind Speed (mph)" on the y-axis (ranging from 0 to 30) against "Date" on the x-axis. The data shows a steady state at 0 mph with a sharp increase to approximately 20 mph.
- Channel Status Updates:** A section for updates, which is currently empty.

Predictive Analytics Example with ThingSpeak



```

Live Editor - C:\Users\ewetjen\AppData\Local\Temp\Temp1_NeuralTideWindForecast.zip\NeuralTidesForecast-13-public.mlx [Read Only]
Tide_forecast.m  NeuralTidesForecast-13-public.mlx  NeuralTidesForecast-13-public-eric.m  historicalcleanUp.m

stressN24 = movmean(stressN,[24 0],'Endpoints','fill');

stressE3 = movmean(stressE,[3 0],'Endpoints','fill');
stressE6 = movmean(stressE,[6 0],'Endpoints','fill');
stressE12 = movmean(stressE,[12 0],'Endpoints','fill');
stressE24 = movmean(stressE,[24 0],'Endpoints','fill');

neuralInSimple=[tideForecastHourly, stressN, stressN3, stressN6, stressN12, stressN24, ...
    stressE, stressE3, stressE6, stressE12, stressE24];
tideActual = tideResampled - MLLWmud;
neuralOutSimple=tideActual;

Train a Fitting neural network

% Solve an Input-Output Fitting problem with a Neural Network
% Script generated by Neural Fitting app
% Created 16-Sep-2016 10:38:24
%
% This script assumes these variables are defined:
%
% neuralInSimple - input data.
% neuralOutSimple - target data.

x = neuralInSimple';
t = neuralOutSimple';

% Choose a Training Function
% For a list of all training functions type: help nntrain
% 'trainlm' is usually fastest.
% 'trainbr' takes longer but may be better for challenging problems.
% 'trainscg' uses less memory. Suitable in low memory situations.
trainFcn = 'trainlm'; % Levenberg-Marquardt backpropagation.

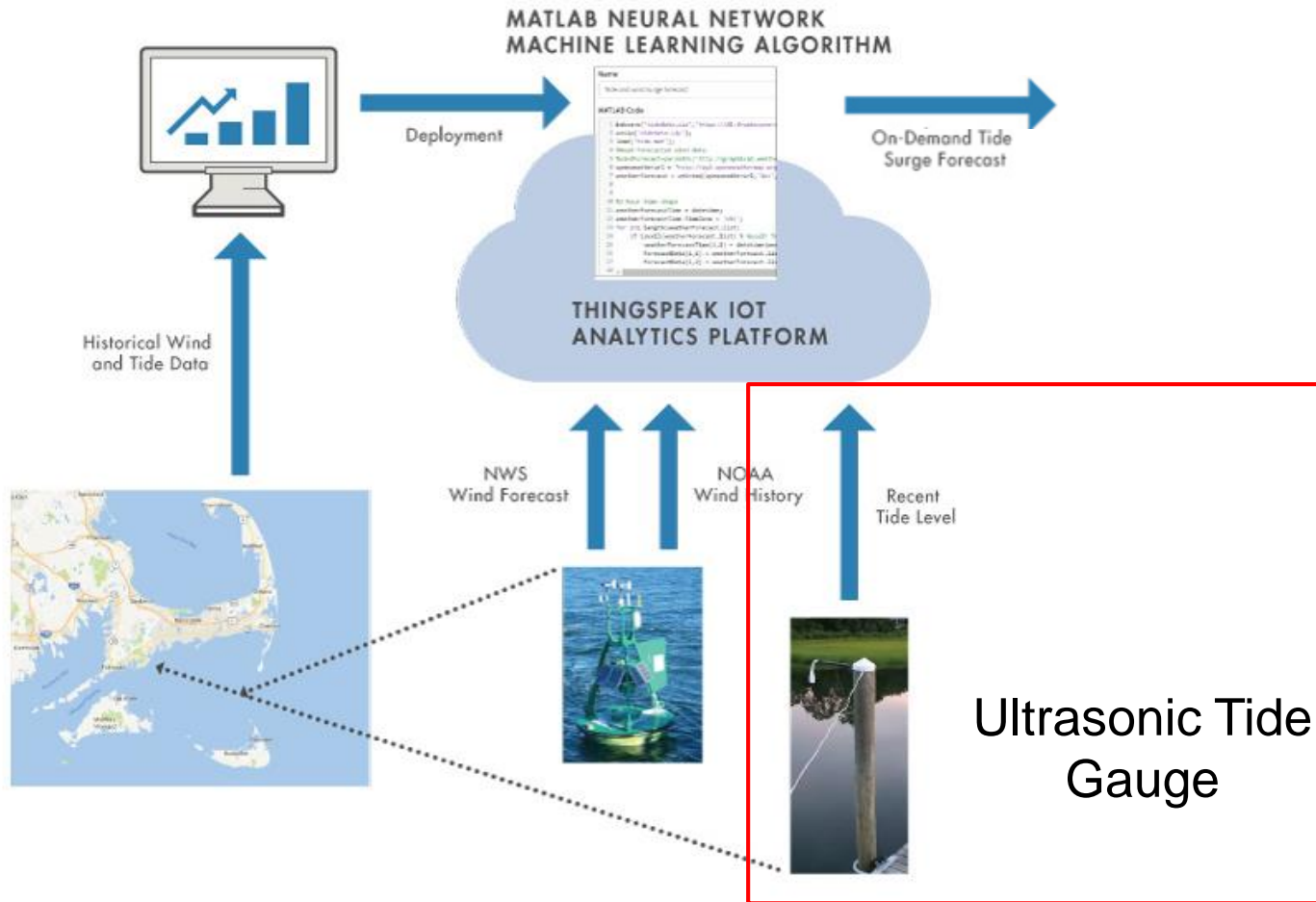
% Create a Fitting Network
hiddenLayerSize = 15;
netWind = fitnet(hiddenLayerSize,trainFcn);

% Choose Input and Output Pre/Post-Processing Functions
% For a list of all processing functions type: help nnprocess
netWind.input.processFcns = {'removeconstantrows','mapminmax'};
netWind.output.processFcns = {'removeconstantrows','mapminmax'};

% Setup Division of Data for Training, Validation, Testing
% For a list of all data division functions type: help nndivide
netWind.divideFcn = 'dividerand'; % Divide data randomly
netWind.divideMode = 'sample'; % Divide up every sample
netWind.divideParam.trainRatio = 70/100;
netWind.divideParam.valRatio = 15/100;
netWind.divideParam.testRatio = 15/100;
    
```

Problem: Common for boats to get stuck due to unusually low tides caused by certain winds

Predictive Analytics Example with ThingSpeak



Problem: Common for boats to get stuck due to unusually low tides caused by certain winds

MATLAB CONFERENCE 2017

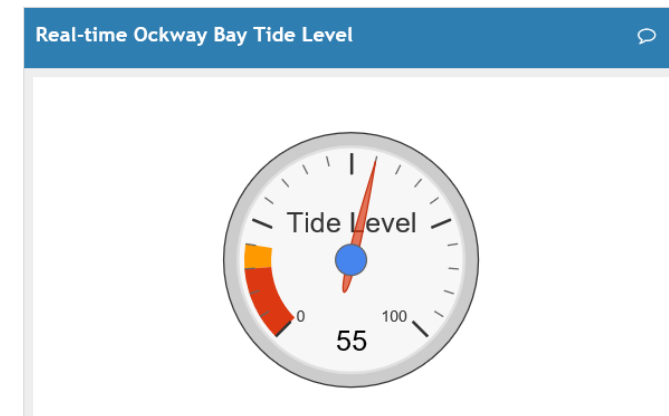
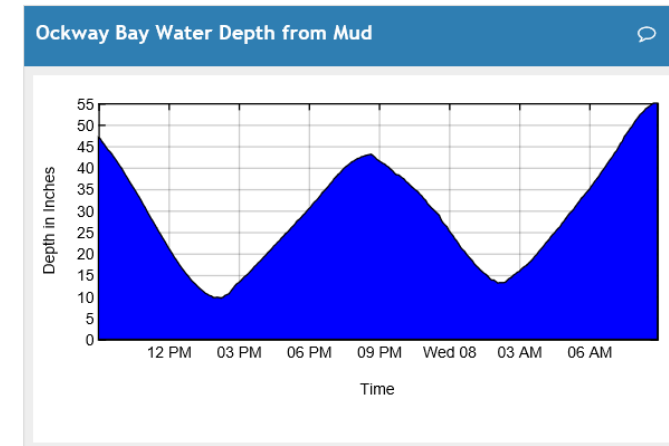
ThingSpeak™ Channels Apps Community Support

Access: Public

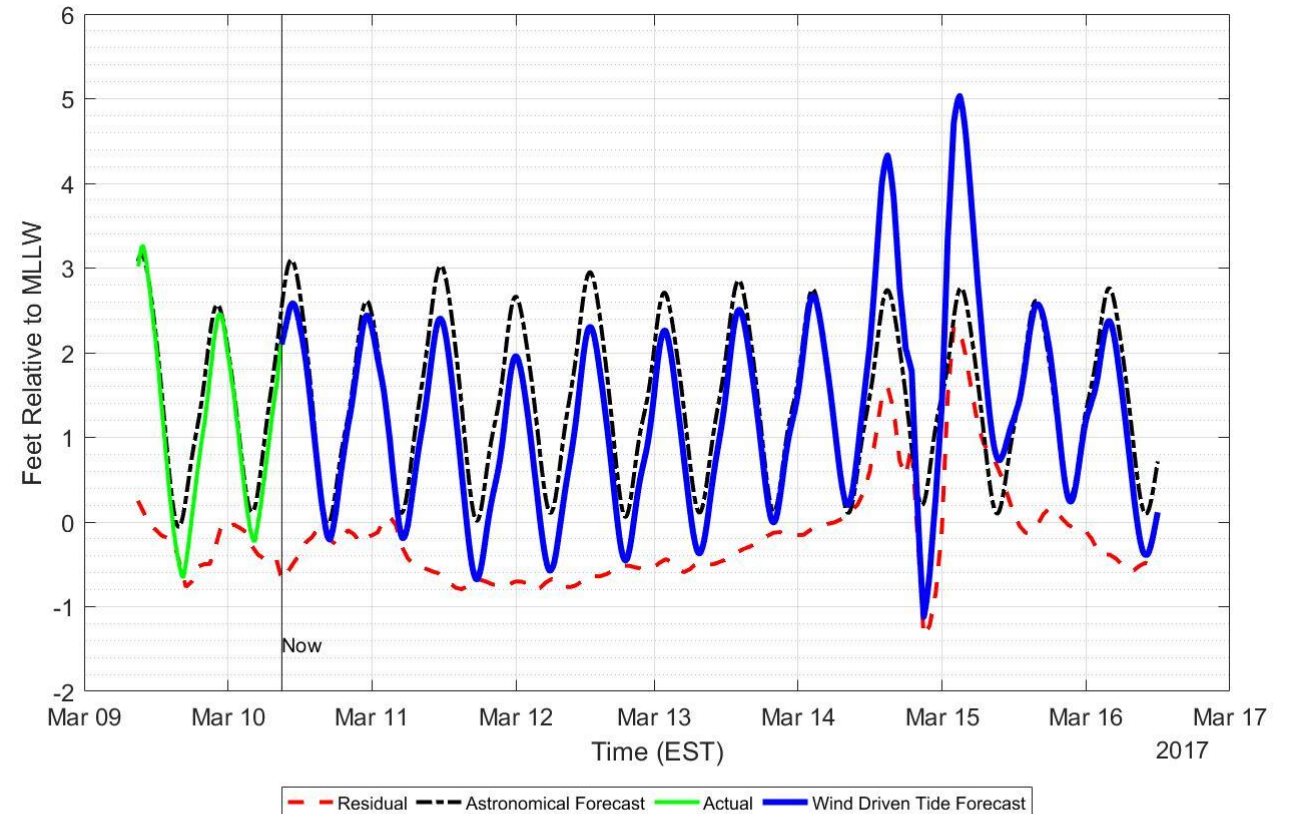
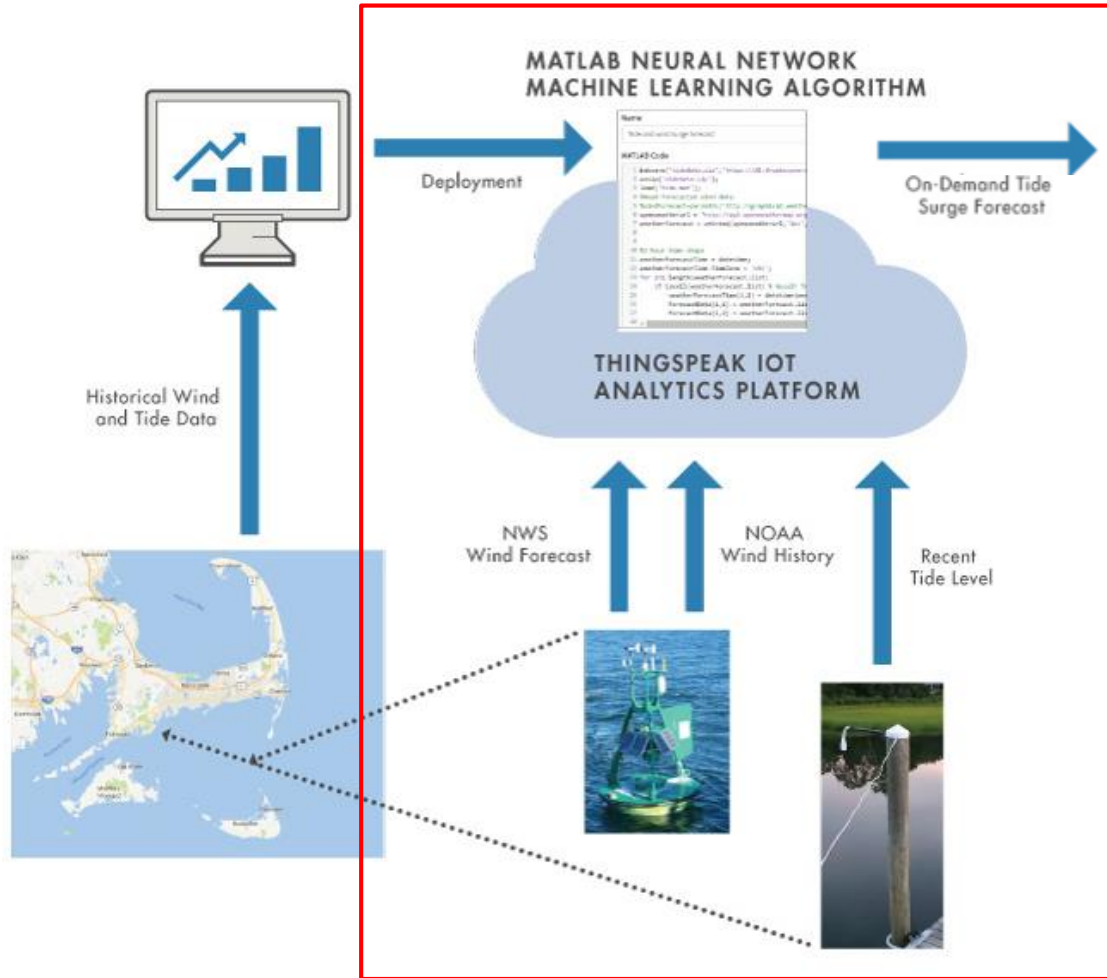
cellular shield.

🔗 tide, water level, ultras

Data Export



Predictive Analytics Example with ThingSpeak



Problem: Common for boats to get stuck due to unusually low tides caused by certain winds

Predictive Analytics Example with ThingSpeak

ThingSpeak™ Channels Apps Community Support How to Buy Account

Un-watch Tweet Like 0 Share

Predicted and Measured Ockway Bay Tide Chart

Channel ID: 137305
 Author: mawrey
 Access: Public

Tide measurement and forecasting with the effect of wind predicted using neural networks.
 tags: tide, wind surge, neural network

Data Export More Information MATLAB Analysis MATLAB Visualiz

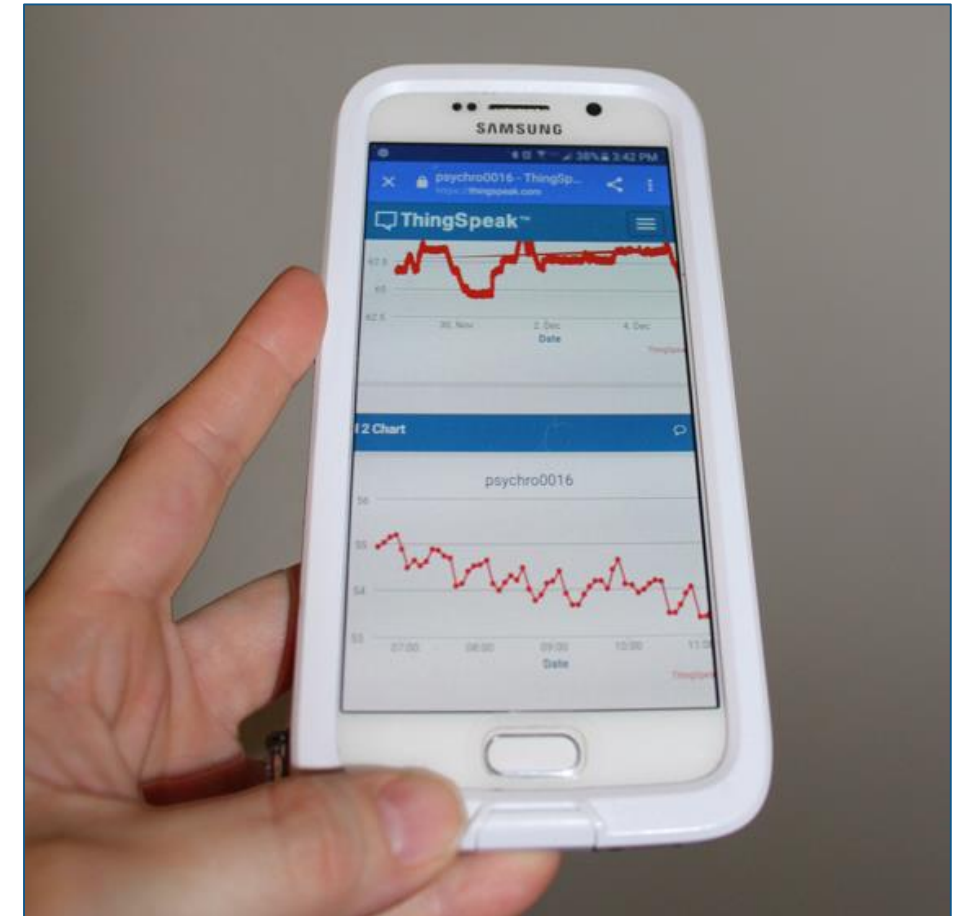
- Analytics on the cloud
- Visualisation accessible from ThingSpeak website
- No infrastructure setup or custom web development

MATLAB and ThingSpeak: Customer Testimonial

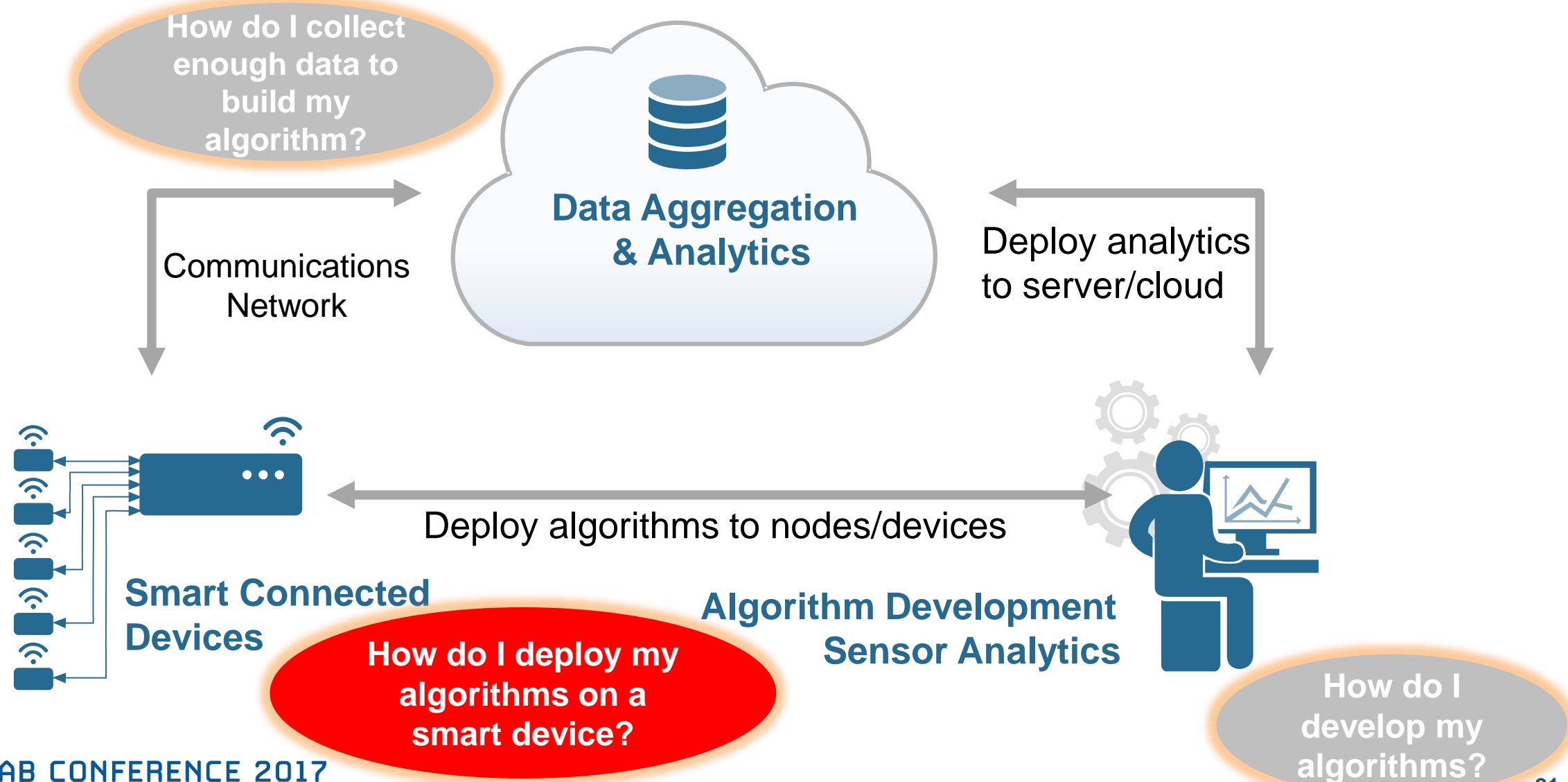
“In just a few months, we implemented a new service that measures and analyzes temperature and humidity changes in dozens—and soon hundreds—of homes.

Without MATLAB and ThingSpeak, we would still just be talking about it. Instead, we’re already pitching this service to utilities. That is a huge competitive advantage for our company.”

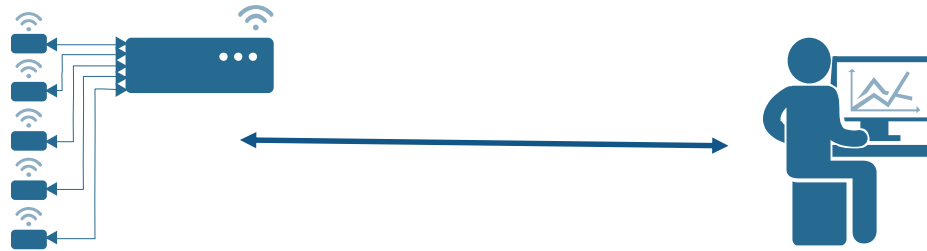
Dave Korn, VP of engineering at Cadmus



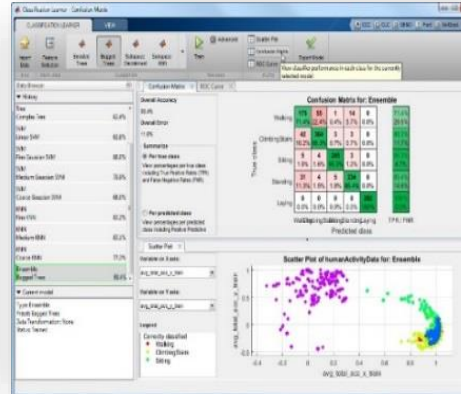
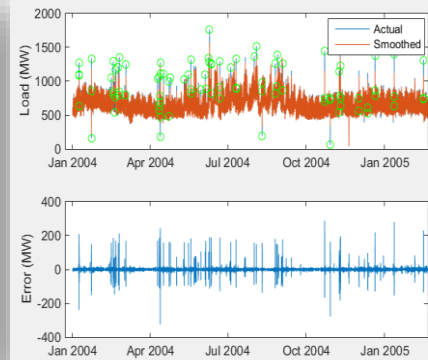
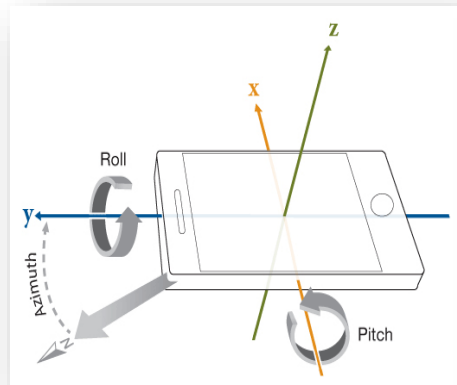
IoT Analytics Challenges




Development of Smart Connected Devices



Automatic Code Generation





```

14 /* Function Definitions */
15
16 /*
17  * Extract Feature vector
18  * Arguments ... const n
19  *          ... const n
20  *          ... const n
21  *          ... const n
22  * Return Type ... double
23  */
24 double predictActivityFrom
25 double mean(44), const
26 {
27     double xval(44);
28     double h_psvf(44);
29     int lastact;
30     double mtemp;
31     int i;
32     int last;
33     double T_maxsq;
34     featuresFromBuffer(is,
35
36     /* Classify with naive2 method */
37     for (lastact = 0; lastact = 44; lastact++) {
38         h_psvf[lastact] = (psvf[lastact] - mean[lastact]) / feat[lastact];
39     }
40 }

```

Connect and Acquire

Signal Pre-Processing

Sensor Signal Analytics

Embedded Implementation

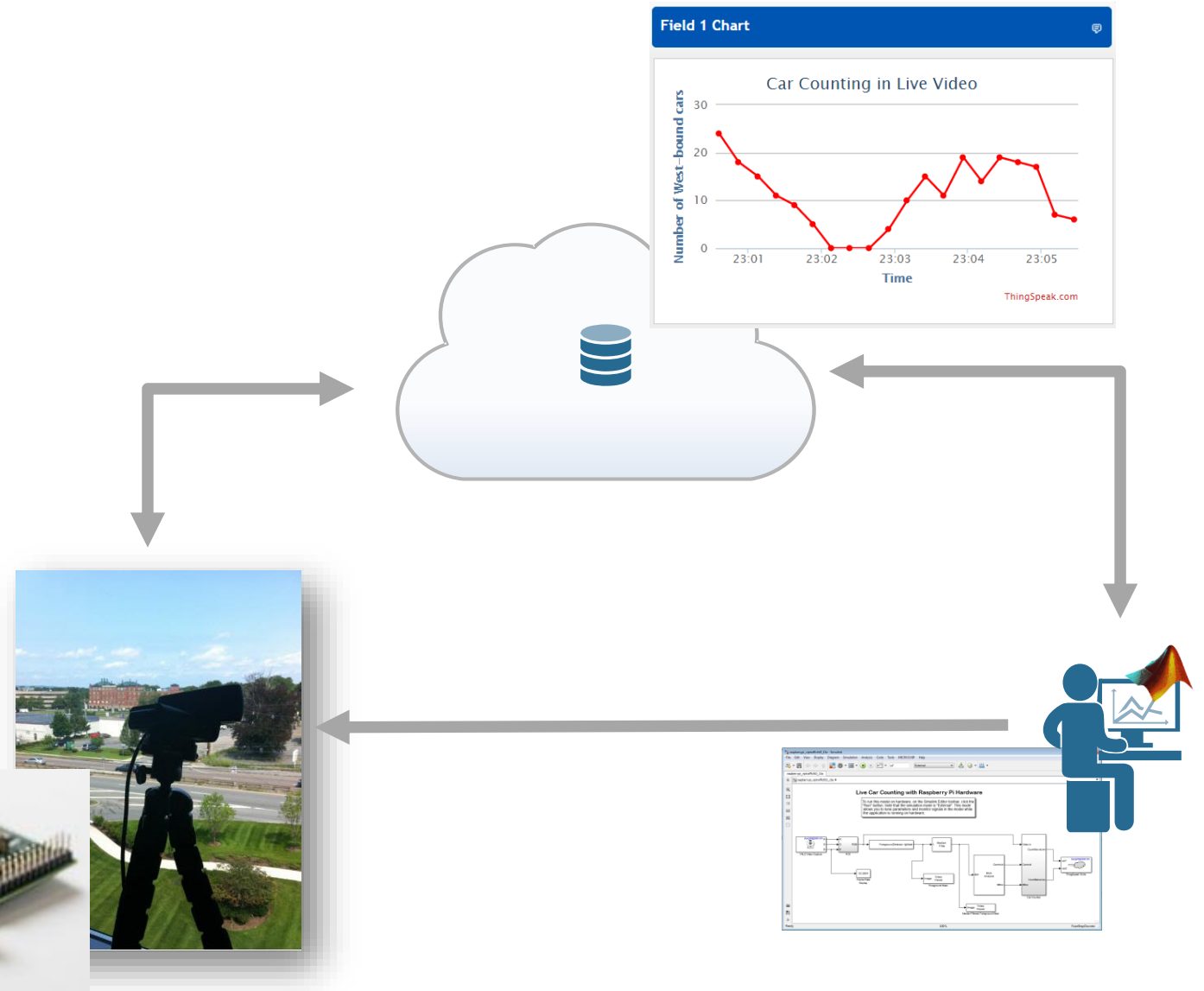
Reduce Data Transfer with Smart Connected Devices

Objectives

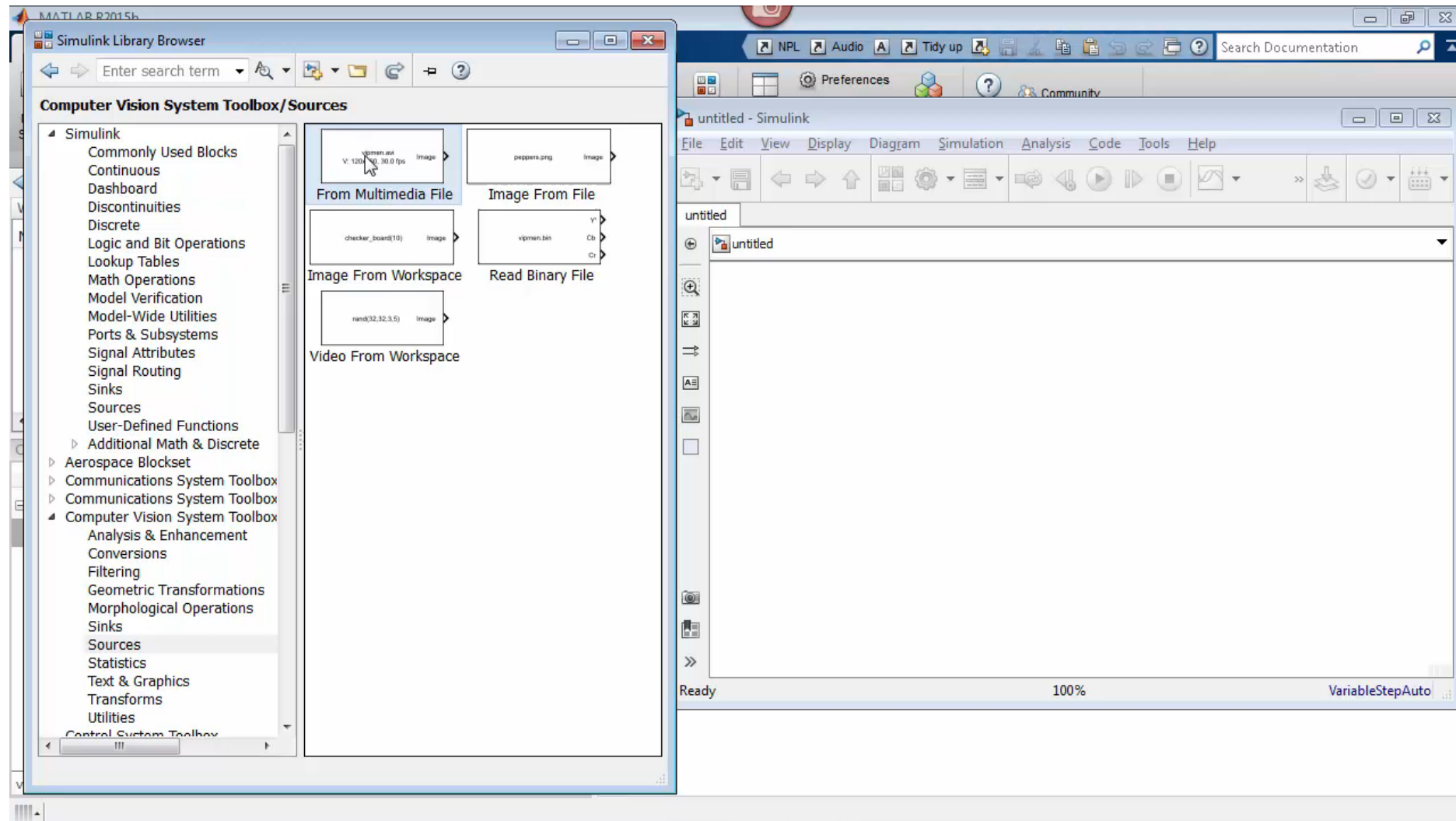
- Measure, explore, discover traffic patterns
- Provide traffic information without sending live video

Solution

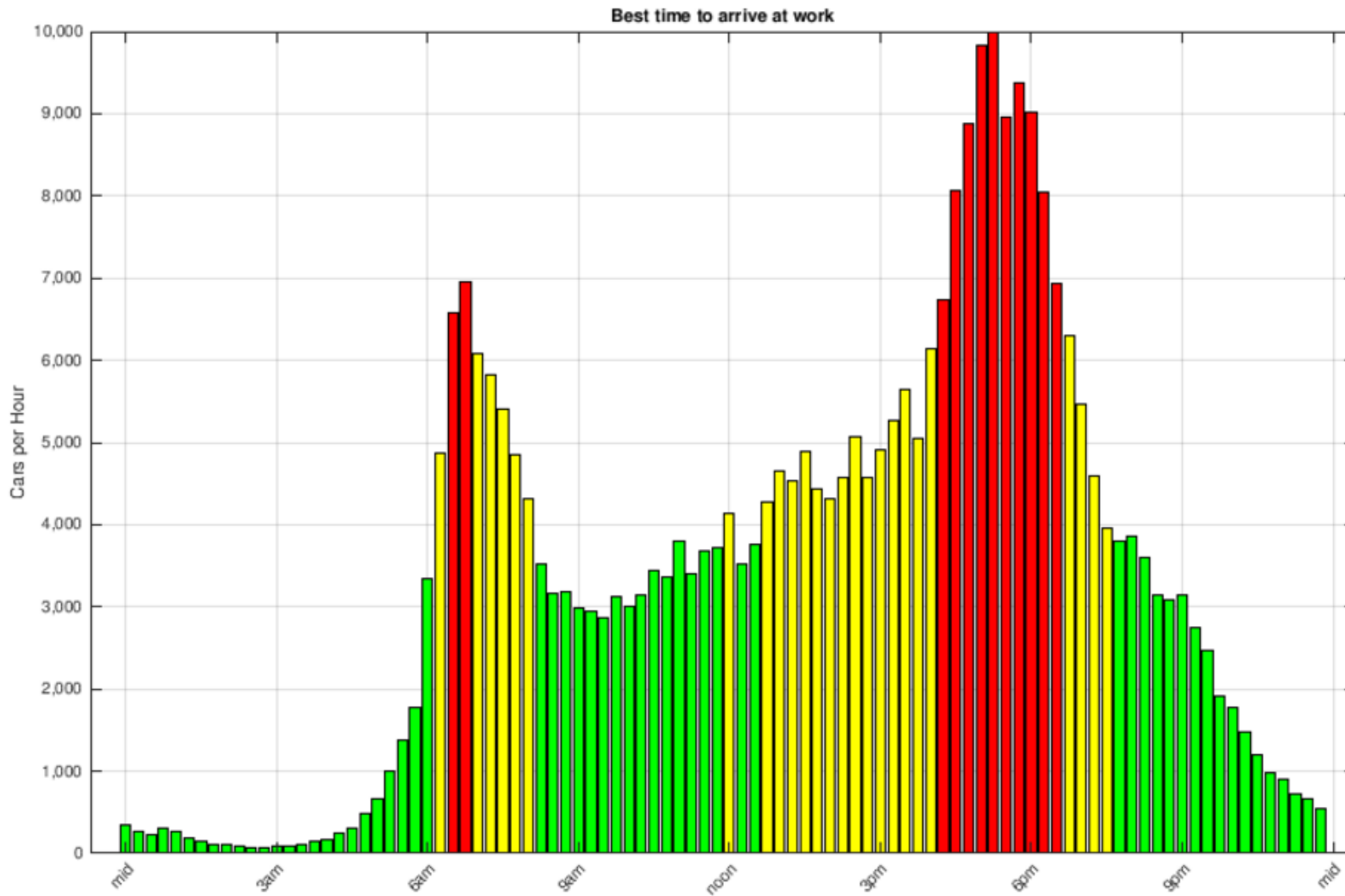
- RaspberryPi + webcam
- Automated deployment of vision algorithms on embedded sensor**



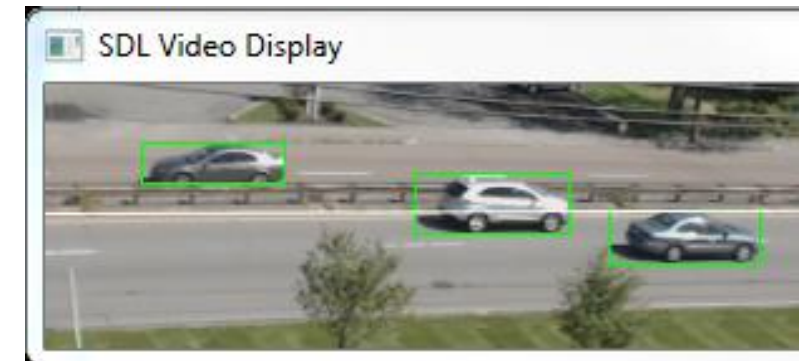
Developing Embeddable Analytics with Simulink



From Data to Insight

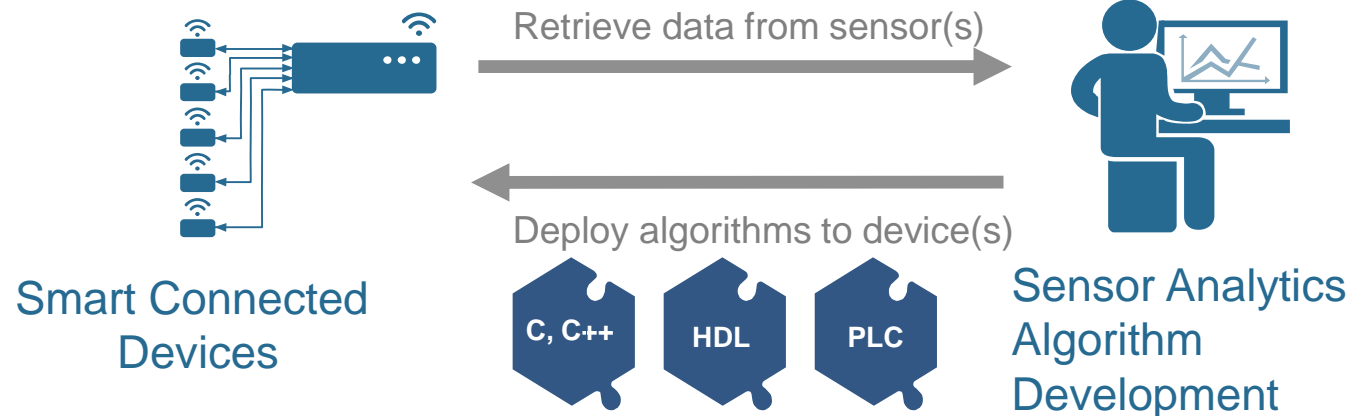


When should I go to work?



MATLAB and Simulink Help Design Smart Connected Devices

- Gather data from sensors using I2C/SPI and other interfaces
- Use pre-built libraries for signal processing , computer vision, machine learning and more
- Automatically generate C / C++ and HDL code
- Hardware Support Packages for a wide variety of devices



Ono Sokki Reduce Development Time for Smart Device

Challenge

- Develop a high-precision speedometer (within 0.1 km/h) using inertial measurement unit sensors.
- Very tight deadline

Technology Applied

- Model, simulate and verify complex algorithms in Simulink
- Use **automatic C code generation** to deploy the algorithm onto an embedded device

Results

- Development time cut significantly
- Project was **completed well ahead of schedule**
- Easier to maintain, and **fewer bugs**



LC-8100 GPS Speedometer System.

Ono Sokki Reduce Development Time for Smart Device

“With MathWorks tools we have a seamless environment for development, simulation, code generation, and processor-in-the-loop verification. **The advantages over hand-coding in C can't be overestimated.**”

Kazuhiro Ichikawa, Ono Sokki

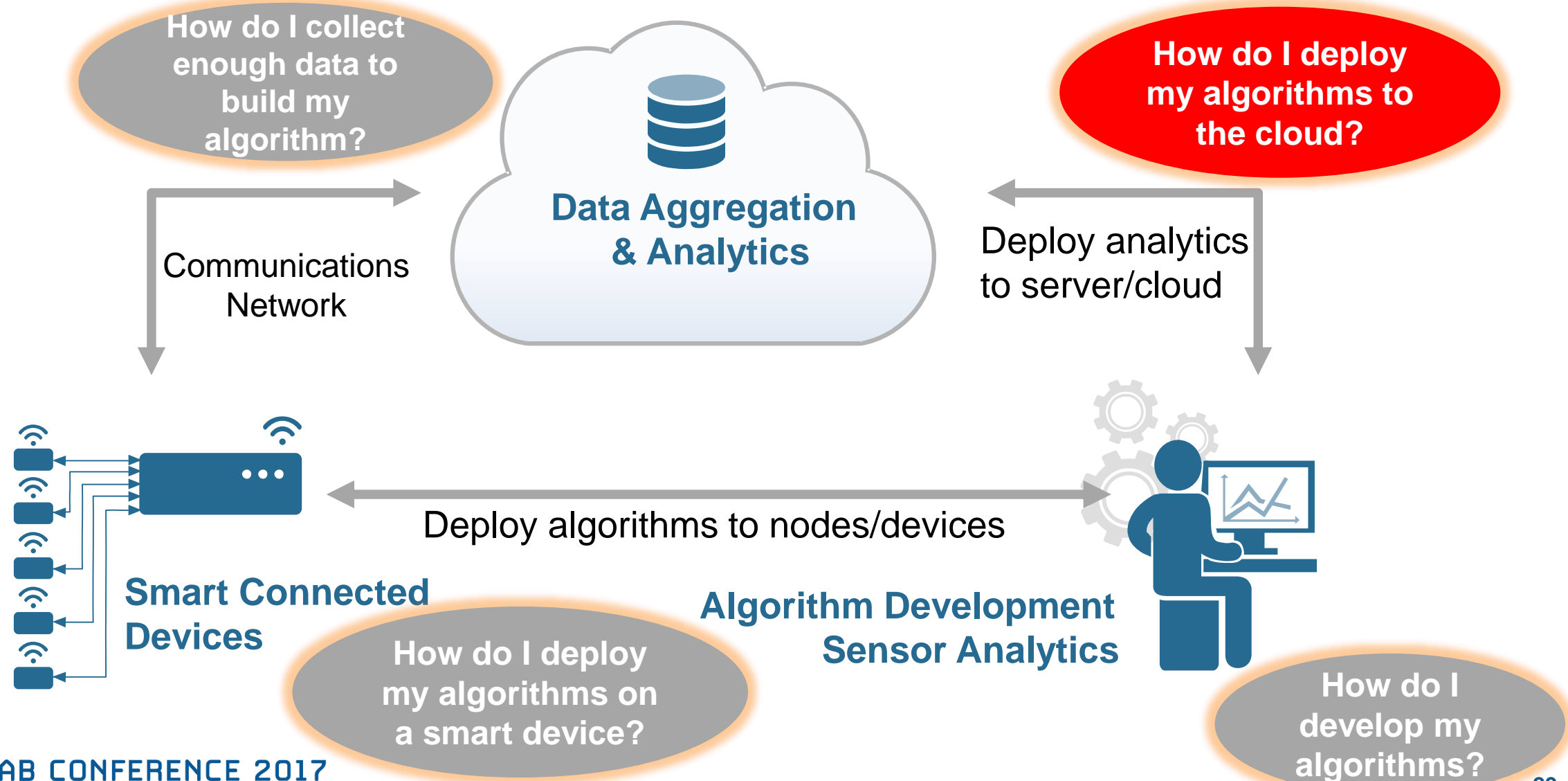


LC-8100 GPS Speedometer System.

Results

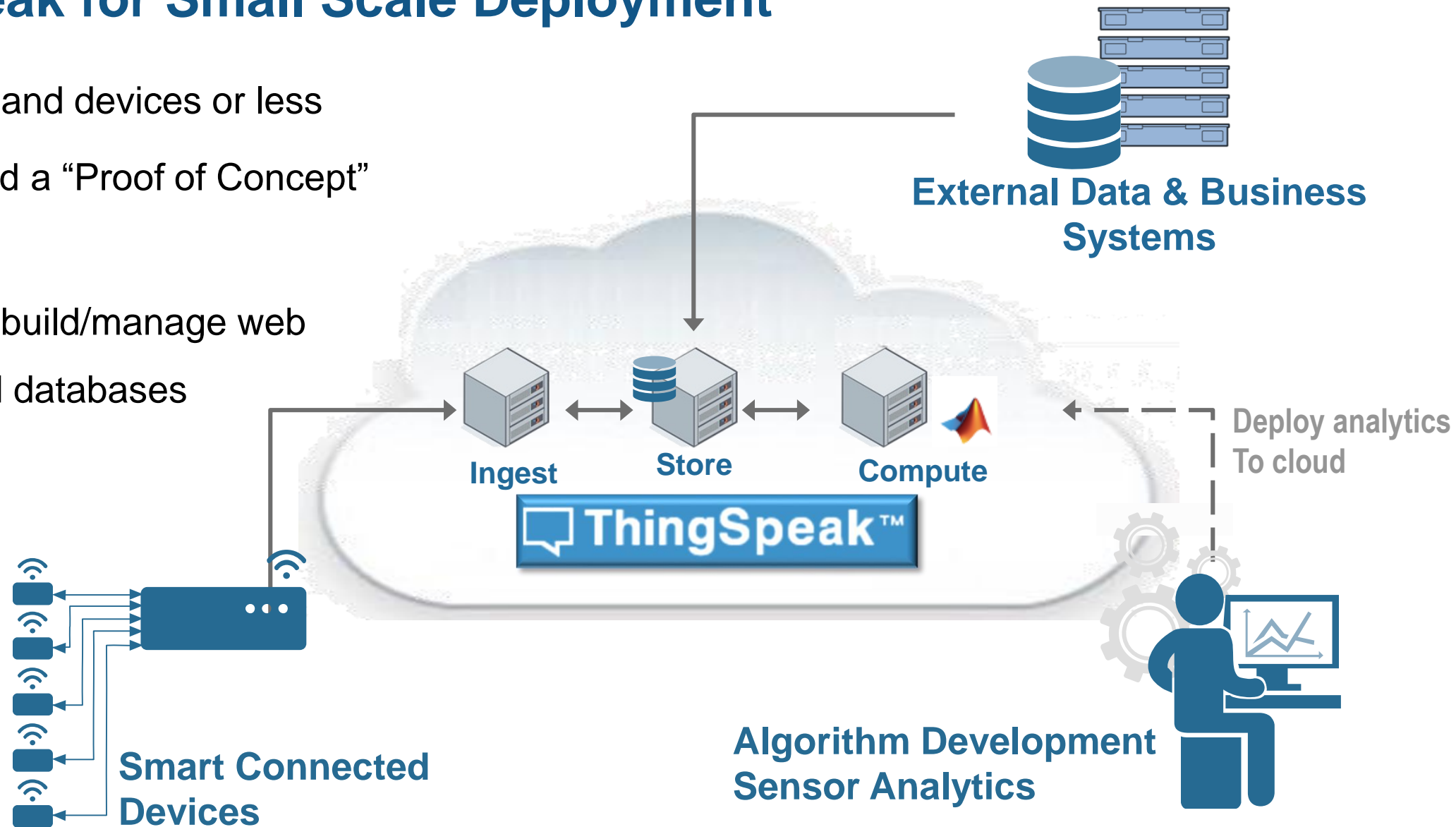
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IoT Analytics Challenges



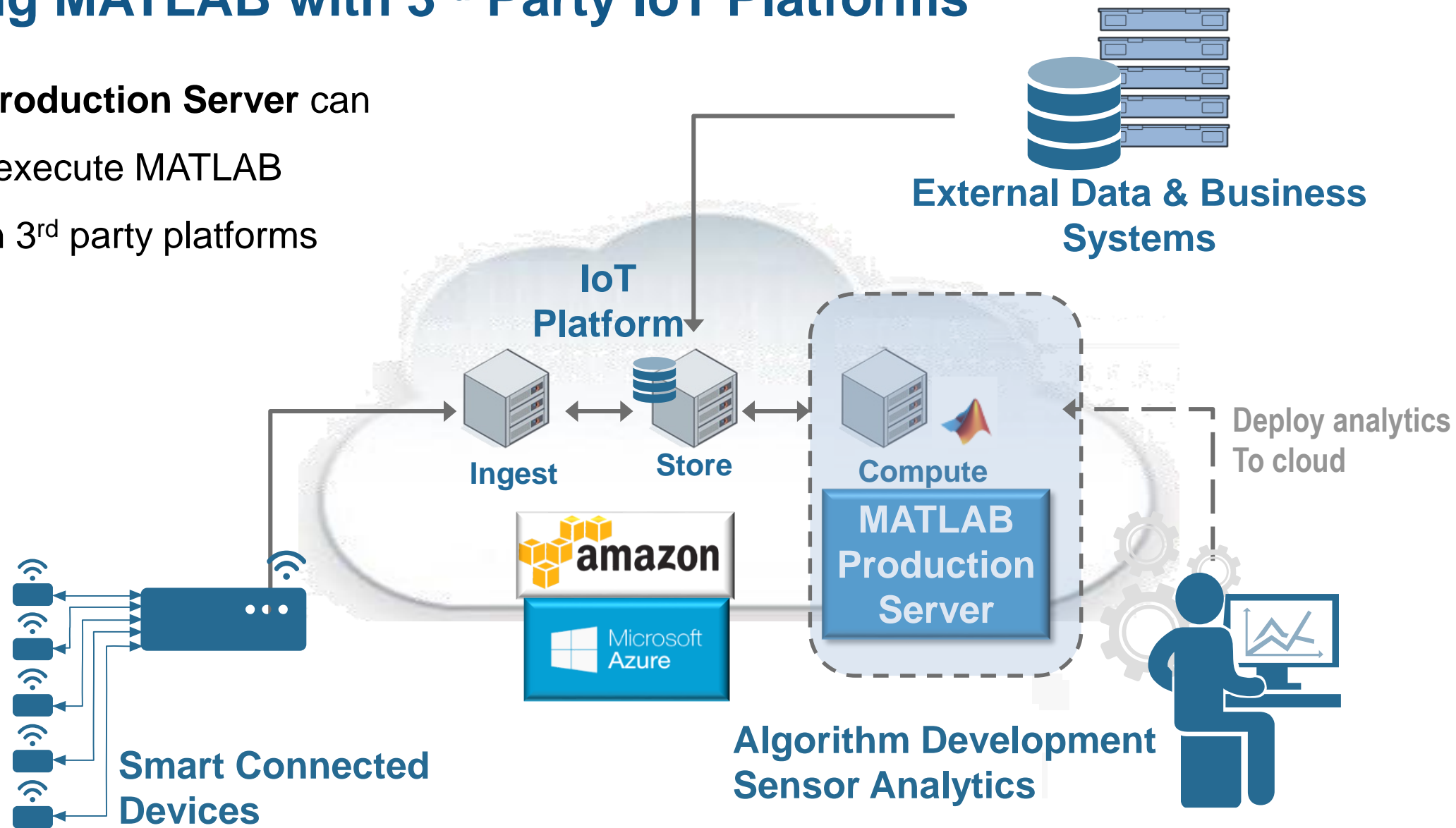
ThingSpeak for Small Scale Deployment

- A few thousand devices or less
- Quickly build a “Proof of Concept” IoT System
- No need to build/manage web servers and databases

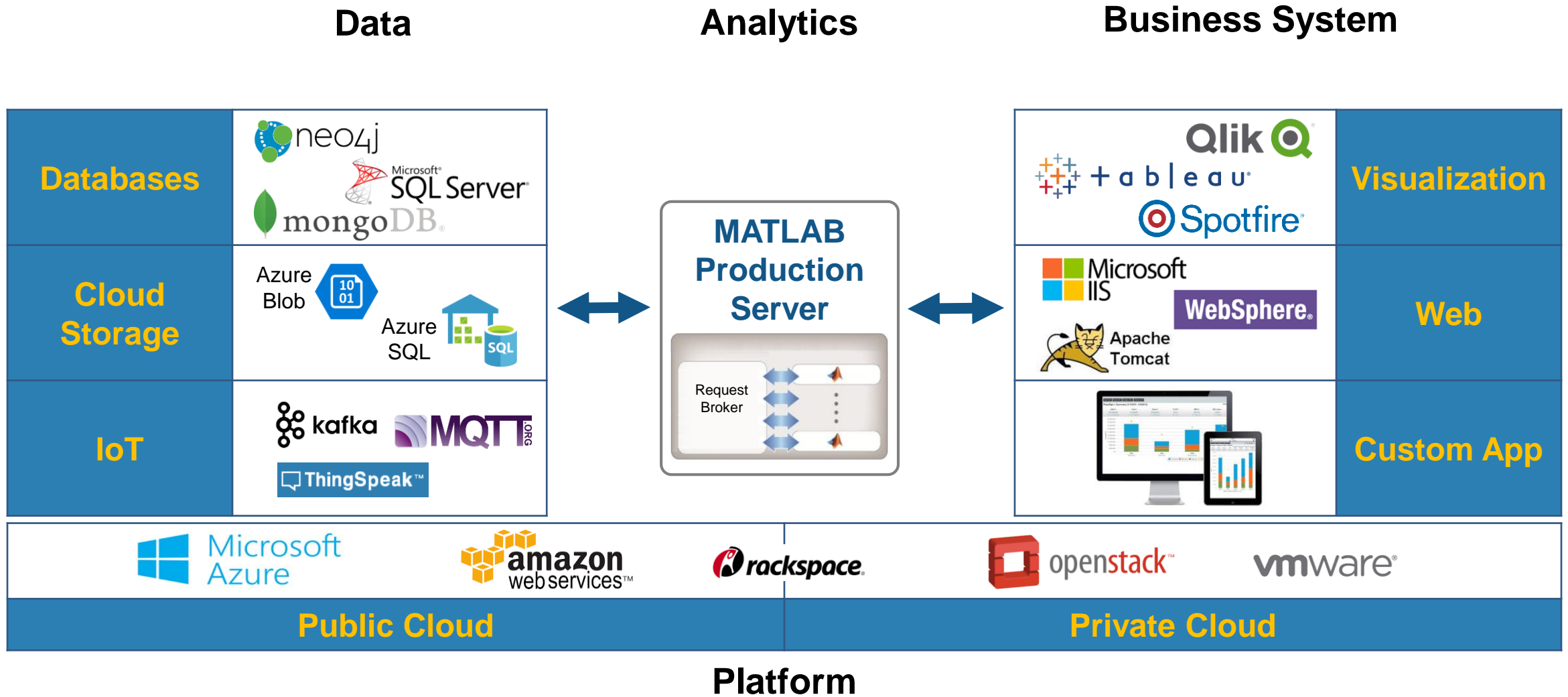


Integrating MATLAB with 3rd Party IoT Platforms

- MATLAB Production Server** can be used to execute MATLAB analytics on 3rd party platforms



Integrating MATLAB in Large Scale Production Systems



Big Data and Predictive Analytics at Shell

Shell analyses big data sets to detect events and abnormalities at downstream chemical plants using predictive analytics with MATLAB®.

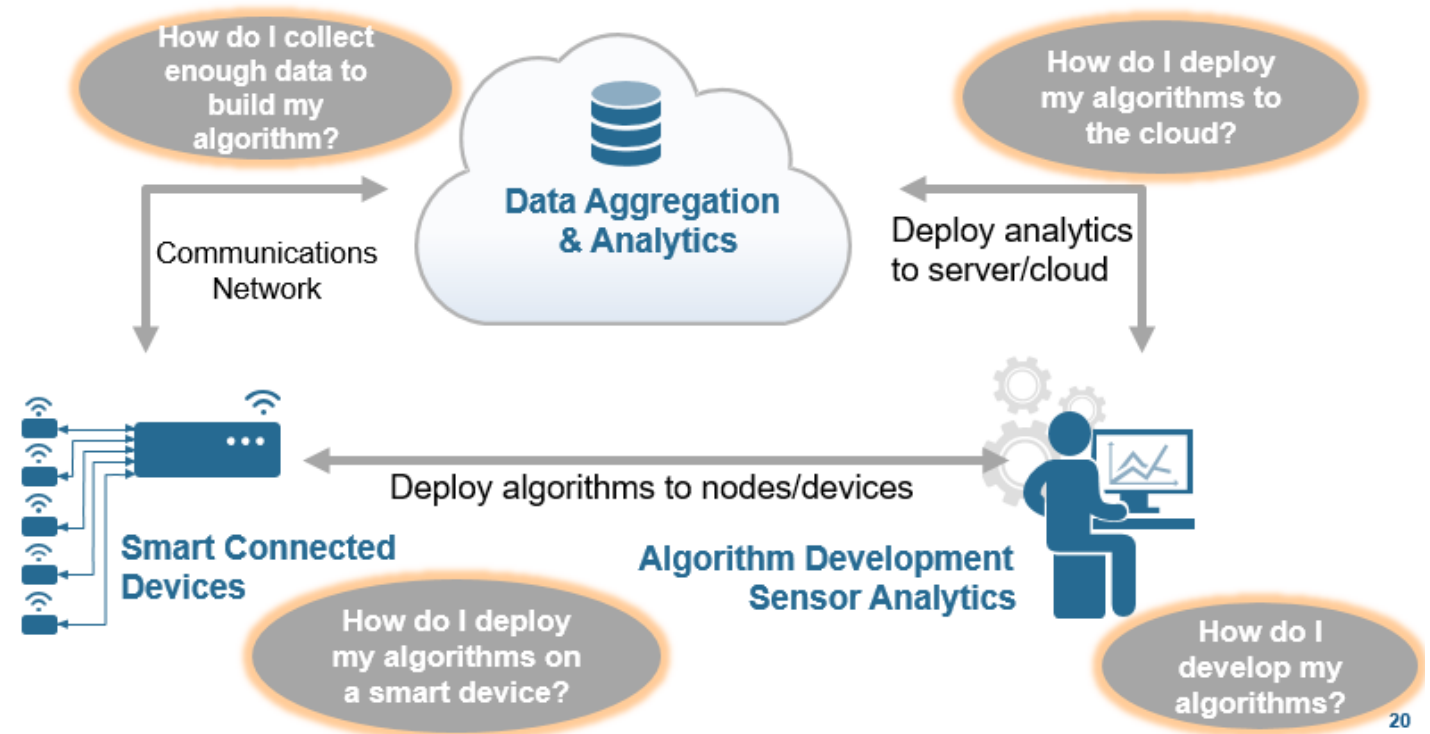
Multivariate statistical models running on **MATLAB Production Server™** are used to do real-time batch and process monitoring, enabling real-time interventions when abnormalities are detected.



<https://au.mathworks.com/videos/big-data-and-predictive-analytics-at-shell-99526.html>

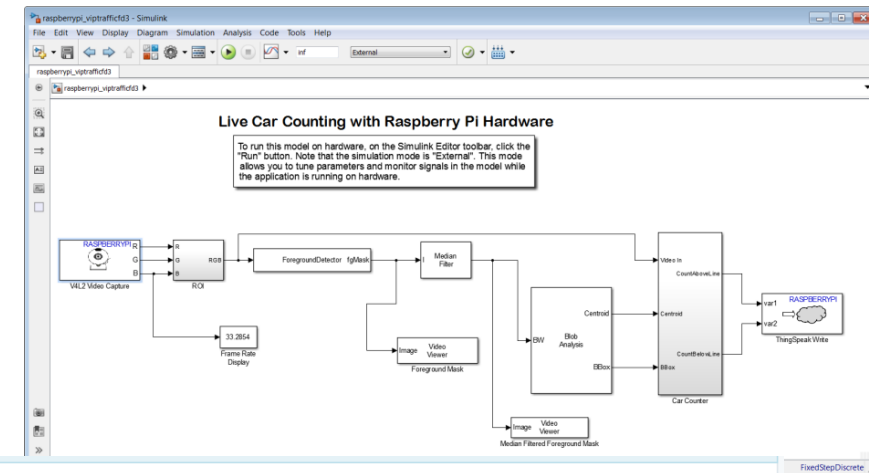
MathWorks Addresses IoT Analytics Challenges

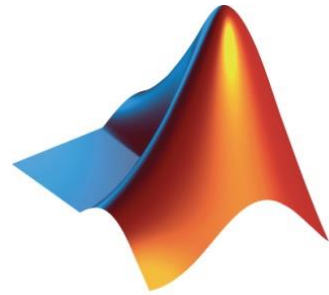
- **Develop analytics algorithms** using MATLAB and toolboxes
- **Quickly collect and analyze IoT data** with ThingSpeak and MATLAB
- **Deploy on smart devices** using code generation for embedded hardware
- **Deploy on cloud** using ThingSpeak and MATLAB Production Server



What You Can Do to Learn More

- [Log-in to ThingSpeak with you MathWorks account and explore](#)
- [View a webinar on Machine Learning with MATLAB](#)
- [Read a Technical Article on Forecasting Tides with MATLAB](#)
- [Read a tutorial on how to send data to ThingSpeak over MQTT](#)





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