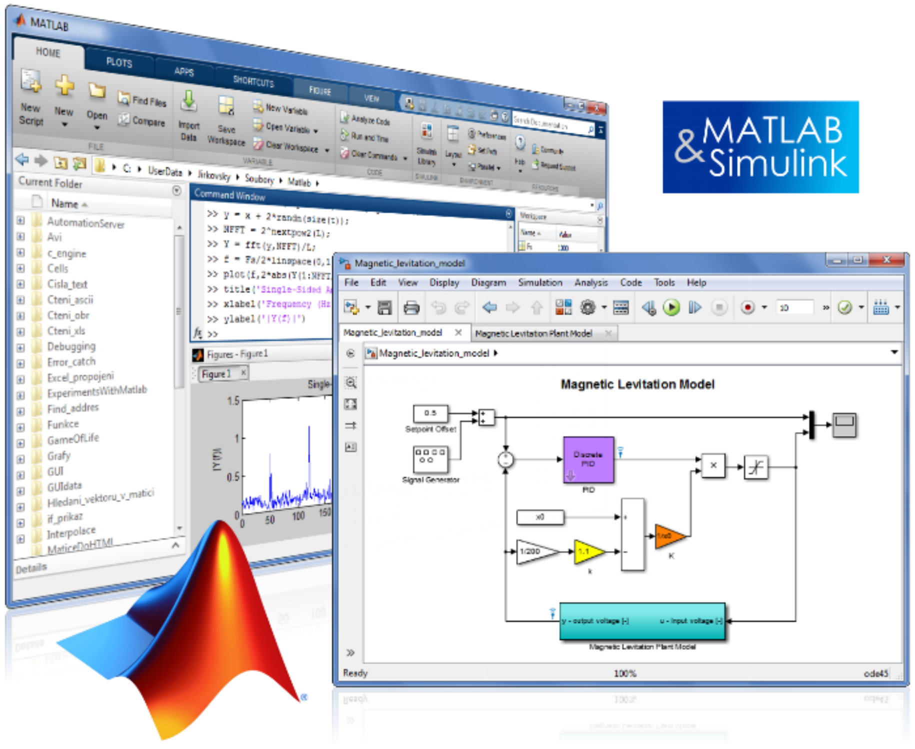
ThingSpeak - IoT Platform with MATLAB Analytics



```
>> y = x + 2*randn(size(t));
>> NFFT = 2^nextpow2(L);
>> Y = fft(y,NFFT)/L;
>> f = Fs/2*linspace(0,1
>> plot(f,2*abs(Y(1:NFFT,
>> title('Single-Sided A
>> xlabel('Frequency (Hz
>> ylabel('|Y(f)|')
>>
```

MATLAB
HOME
PLOTS
APPS
SHORTCUTS
Current Folder
Command Window
Figures - Figure1
Magnetic_levitation_model
File Edit View Display Diagram Simulation Analysis Code Tools Help
Magnetic Levitation Model
Setpoint Offset
Signal Generator
Discrete PID
Magnetic Levitation Plant Model
Ready
100%
ode45

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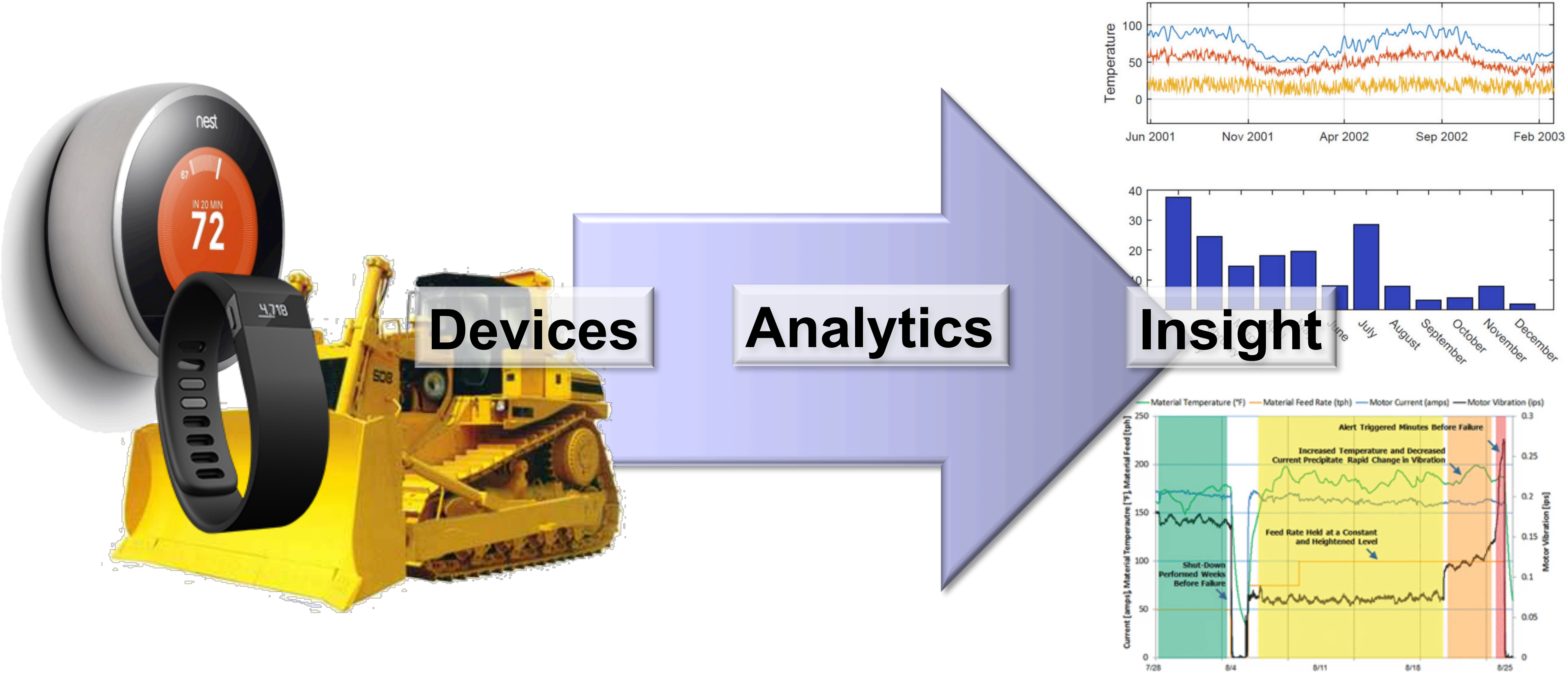
Michal Blaho
blaho@humusoft.sk

www.humusoft.cz
info@humusoft.cz
www.mathworks.com

Internet of Things



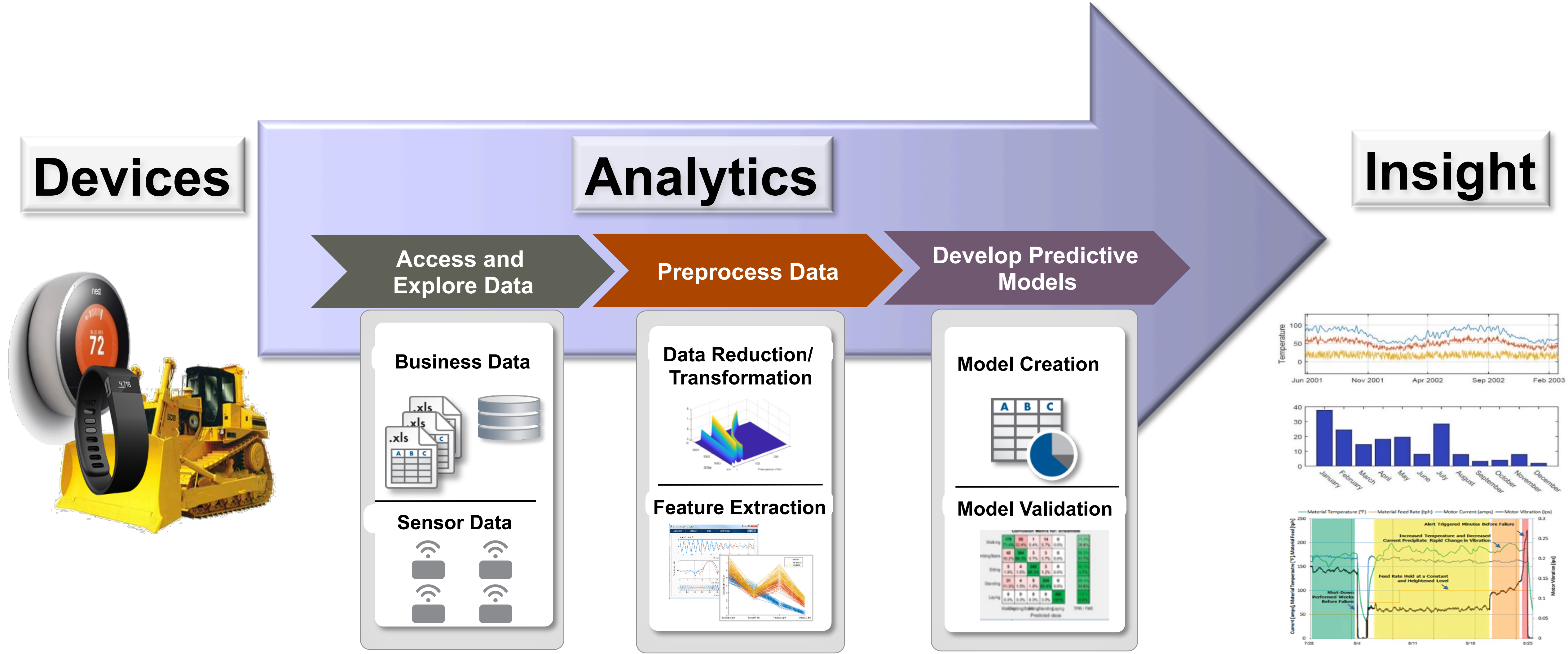
Devices

Analytics

Insight

nest
IN 20 MIN
72
67
4,718
508
Temperature
100
50
0
Jun 2001
Nov 2001
Apr 2002
Sep 2002
Feb 2003
40
30
20
10
June
July
August
September
October
November
December
Material Temperature (°F)
Material Feed Rate (tph)
Motor Current (amps)
Motor Vibration (ips)
Current [amps], Material Temperautre [°F], Material Feed [tph]
Motor Vibration [ips]
250
200
150
100
50
0
0.3
0.25
0.2
0.15
0.1
0.05
0
7/28
8/4
8/11
8/18
8/25
Alert Triggered Minutes Before Failure
Increased Temperature and Decreased Current Precipitate Rapid Change in Vibration
Feed Rate Held at a Constant and Heightened Level
Shut-Down Performed Weeks Before Failure

IoT Analytics



Devices

Analytics

Insight

Access and Explore Data

- Business Data
- Sensor Data

Preprocess Data

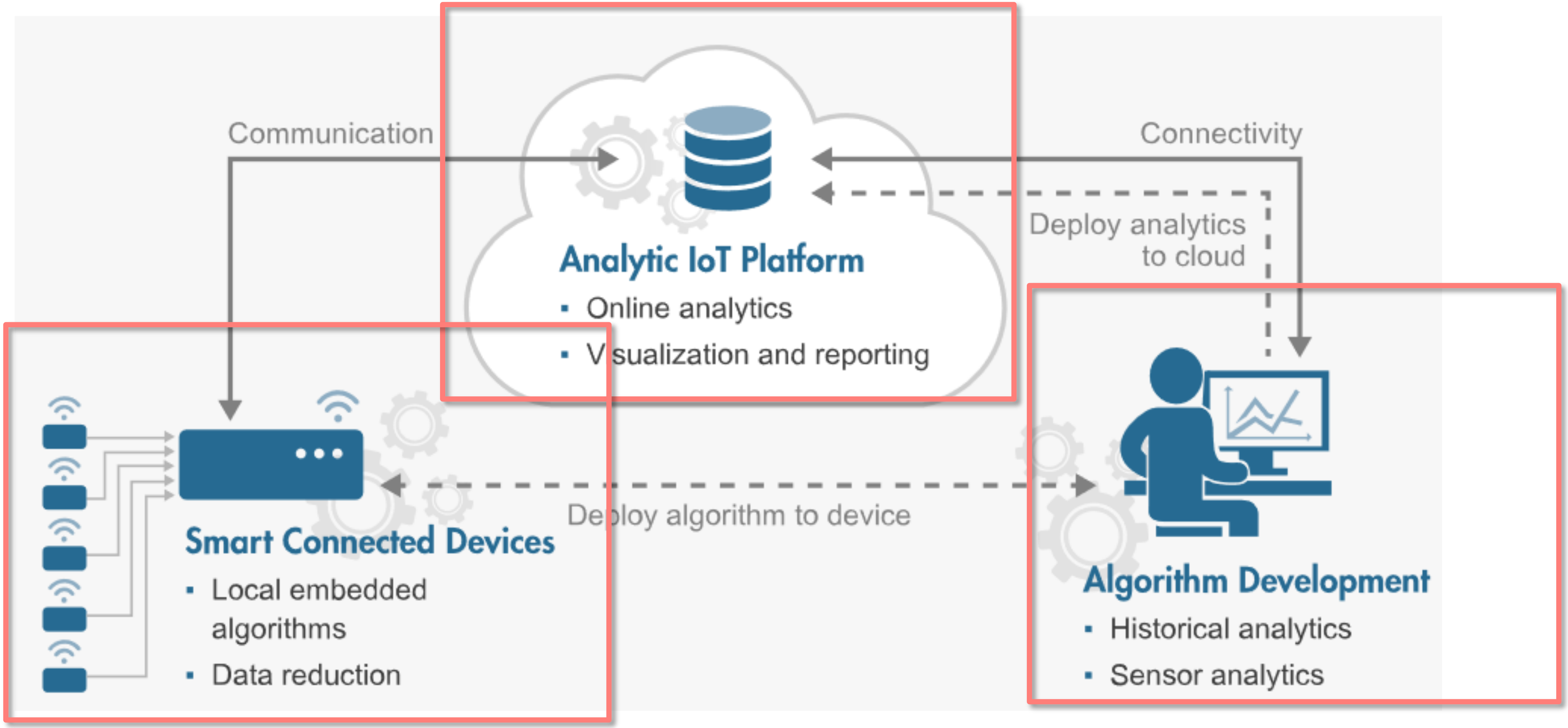
- Data Reduction/ Transformation
- Feature Extraction

Develop Predictive Models

- Model Creation
- Model Validation

Figure 3. Vibration analysis: Data processed by the company's vibration analysis tool, and leading up to the fan's catastrophic failure, provides an ambiguous indication of the asset's degrading condition.

IoT Analytics Framework



Communication

Connectivity

Deploy analytics to cloud

Analytic IoT Platform
- Online analytics
- Visualization and reporting

Deploy algorithm to device

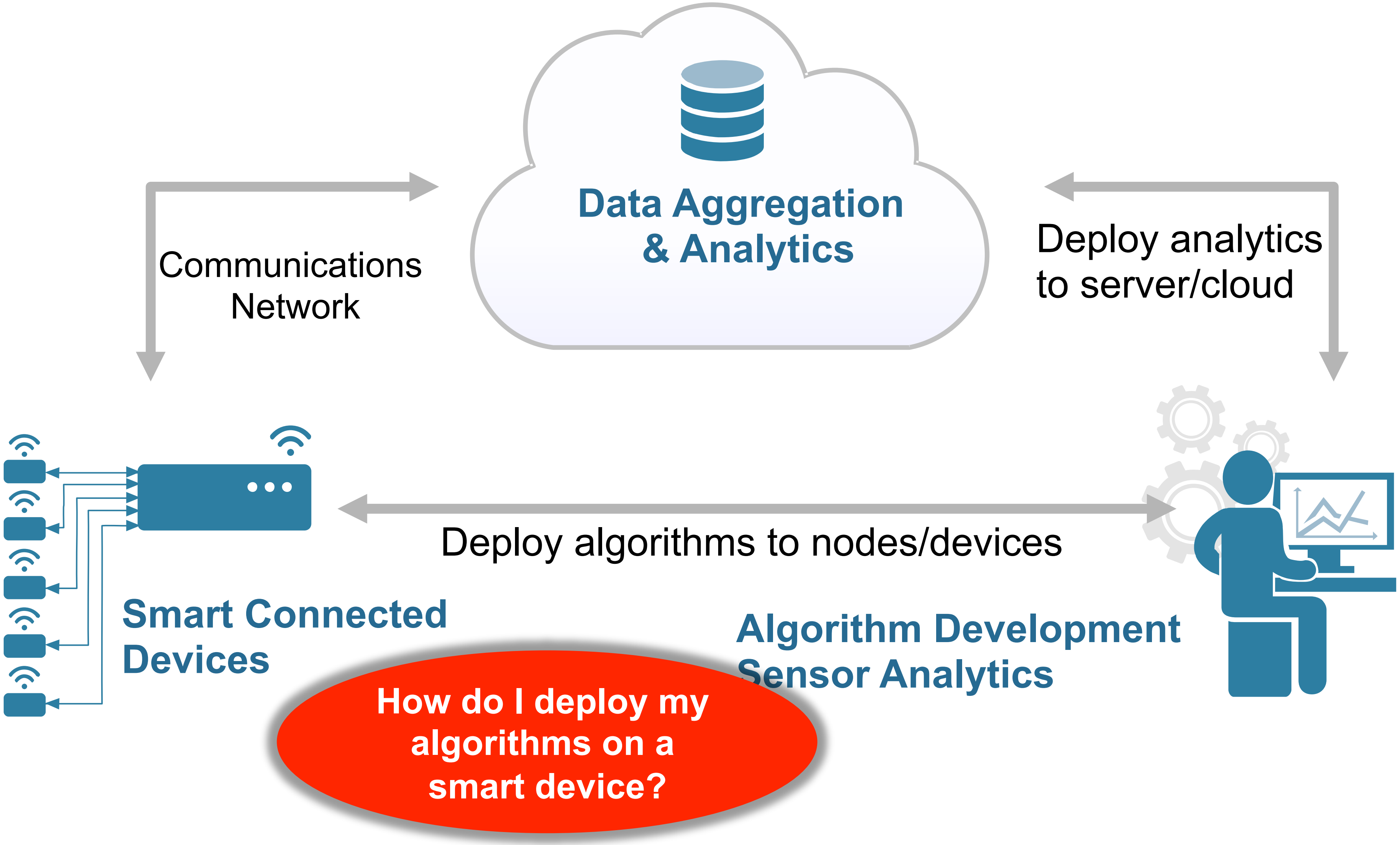
Smart Connected Devices
- Local embedded algorithms
- Data reduction

Algorithm Development
- Historical analytics
- Sensor analytics

IoT Analytics Challenges

- How do I deploy my algorithms on a smart device?
- How do I collect enough data to build my algorithm?
- How do I develop my algorithms?
- How do I deploy my algorithms to the cloud?

IoT Analytics Challenges



Data Aggregation & Analytics

Communications Network

Deploy analytics to server/cloud

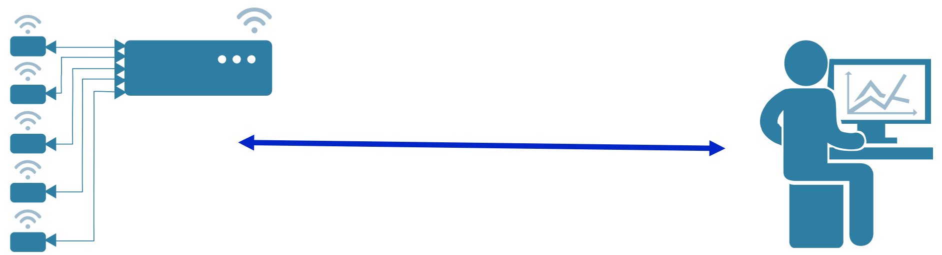
Deploy algorithms to nodes/devices

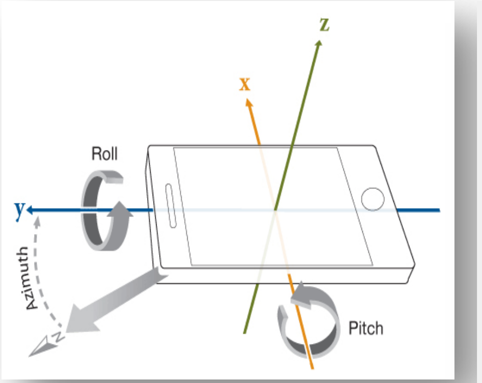
Smart Connected Devices

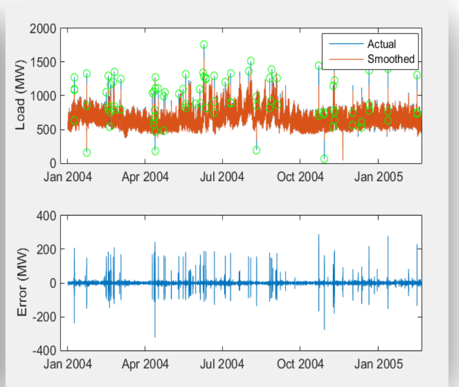
Algorithm Development Sensor Analytics

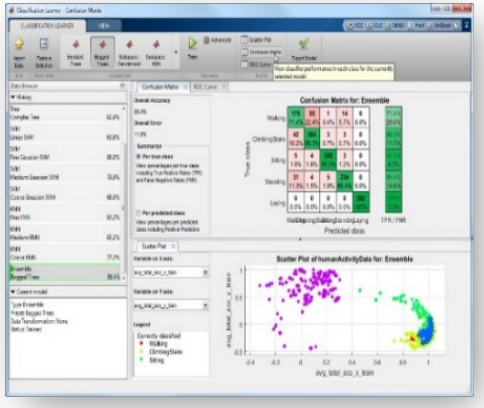
How do I deploy my algorithms on a smart device?

Sensor Analytics and Development of Smart Devices







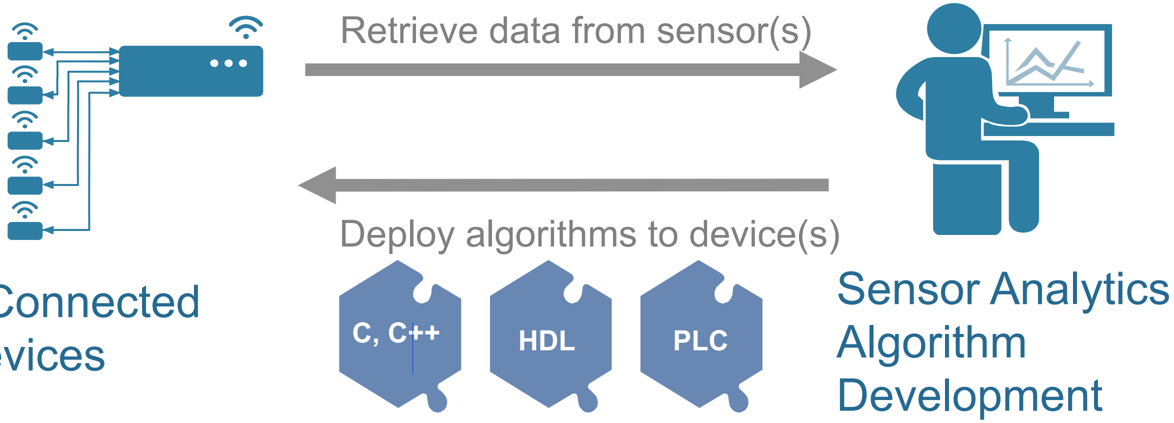

Confusion Matrix for: Ensemble
Predicted class
True class
Scatter Plot of humanActivityData for: Ensemble

```
/* Function Definitions */

/*
 * Extract feature vector
 * Arguments    : const d
 *                double
 *                const d
 *                const d
 * Return Type  : double
 */
double predictActivityFro                    ble at[3             fs,
  double fmean[66], const
{
  double rawf[66];
  double b_rawf[66];
  int istart;
  double scores[6];
  double mtmp;
  int itmp;
  int ix;
  boolean_T exitgl;
  featuresFromBuffer(at,

  /*  Classify with neural network */
  for (istart = 0; istart < 66; istart++) {
    b_rawf[istart] = (rawf[istart] - fmean[istart]) / fstd[istart];
```

Connect and Acquire → Signal Processing → Machine Learning → Embedded Implementation

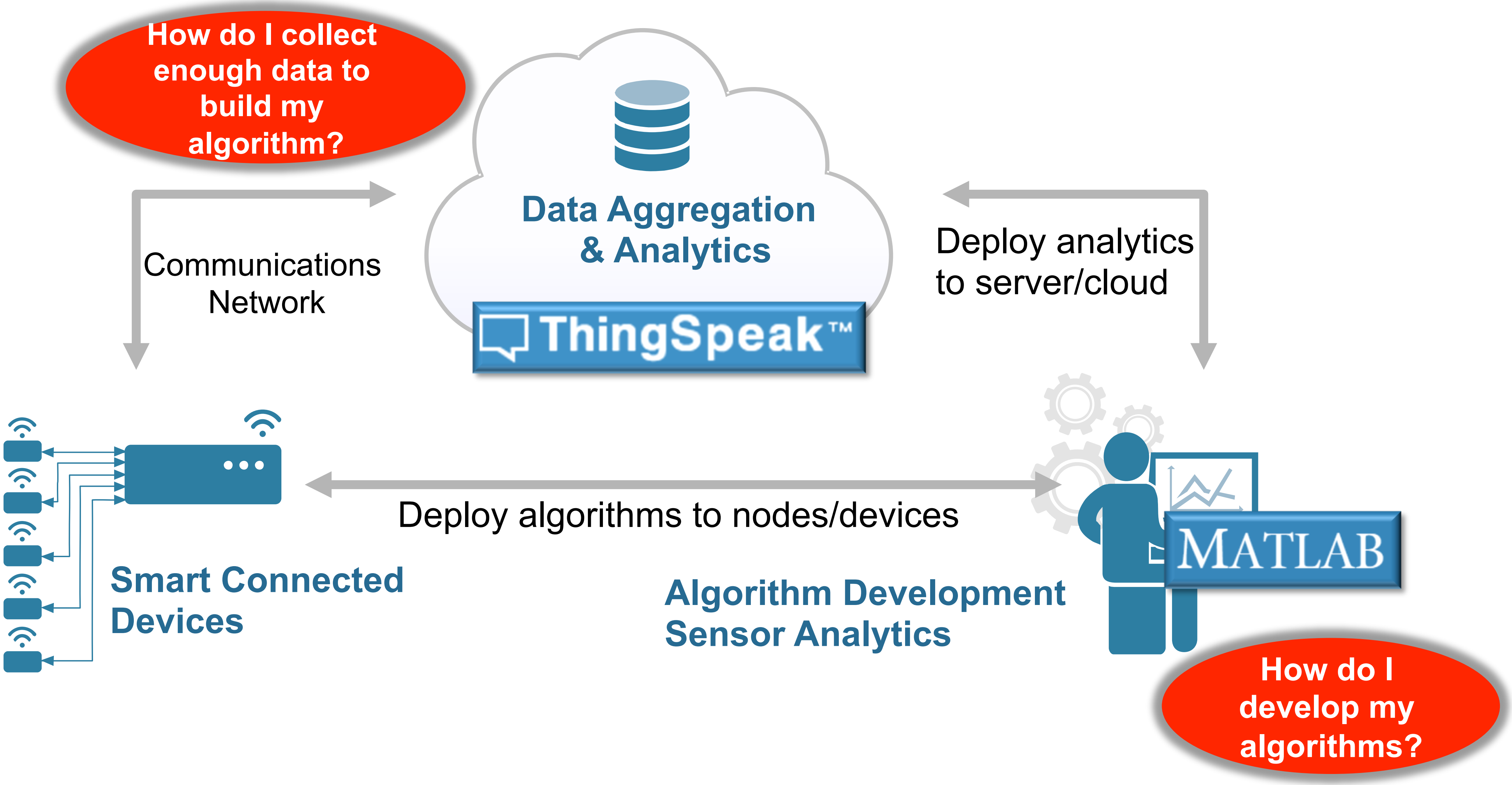
Designing Smart Connected Devices

- 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++, HDL, PLC code
- Embedded targeting packages for a wide variety of hardware



Retrieve data from sensor(s)
Deploy algorithms to device(s)
Smart Connected Devices
C, C++
HDL
PLC
Sensor Analytics Algorithm Development

IoT Analytics Challenges



How do I collect enough data to build my algorithm?

Data Aggregation & Analytics

Communications Network

Deploy analytics to server/cloud

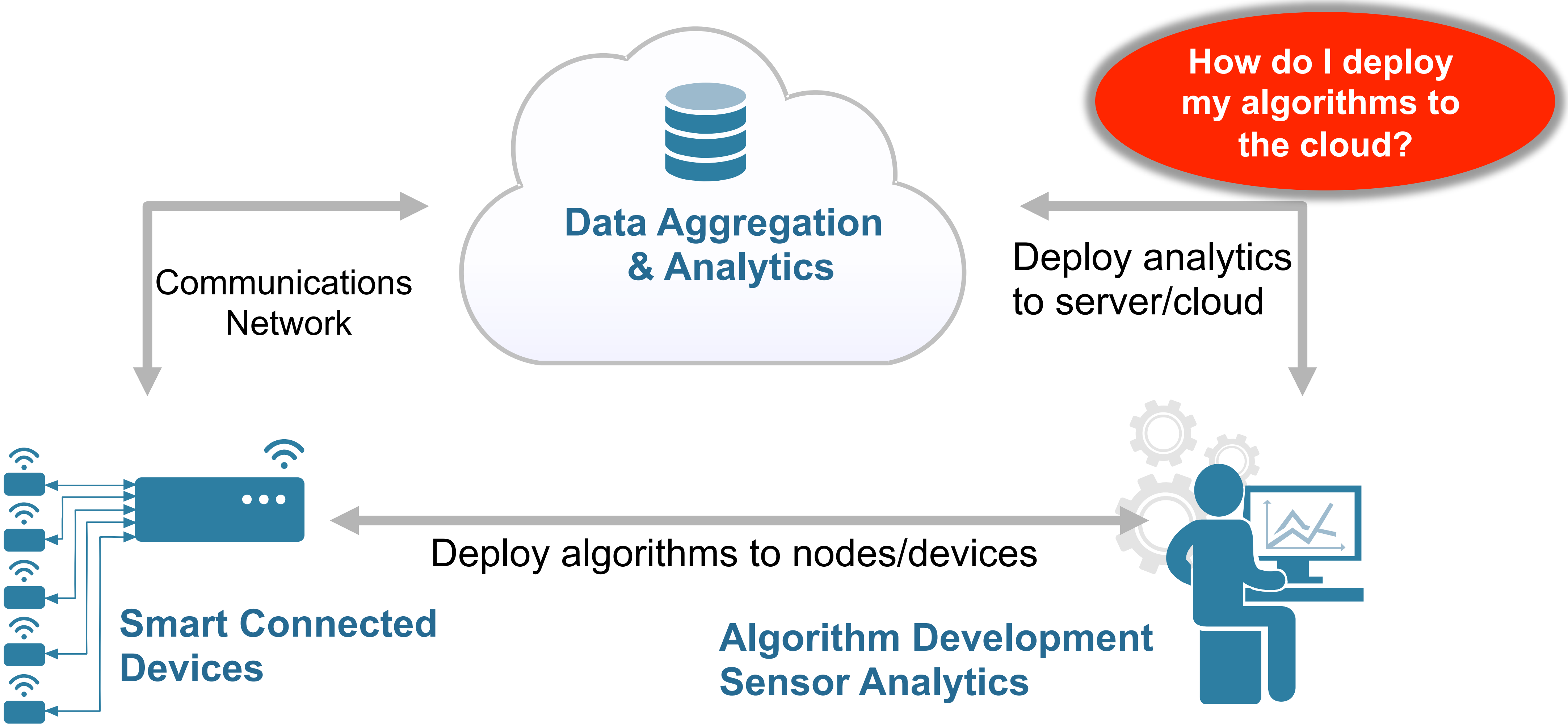
Deploy algorithms to nodes/devices

Smart Connected Devices

Algorithm Development Sensor Analytics

How do I develop my algorithms?

IoT Analytics Challenges



How do I deploy my algorithms to the cloud?

Data Aggregation & Analytics

Communications Network

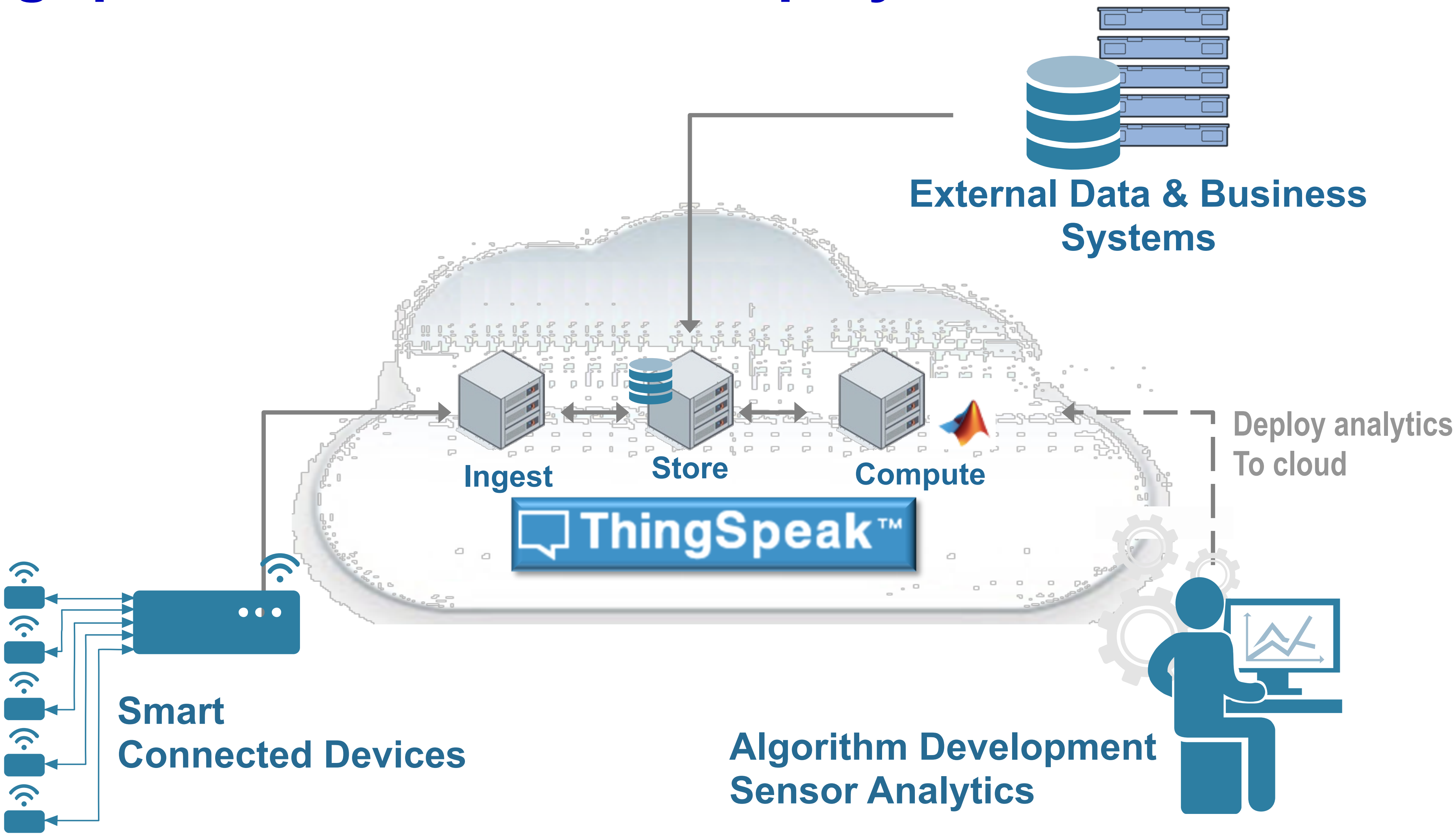
Deploy analytics to server/cloud

Deploy algorithms to nodes/devices

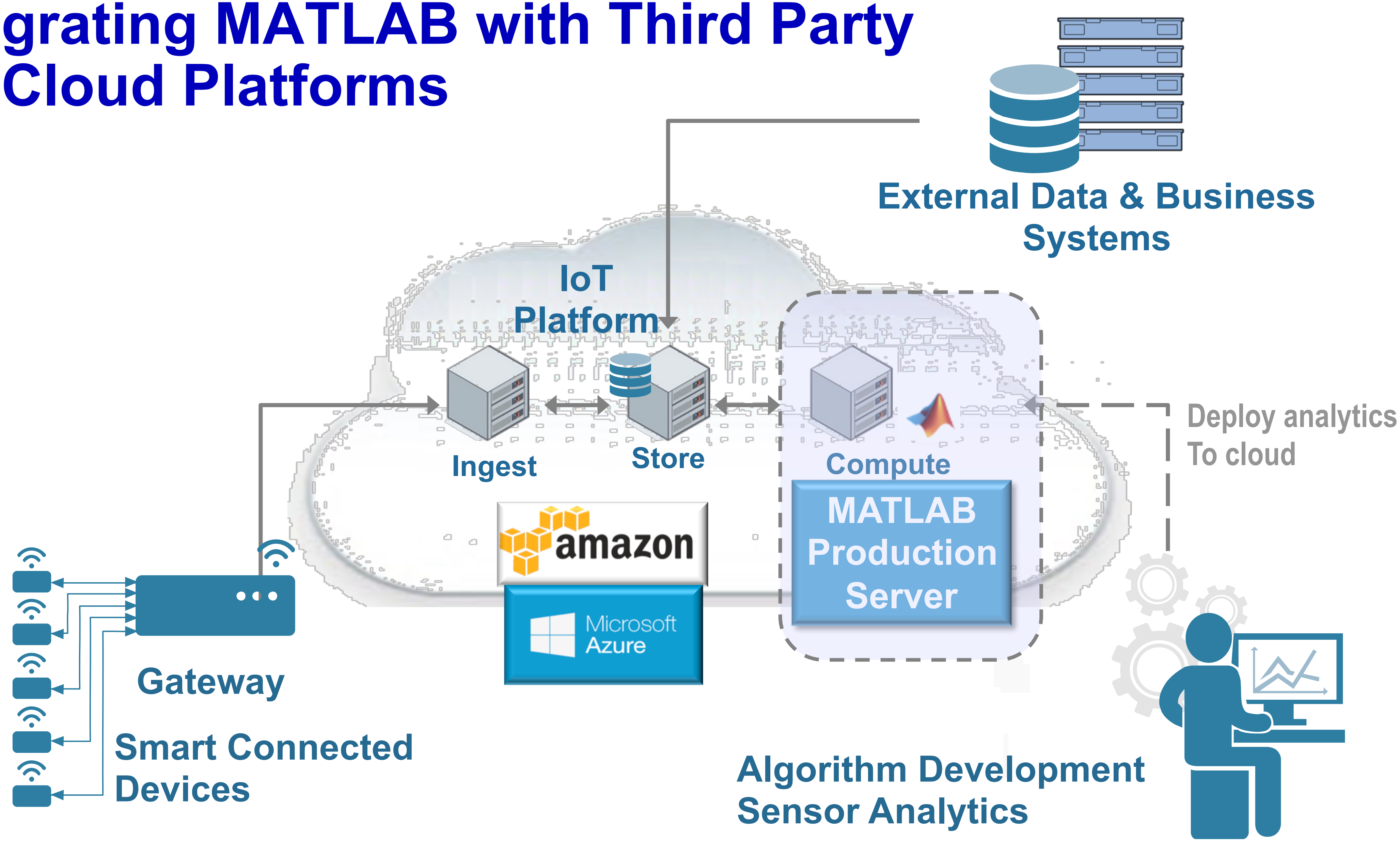
Smart Connected Devices

Algorithm Development Sensor Analytics

ThingSpeak for Small Scale Deployment


External Data & Business Systems
Ingest
Store
Compute
ThingSpeak™
Deploy analytics To cloud
Smart Connected Devices
Algorithm Development Sensor Analytics

Integrating MATLAB with Third Party IoT Cloud Platforms



External Data & Business Systems

IoT Platform

Ingest

Store

Compute

MATLAB Production Server

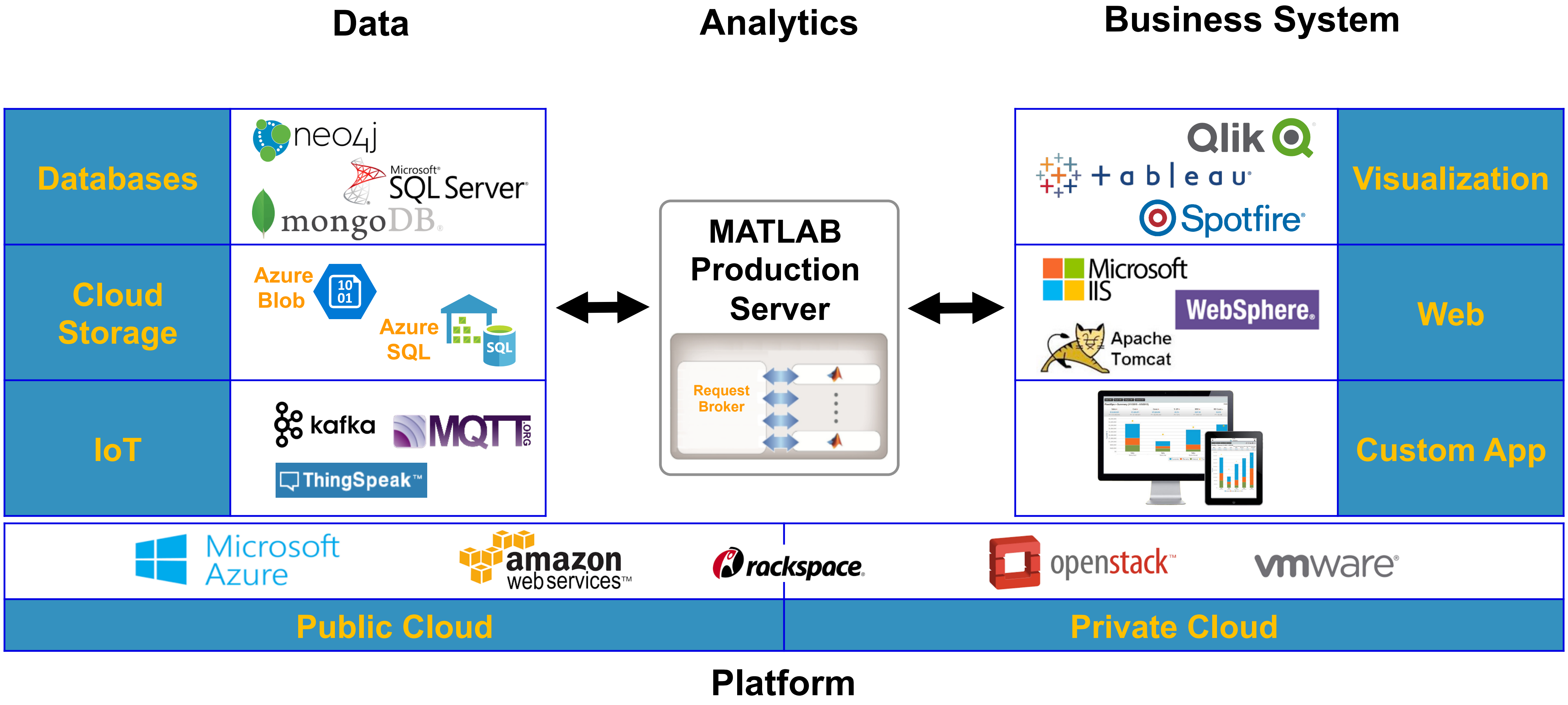
Deploy analytics To cloud

Gateway

Smart Connected Devices

Algorithm Development Sensor Analytics

Integrating MATLAB in Large Scale Production Systems



Data

Analytics

Business System

Databases

neo4j

Microsoft SQL Server

mongoDB

Cloud Storage

Azure Blob

Azure SQL

IoT

kafka

MQTT.ORG

ThingSpeak™

MATLAB Production Server

Request Broker

Visualization

Qlik

tableau

Spotfire

Web

Microsoft IIS

WebSphere

Apache Tomcat

Custom App

Microsoft Azure

amazon web services™

rackspace

openstack™

vmware

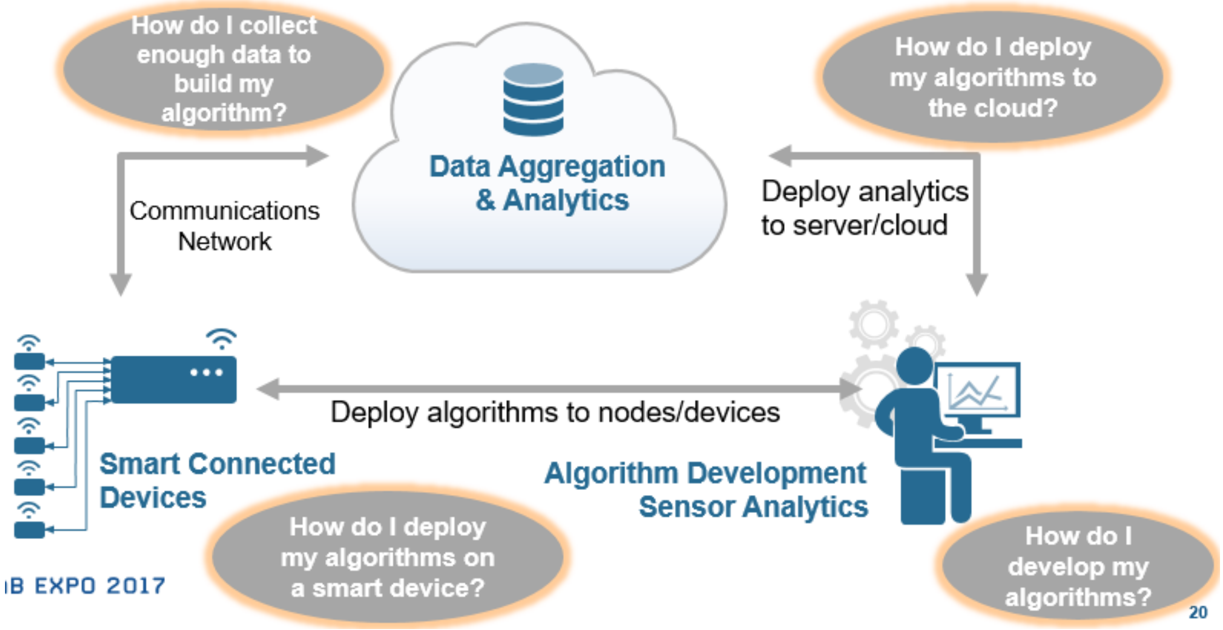
Public Cloud

Private Cloud

Platform

MathWorks Addresses IoT Analytics Challenges

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



How do I collect enough data to build my algorithm?

Data Aggregation & Analytics

How do I deploy my algorithms to the cloud?

Communications Network

Deploy analytics to server/cloud

Deploy algorithms to nodes/devices

Smart Connected Devices

Algorithm Development Sensor Analytics

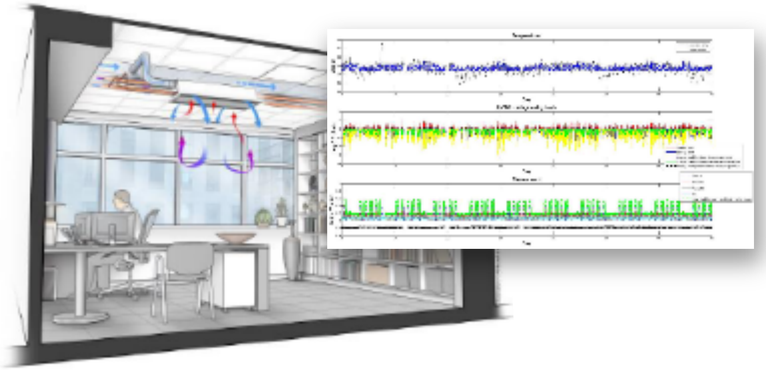
How do I deploy my algorithms on a smart device?

How do I develop my algorithms?

ıB EXPO 2017

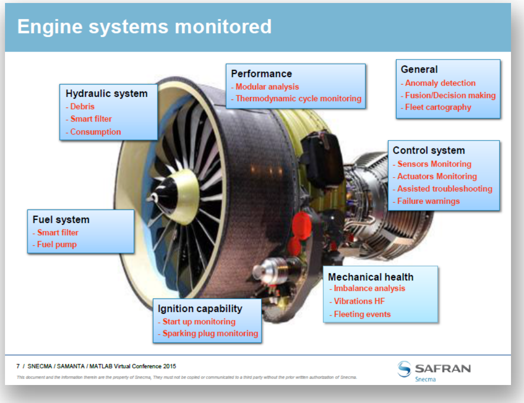
20

Industrial Customer Examples



Online optimization of building energy use

- Real-time, cloud-based system
- Combines analytics with optimization for predictive control of single-building HVAC
- Energy consumption reduced 15-25%



Engine systems monitored

Hydraulic system
- Debris
- Smart filter
- Consumption

Performance
- Modular analysis
- Thermodynamic cycle monitoring

General
- Anomaly detection
- Fusion/Decision making
- Fleet cartography

Control system
- Sensors Monitoring
- Actuators Monitoring
- Assisted troubleshooting
- Failure warnings

Fuel system
- Smart filter
- Fuel pump

Mechanical health
- Imbalance analysis
- Vibrations HF
- Fleeting events

Ignition capability
- Start up monitoring
- Sparking plug monitoring

7 / SNECMA / SAMANTA / MATLAB Virtual Conference 2015

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SAFRAN Snecma

Online engine health monitoring

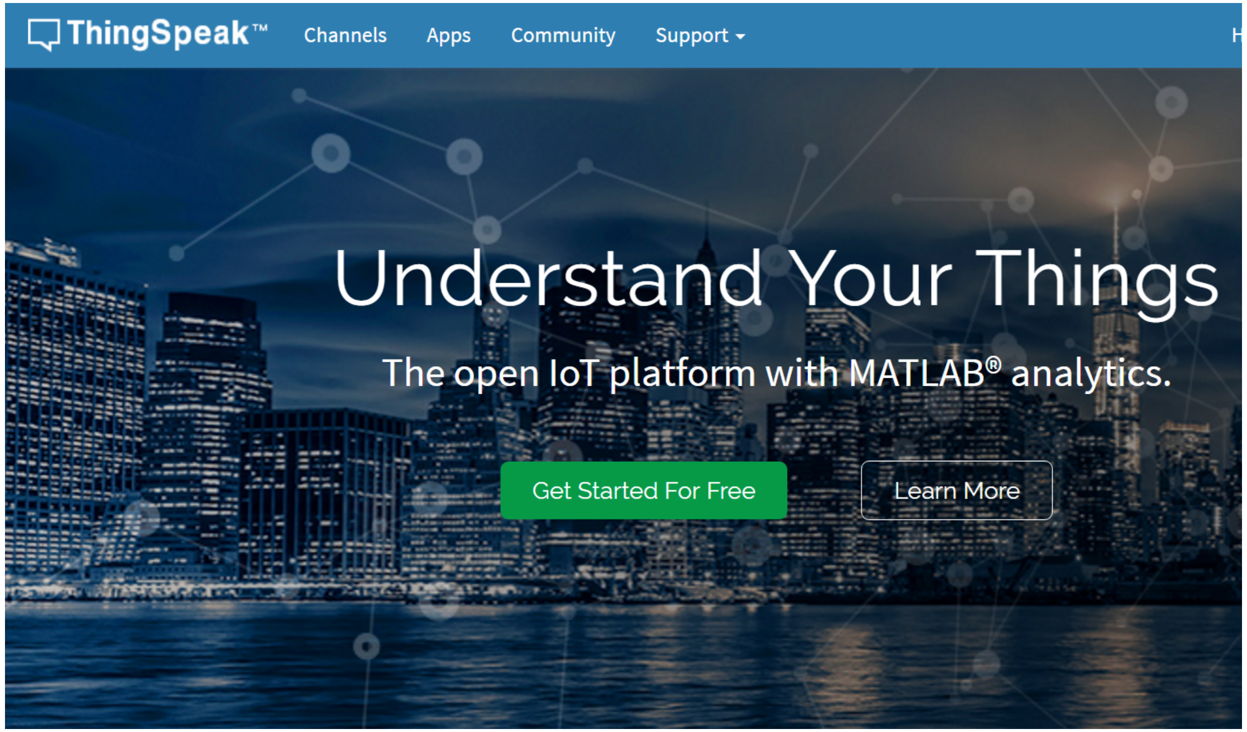
- Real-time analytics integrated with enterprise service systems
- Predict sub-system performance (oil, fuel, liftoff, mechanical health, controls)
- Improve aircraft availability and reduce maintenance costs

Cloud-based wheeze analysis

- Medical device to monitor and manage asthma and COPD
- Leverages analytics in cloud and embedded system

What Is ThingSpeak?

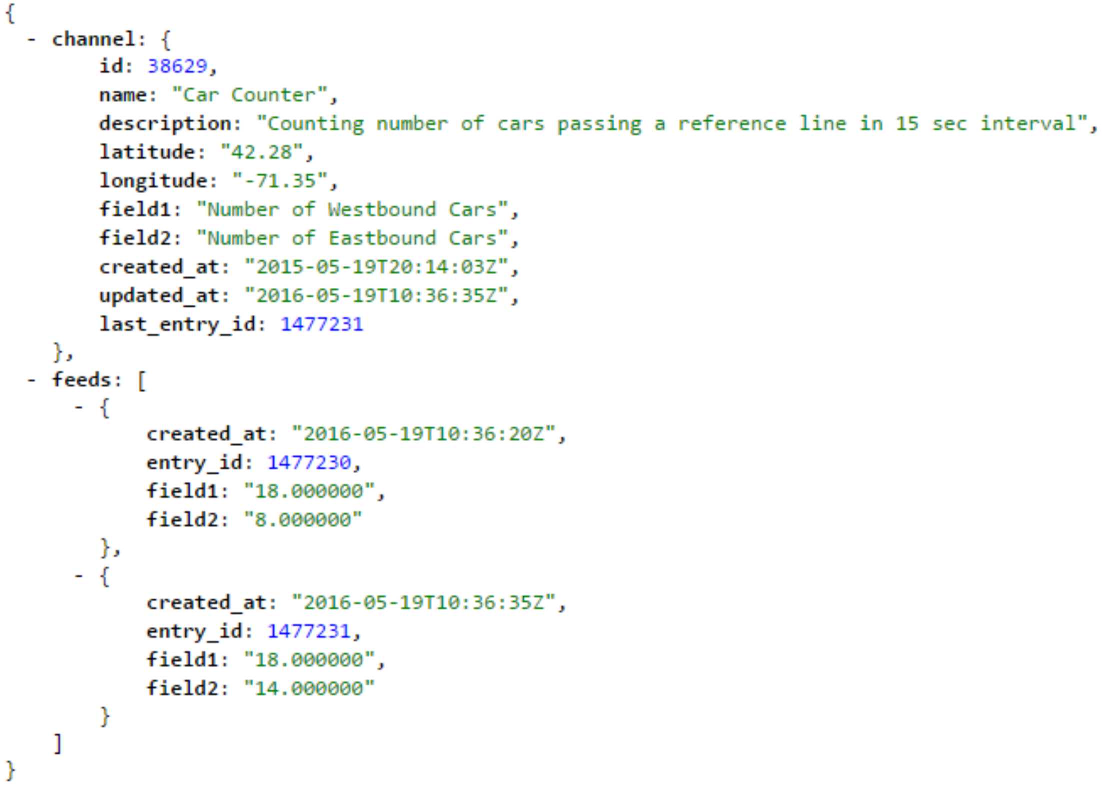
Web Site For People



Understand Your Things

The open IoT platform with MATLAB® analytics.

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

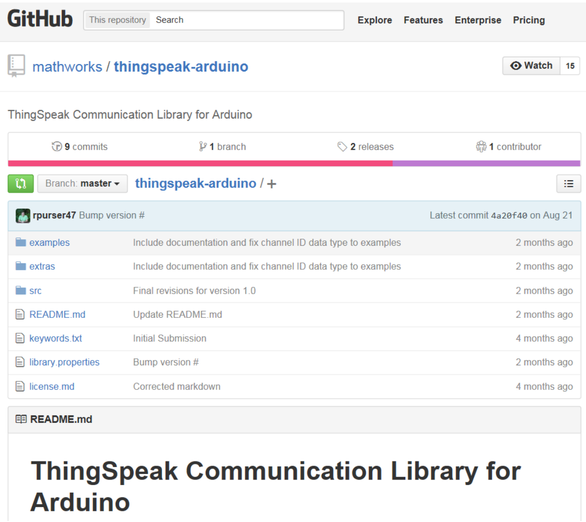
- New MathWorks web service hosted on AWS
- Lets you collect, analyze and act on data from “things”
- Over 130,000 users worldwide
- It has MATLAB for IoT Analytics
- It’s free to get started

https://thingspeak.com

Collect Analyze Act

Getting data into ThingSpeak

- Rest API
- MQTT API
- Native Libraries
  - Arduino
  - Particle
- Simulink Support Packages
  - Raspberry Pi
  - Arduino
  - BeagleBone Black
  - iPhone
  - Android



mathworks / thingspeak-arduino

ThingSpeak Communication Library for Arduino

9 commits | 1 branch | 2 releases | 1 contributor

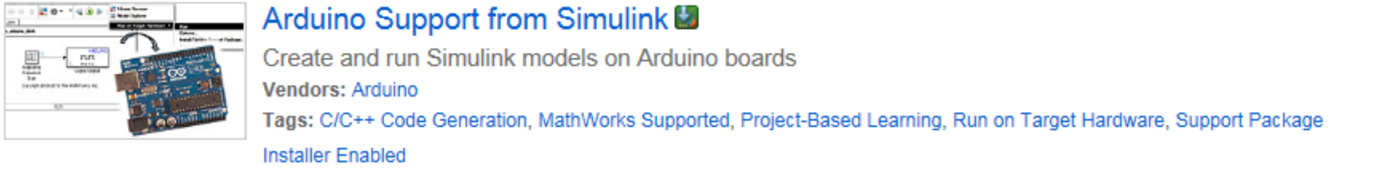
Branch: master | thingspeak-arduino / +

rpurser47 Bump version # — Latest commit 4a20f40 on Aug 21

examples	Include documentation and fix channel ID data type to examples	2 months ago
extras	Include documentation and fix channel ID data type to examples	2 months ago
src	Final revisions for version 1.0	2 months ago
README.md	Update README.md	2 months ago
keywords.txt	Initial Submission	4 months ago
library.properties	Bump version #	2 months ago
license.md	Corrected markdown	4 months ago

README.md

ThingSpeak Communication Library for Arduino

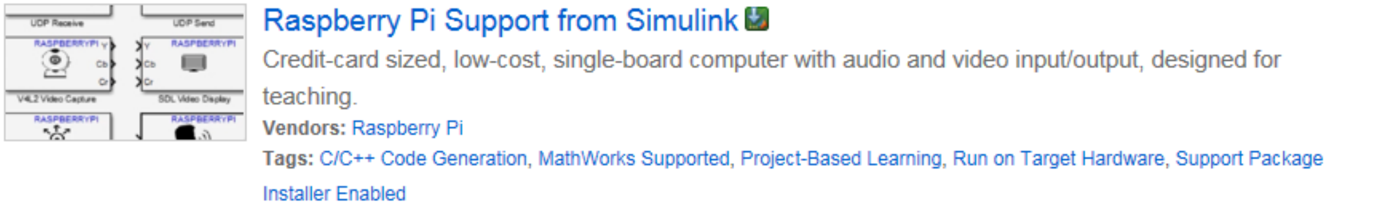


Arduino Support from Simulink

Create and run Simulink models on Arduino boards

Vendors: Arduino

Tags: C/C++ Code Generation, MathWorks Supported, Project-Based Learning, Run on Target Hardware, Support Package Installer Enabled



Raspberry Pi Support from Simulink

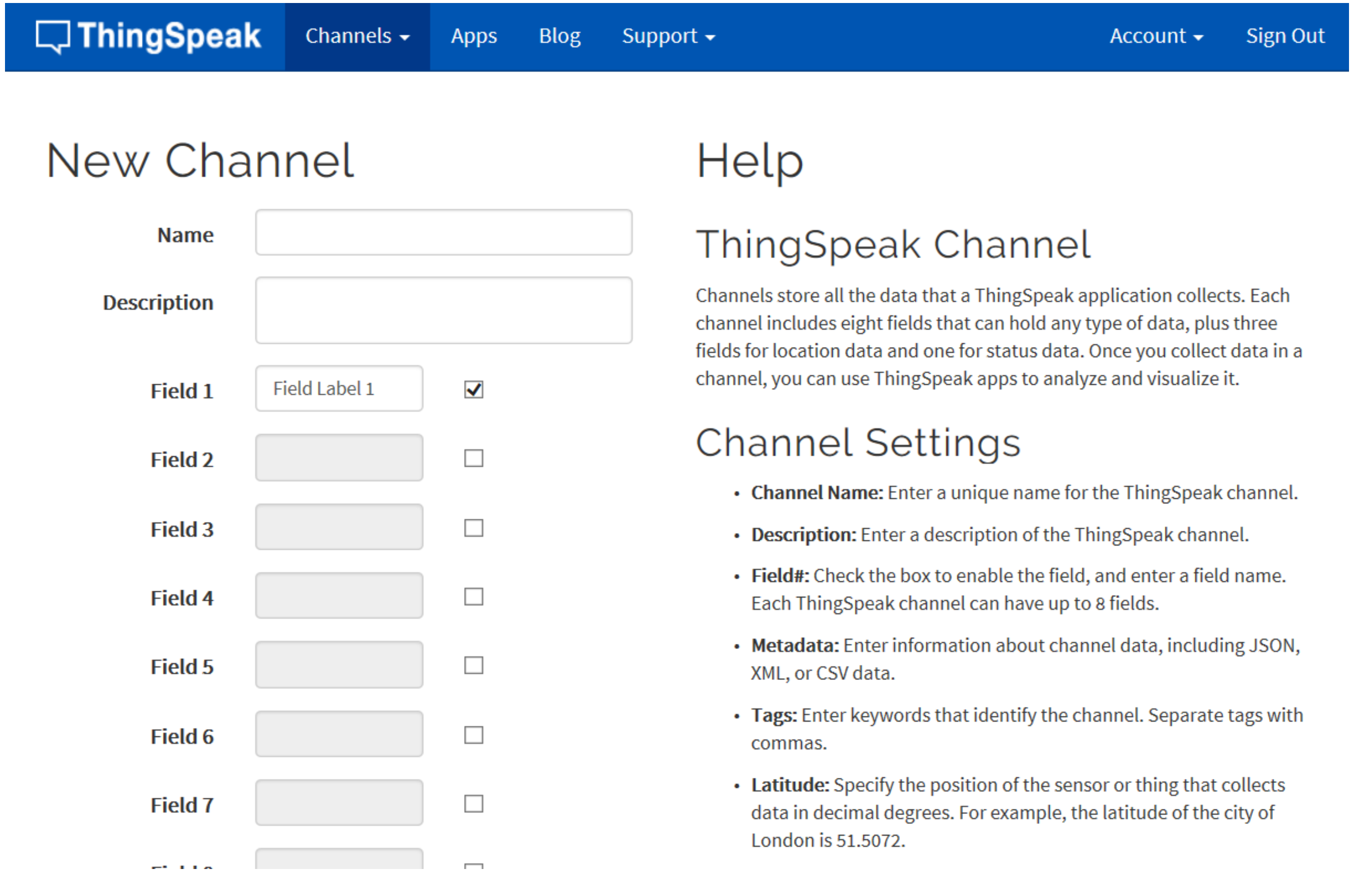
Credit-card sized, low-cost, single-board computer with audio and video input/output, designed for teaching.

Vendors: Raspberry Pi

Tags: C/C++ Code Generation, MathWorks Supported, Project-Based Learning, Run on Target Hardware, Support Package Installer Enabled

Getting data into ThingSpeak

- For any new data, first login and create a channel in ThingSpeak
- Channels have read and write API keys and can be public or private
- A channel is made up of 8 fields and can store 8 streams of data (Temp, Humidity, etc.)
- Channels can be updated at a maximum rate of once every 15 seconds (free) or 1 second (paid)



New Channel

Name		
Description		
Field 1	Field Label 1	☑
Field 2		□
Field 3		□
Field 4		□
Field 5		□
Field 6		□
Field 7		□

Help

ThingSpeak Channel

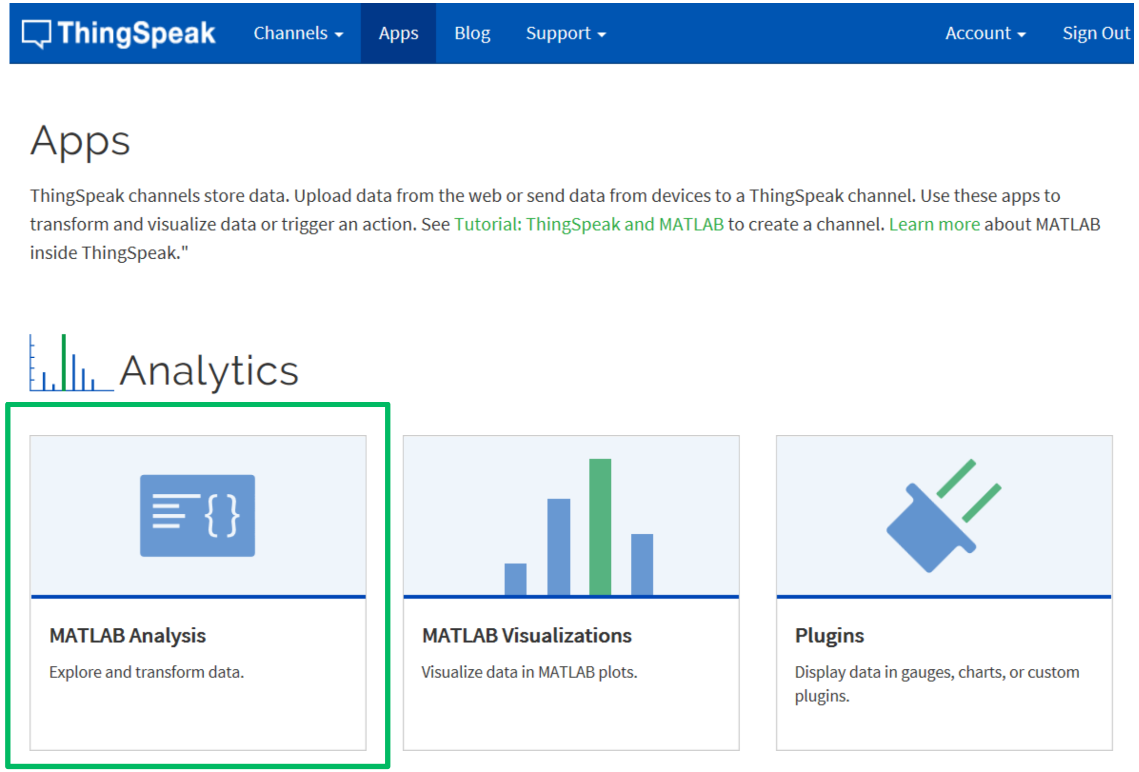
Channels store all the data that a ThingSpeak application collects. Each channel includes eight fields that can hold any type of data, plus three fields for location data and one for status data. Once you collect data in a channel, you can use ThingSpeak apps to analyze and visualize it.

Channel Settings

- **Channel Name:** Enter a unique name for the ThingSpeak channel.
- **Description:** Enter a description of the ThingSpeak channel.
- **Field#:** Check the box to enable the field, and enter a field name. Each ThingSpeak channel can have up to 8 fields.
- **Metadata:** Enter information about channel data, including JSON, XML, or CSV data.
- **Tags:** Enter keywords that identify the channel. Separate tags with commas.
- **Latitude:** Specify the position of the sensor or thing that collects data in decimal degrees. For example, the latitude of the city of London is 51.5072.

ThingSpeak: Custom Analysis with MATLAB Analysis App

- ThingSpeak is integrated with MATLAB in the Cloud
- Use the Apps Tab to use MATLAB inside ThingSpeak



Apps

ThingSpeak channels store data. Upload data from the web or send data from devices to a ThingSpeak channel. Use these apps to transform and visualize data or trigger an action. See Tutorial: ThingSpeak and MATLAB to create a channel. Learn more about MATLAB inside ThingSpeak."

Analytics

MATLAB Analysis

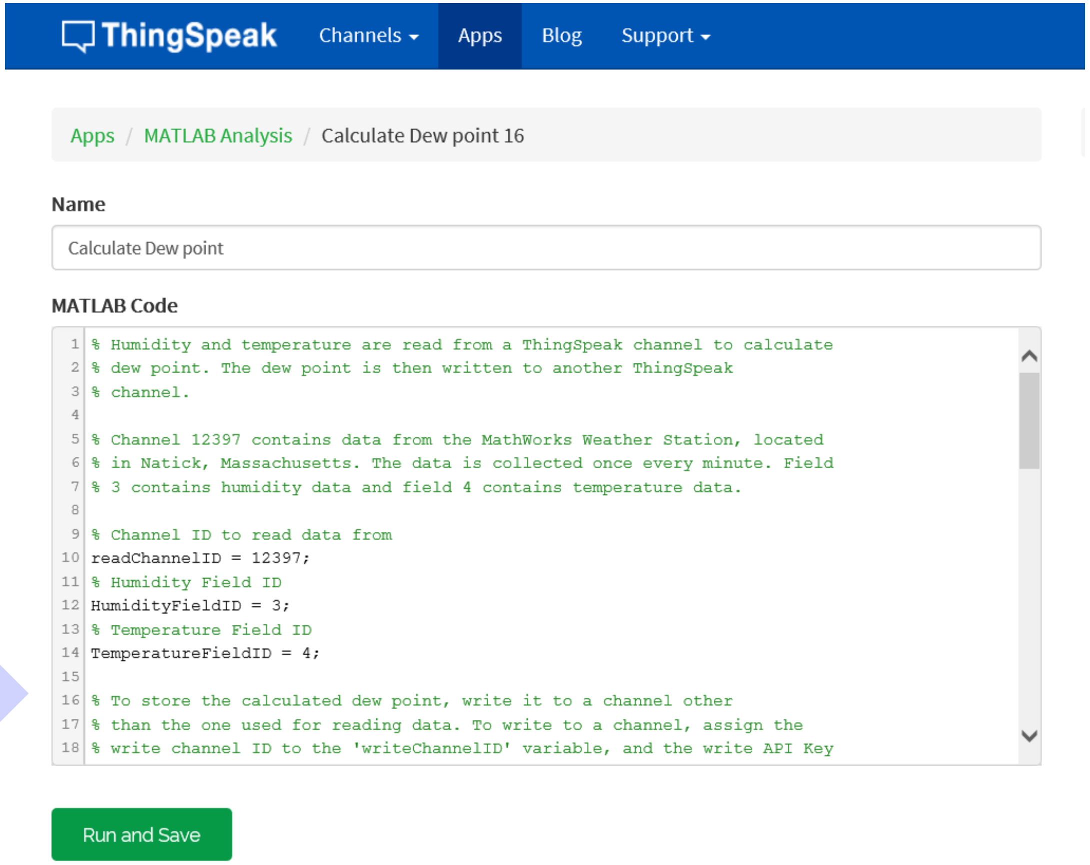
Explore and transform data.

MATLAB Visualizations

Visualize data in MATLAB plots.

Plugins

Display data in gauges, charts, or custom plugins.



Apps / MATLAB Analysis / Calculate Dew point 16

Name

Calculate Dew point

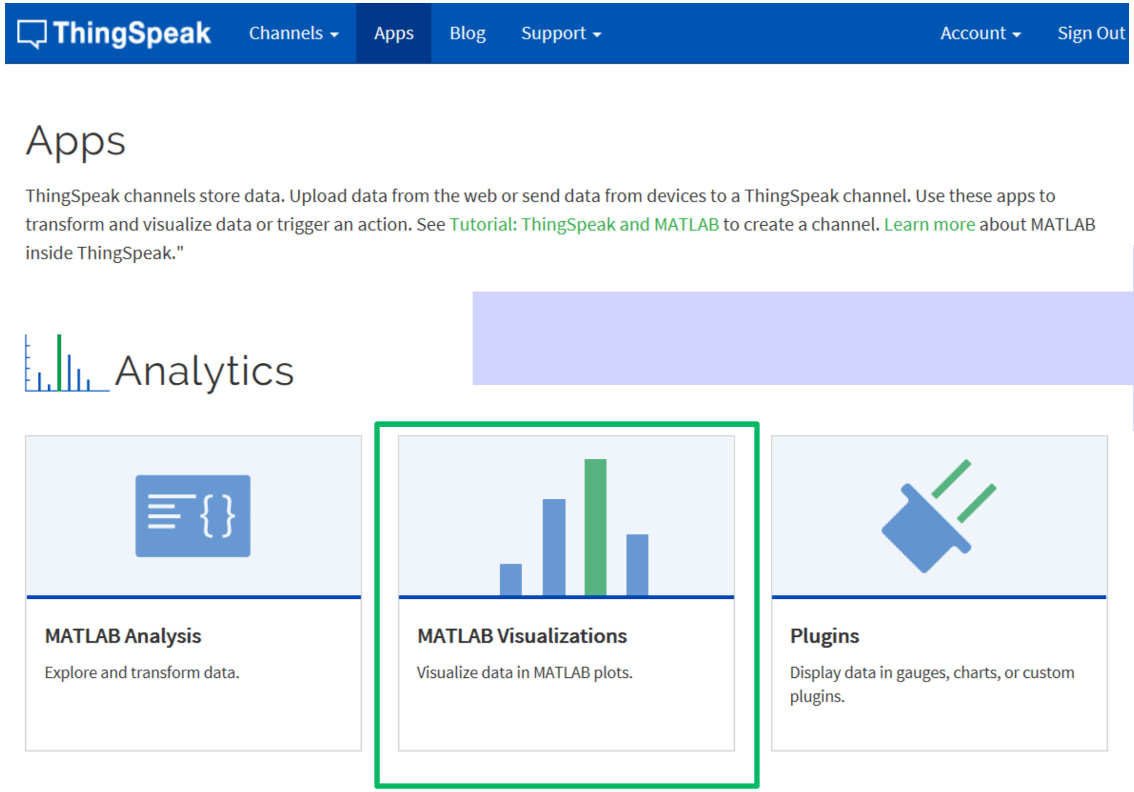
MATLAB Code

```
% Humidity and temperature are read from a ThingSpeak channel to calculate
% dew point. The dew point is then written to another ThingSpeak
% channel.

% Channel 12397 contains data from the MathWorks Weather Station, located
% in Natick, Massachusetts. The data is collected once every minute. Field
% 3 contains humidity data and field 4 contains temperature data.

% Channel ID to read data from
readChannelID = 12397;
% Humidity Field ID
HumidityFieldID = 3;
% Temperature Field ID
TemperatureFieldID = 4;

% To store the calculated dew point, write it to a channel other
% than the one used for reading data. To write to a channel, assign the
% write channel ID to the 'writeChannelID' variable, and the write API Key
```

MATLAB Toolbox Access

- Statistics and Machine Learning Toolbox™
- Curve Fitting Toolbox™
- Control System Toolbox™
- Signal Processing Toolbox™
- Mapping Toolbox™
- System Identification Toolbox™
- Neural Network Toolbox™
- DSP System Toolbox™
- Datafeed Toolbox™
- Financial Toolbox™
- Image Processing Toolbox
- Text Analytics Toolbox

ThingSpeak: Custom Visualization with MATLAB Visualizations Apps



Apps

ThingSpeak channels store data. Upload data from the web or send data from devices to a ThingSpeak channel. Use these apps to transform and visualize data or trigger an action. See Tutorial: ThingSpeak and MATLAB to create a channel. Learn more about MATLAB inside ThingSpeak."

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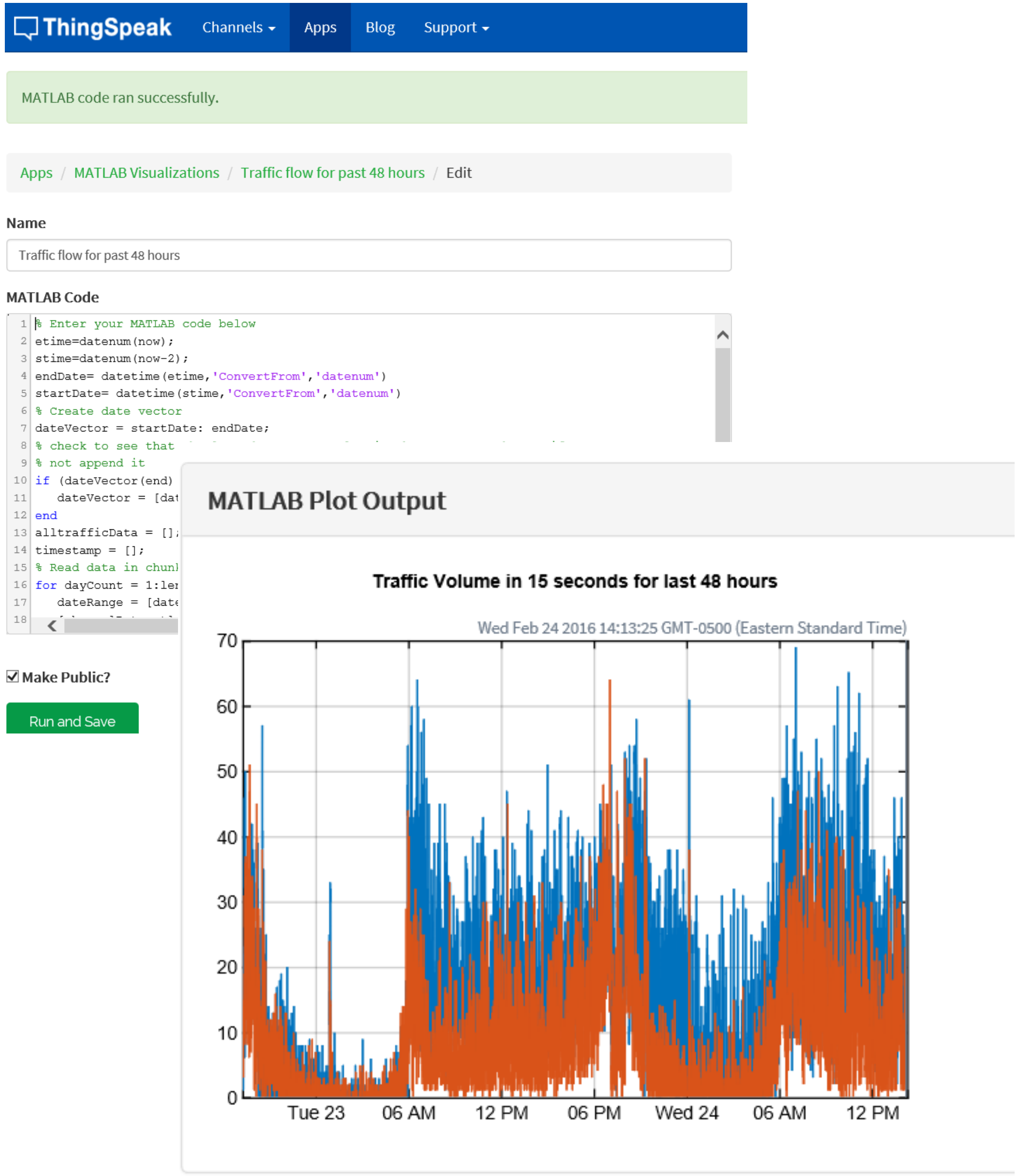


MATLAB code ran successfully.

Apps / MATLAB Visualizations / Traffic flow for past 48 hours / Edit

Name

Traffic flow for past 48 hours

MATLAB Code

```
% Enter your MATLAB code below
etime=datenum(now);
stime=datenum(now-2);
endDate= datetime(etime,'ConvertFrom','datenum')
startDate= datetime(stime,'ConvertFrom','datenum')
% Create date vector
dateVector = startDate: endDate;
% check to see that
% not append it
if (dateVector(end)
   dateVector = [dat
end
alltrafficData = [];
timestamp = [];
% Read data in chunl
for dayCount = 1:ler
   dateRange = [date
```

☑ Make Public?

Run and Save

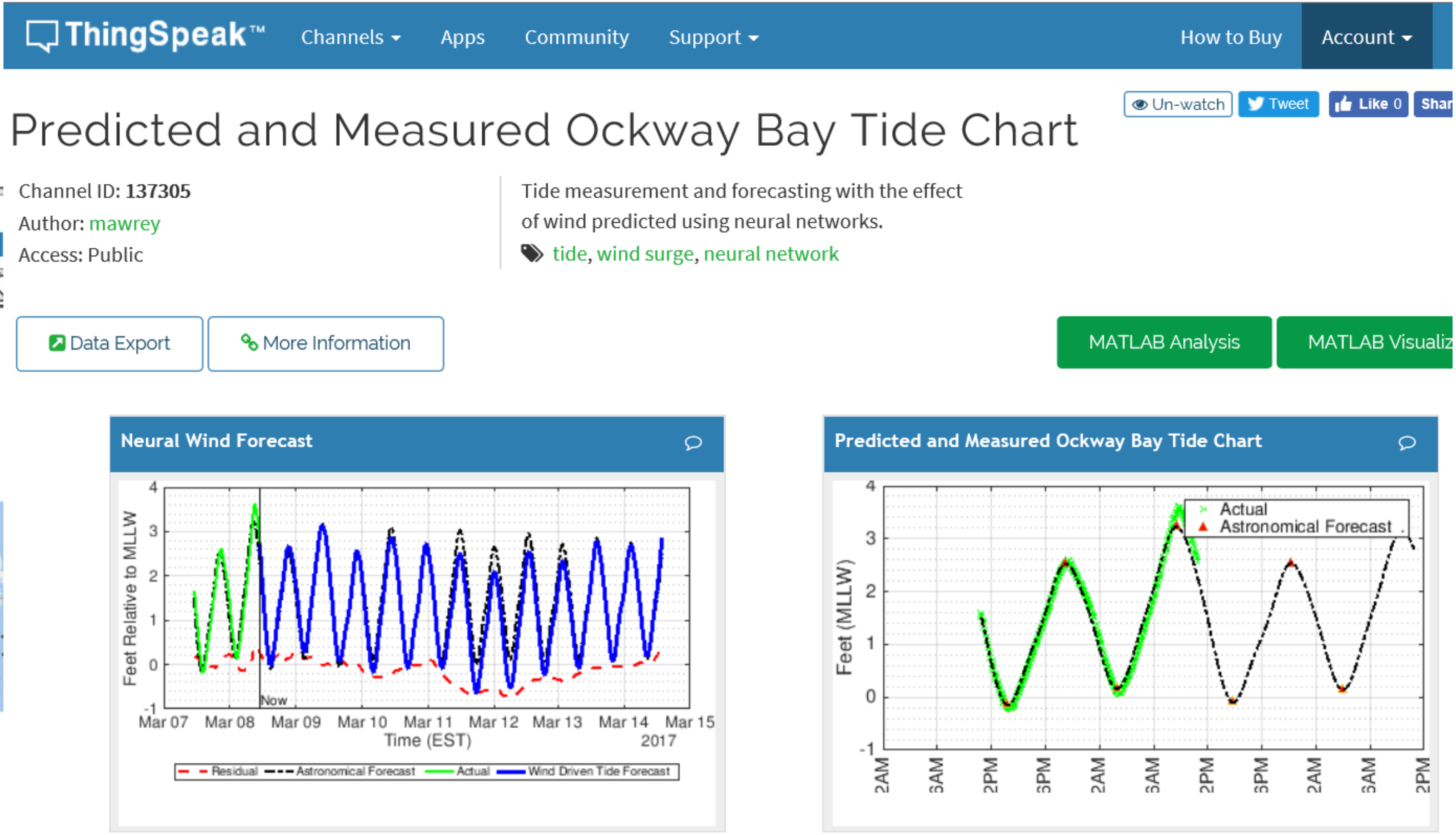
MATLAB Plot Output

Traffic Volume in 15 seconds for last 48 hours

Wed Feb 24 2016 14:13:25 GMT-0500 (Eastern Standard Time)

Predictive Analytics Example with ThingSpeak

Historical Wind and Tide Data



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.

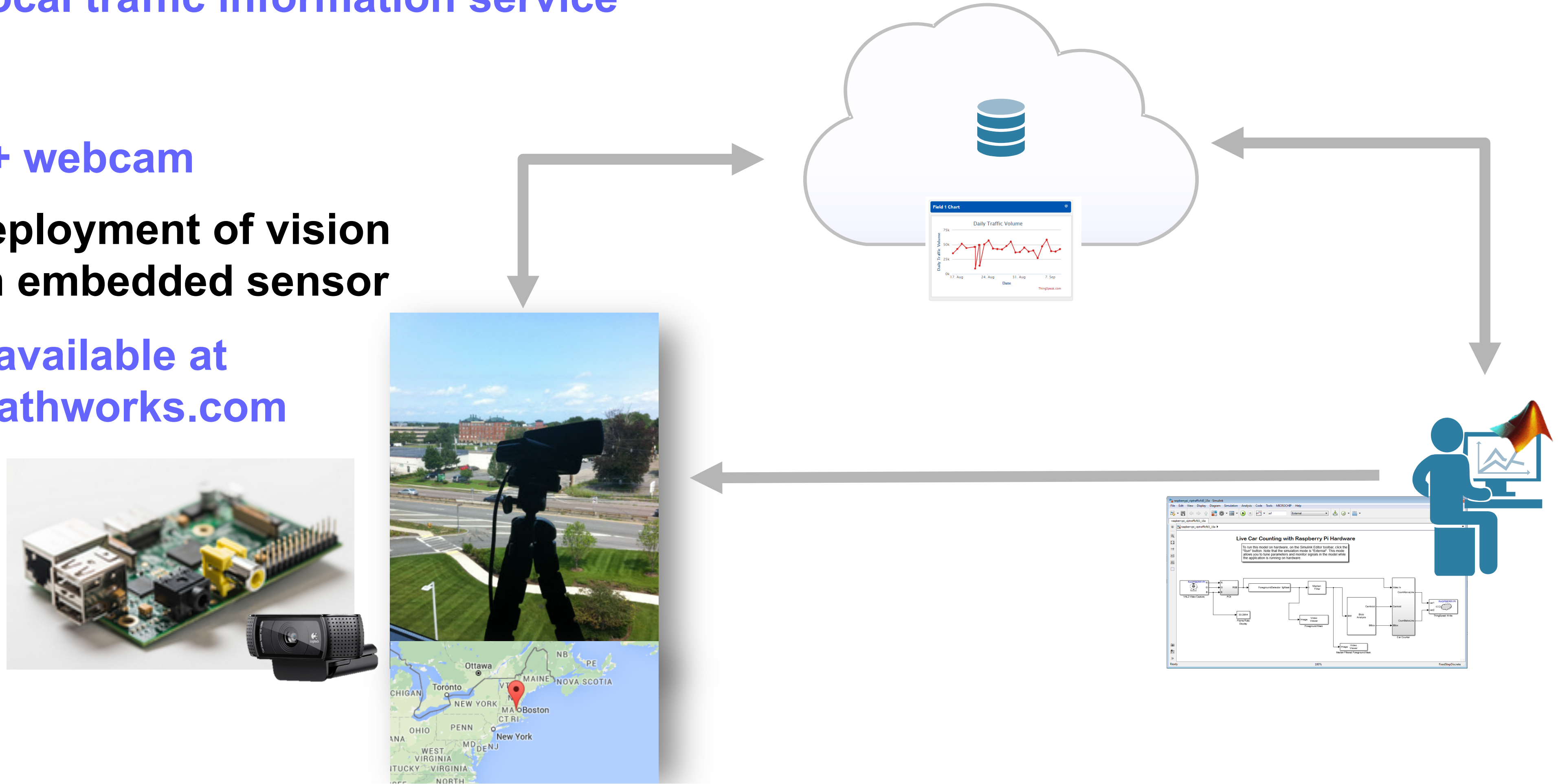
tide, wind surge, neural network

Neural Wind Forecast

Predicted and Measured Ockway Bay Tide Chart

Monitoring Traffic

- **Objectives**
  - Measure, explore, discover traffic patterns
  - Provide live local traffic information service
- **Solution**
  - RaspberryPi + webcam
  - Automated deployment of vision algorithms on embedded sensor
  - Full example available at makerzone.mathworks.com



raspberrypi_viptrafficfd3_15a - Simulink

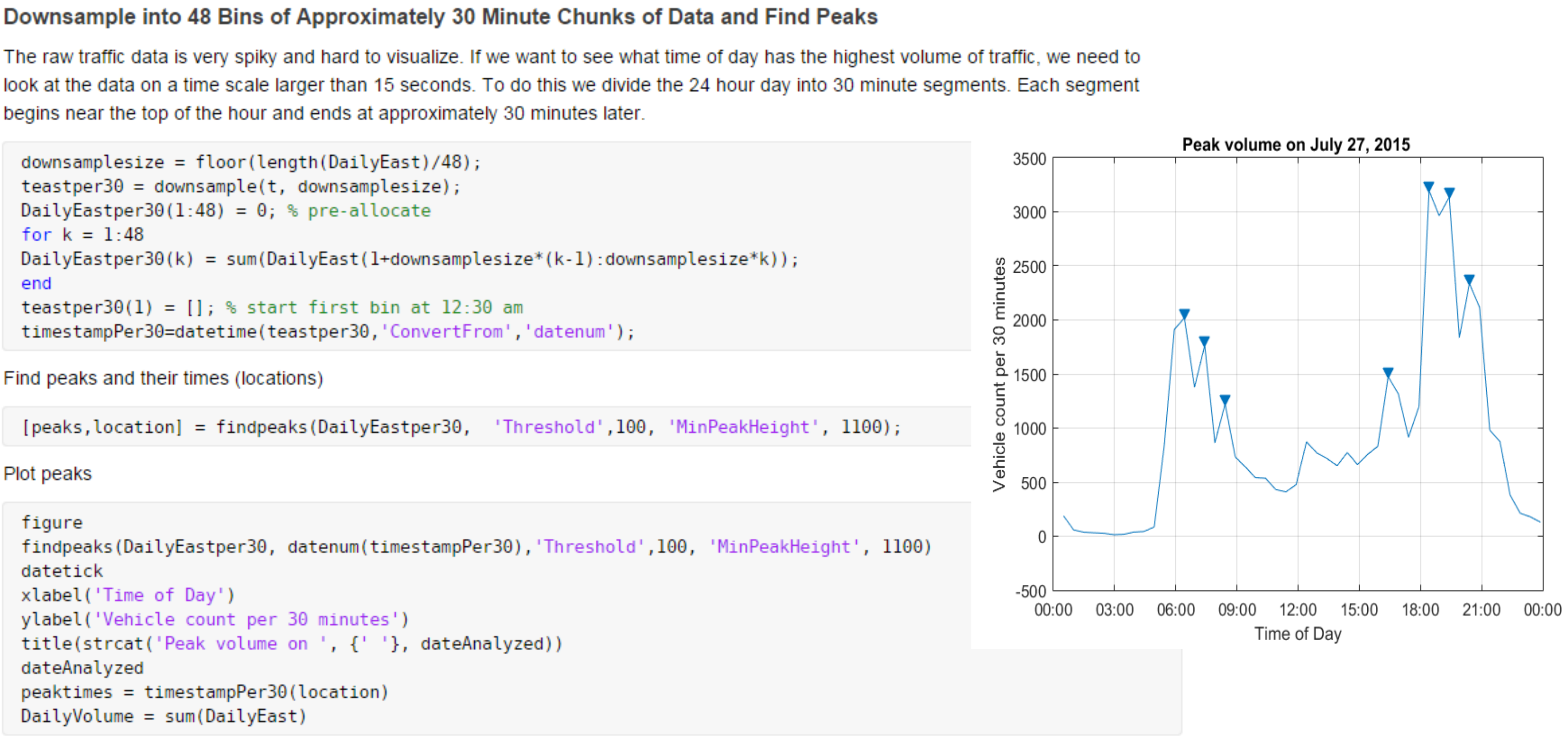
File Edit View Display Diagram Simulation Analysis Code Tools MICROCHIP Help

inf External

Live Car Counting with Raspberry Pi Hardware

To run this model on hardware, on the Simulink Editor toolbar, click the "Run" button. Note that the simulation mode is "External". This mode allows you to tune parameters and monitor signals in the model while the application is running on hardware.

From Offline Analysis to Online Analysis on the Cloud



Downsample into 48 Bins of Approximately 30 Minute Chunks of Data and Find Peaks

The raw traffic data is very spiky and hard to visualize. If we want to see what time of day has the highest volume of traffic, we need to look at the data on a time scale larger than 15 seconds. To do this we divide the 24 hour day into 30 minute segments. Each segment begins near the top of the hour and ends at approximately 30 minutes later.

```
downsamplesize = floor(length(DailyEast)/48);
teastper30 = downsample(t, downsamplesize);
DailyEastper30(1:48) = 0; % pre-allocate
for k = 1:48
DailyEastper30(k) = sum(DailyEast(1+downsamplesize*(k-1):downsamplesize*k));
end
teastper30(1) = []; % start first bin at 12:30 am
timestampPer30=datetime(teastper30,'ConvertFrom','datenum');
```

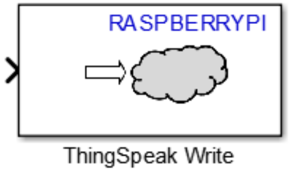
Find peaks and their times (locations)

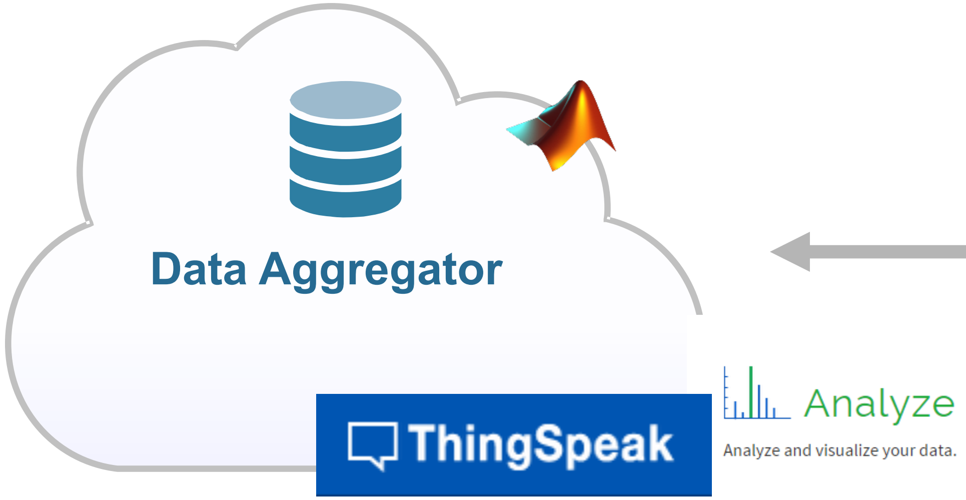
```
[peaks,location] = findpeaks(DailyEastper30,  'Threshold',100, 'MinPeakHeight', 1100);
```

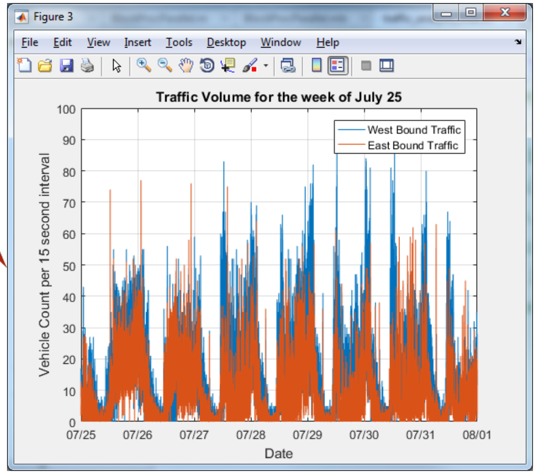
Plot peaks

```
figure
findpeaks(DailyEastper30, datenum(timestampPer30),'Threshold',100, 'MinPeakHeight', 1100)
datetick
xlabel('Time of Day')
ylabel('Vehicle count per 30 minutes')
title(strcat('Peak volume on ', {' '}, dateAnalyzed))
dateAnalyzed
peaktimes = timestampPer30(location)
DailyVolume = sum(DailyEast)
```

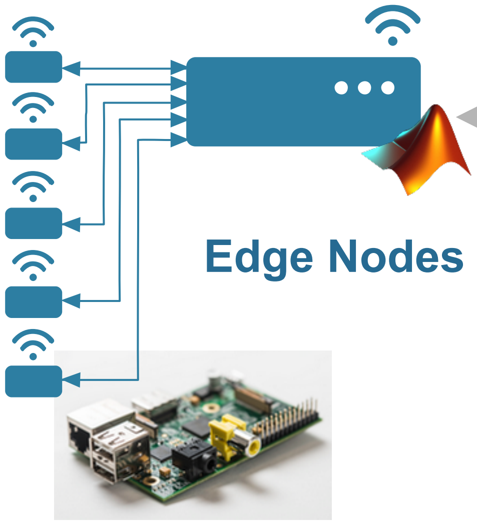
IoT Solutions Examples



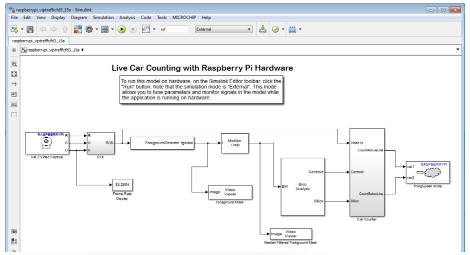




```
thingSpeakRead(12397,'Fiel
```

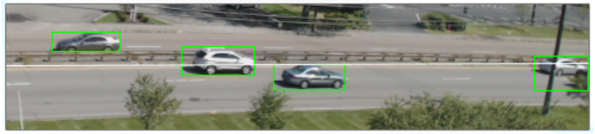


Edge Nodes


raspberrypi_viptrafficfd3_15a - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools MICROCHIP Help
inf
External
raspberrypi_viptrafficfd3_15a

Live Car Counting with Raspberry Pi Hardware

To run this model on hardware, on the Simulink Editor toolbar, click the "Run" button. Note that the simulation mode is "External". This mode allows you to tune parameters and monitor signals in the model while the application is running on hardware.



Exploratory Analysis

- Historical analytics
- Algorithm development

MATLAB & Simulink Capabilities for IoT

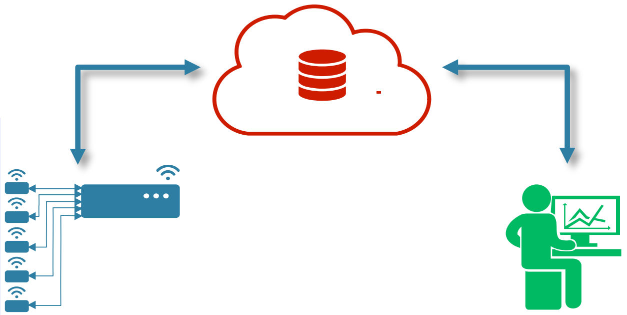
Deployment
- .NET, COM components
- Java components
- Multicore and GPU systems
- Spreadsheet plug-ins
- Database plug-ins
- Hadoop
- Cloud services (AWS)
- ThingSpeak Apps
- Smartphone/tablet integration

File I/O
- Text
- Spreadsheet
- XML
- CDF/HDF
- Image
- Audio
- Video
- Geospatial
- Web content

Real-Time Sources
- Sensors
- GPS
- Instrumentation
- Cameras
- Communication systen
- Machines:
  - embedded system:
  - fieldbus
- Financial datafeeds

Repositories
- Databases (SQL)
- NoSQL
- Hadoop

Communication Protocols
- CAN
- DDS
- OPC
- XCP



Physical Component Modeling
- Electronic
- Mechanical
- Hydraulic, etc.

Communications Protocol Modeling
- LTE, Zigbee, 802.11, etc.

Automatic Code Generation
- Programmable chips (MCU, DSP, etc.)
- FPGAs

Verification/Validation and Process Support
- Model- and Code proving
- Lifecycle management tools

Data Clean-up
- Filtering
- Image processing
- Signal processing
- Telemetry
- RF sampling

nalysis, Modeling, Design

Data visualization

Statistics

Regression

Machine learning (supervised &unsupervised)

Neural networks

- Optimization (gradient-based & stochastic)
- Symbolic computing
- Image analysis
- Financial analysis
- Geospatial computing
- Object recognition
- Speech recognition

Summary

- **MATLAB and Simulink provide a broad range of capabilities for IoT**
  - Performing interactive and advanced analytics
  - Deploying analytics to production environments
  - Developing real-time systems, from sensing and control nodes to complex devices
  - Designing communications, including simulation and real-time connectivity
- **An open-system architecture**
  - User-extensible, with well-documented APIs
  - Can be integrated with third-party edge-node platforms, aggregators, and production IT systems