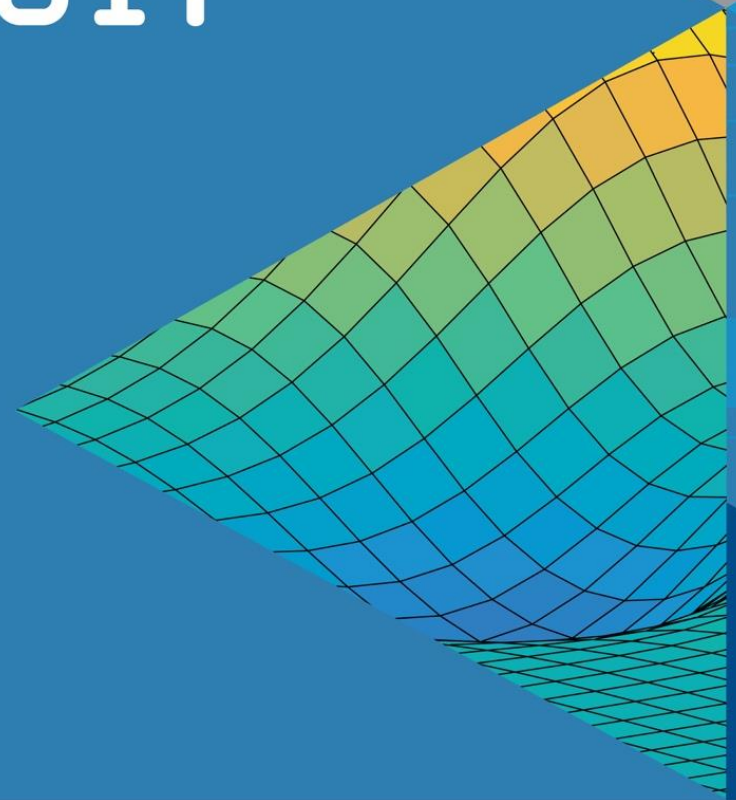
MATLAB EXPO 2017

Déploiement embarqué et connectivité hardware avec MATLAB et Simulink

Paul Cox, MathWorks

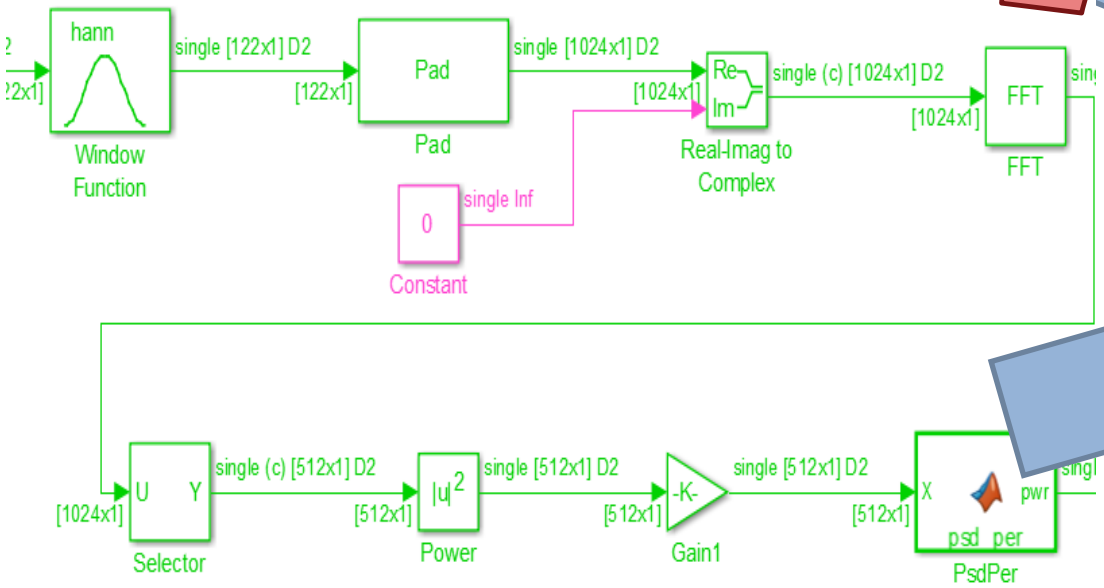


Agenda

- **Introduction**
- Hardware Support Packages for MATLAB and Simulink
- Processor-in-the-Loop Execution
- Code Generation within the Internet of Things (IoT)
- Conclusion
- Questions

From algorithm to hardware: why and how?

```
U = win'*win; % scalar,
% FFT
x = x.*win;   % n-by-1
X = fft(x,nfft); % comple
X = X(1:nfft/2+1); % (nf
Pxx = X.*conj(X)/U;
Pxx = 2*Pxx/fs; Pxx(1)
df = fs/nfft;
```



From MATLAB and Simulink to Hardware

Automatic Code Generation

C/C++

VHDL
Verilog

ST

CPU
DSP

ASIC
FPGA

PLC

Code Generation in Industry

ABB Accelerates the Delivery of Large-Scale, Grid-Connected Inverter Products with Model-Based Design

"Simulink and Embedded Coder enabled us to open the door to new markets. With increased productivity from extensive simulation and efficient code generation, we have confidence in our ability to produce the systems that larger customers are asking for in the time frames they want."

— *Dr. Robert Turner, ABB*

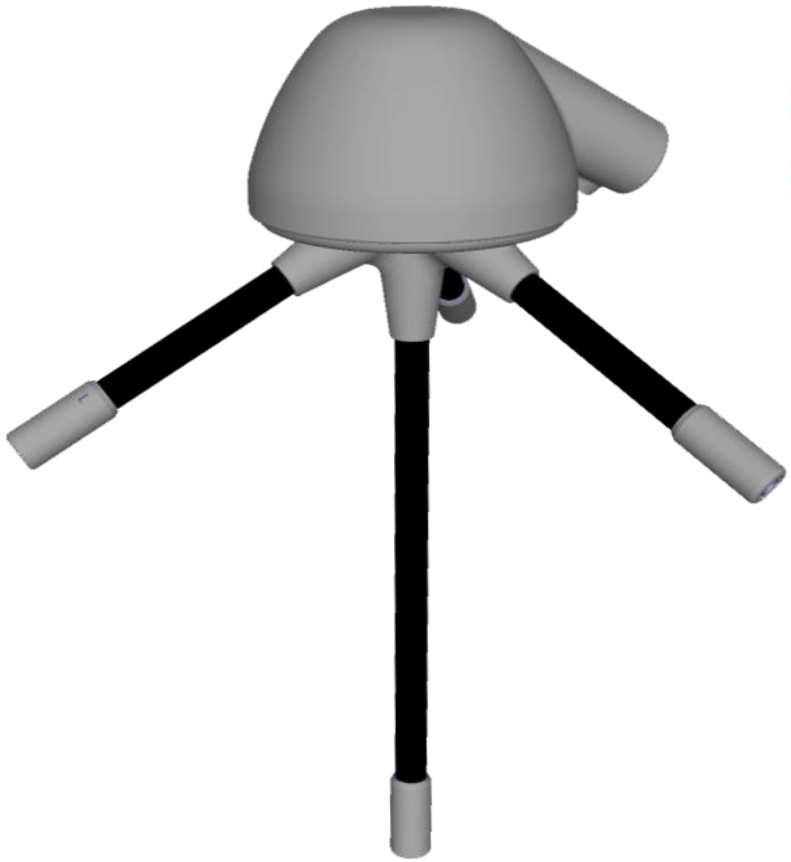
Code Generation in Academia

NASA Interns Develop Guidance, Navigation, and Control Software for Quadcopter with Model-Based Design

Model-Based Design makes both working engineers and interns at NASA MSFC more productive. The students have more fun because they can run the GNC algorithms they create in Simulink on a real processor and quickly get things done.

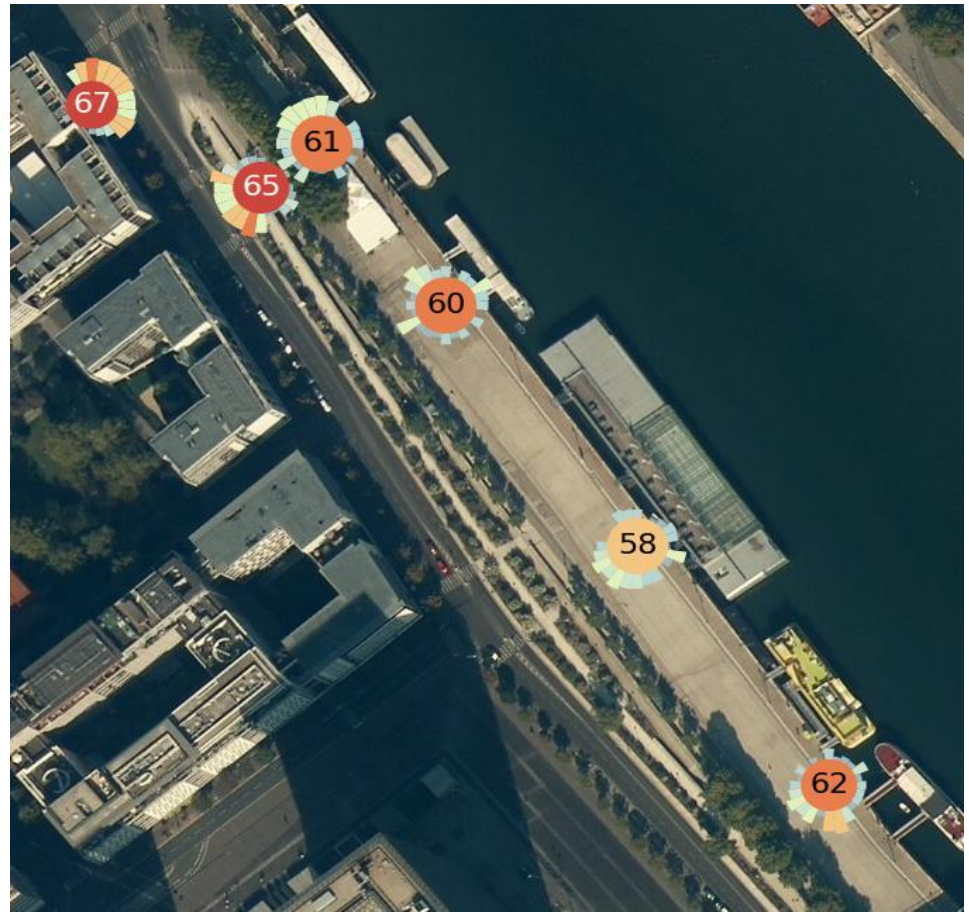
NASA intern working with the quadcopter vehicle and ArduPilot Mega 2.5 hardware.

Code Generation Case Study : Bruitparif Medusa
Noise monitoring distributed network



Bruitparif

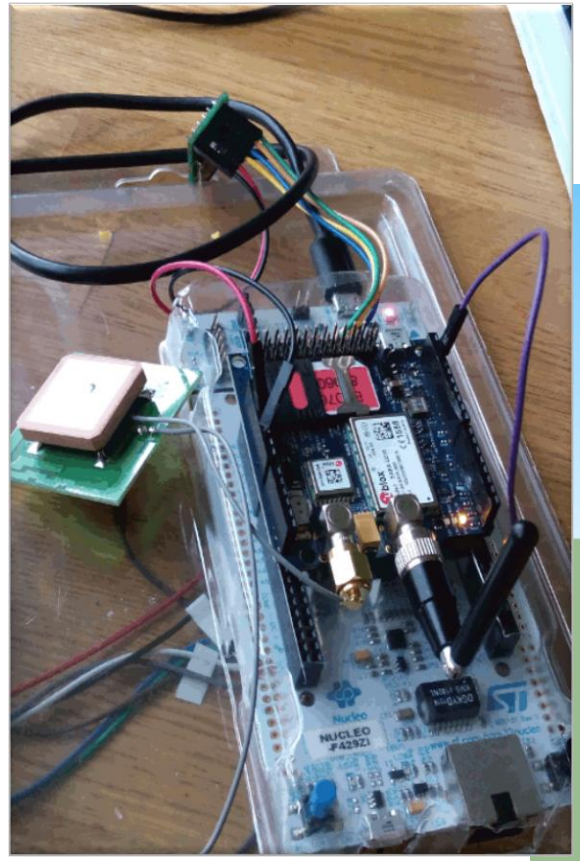
Observatoire du bruit

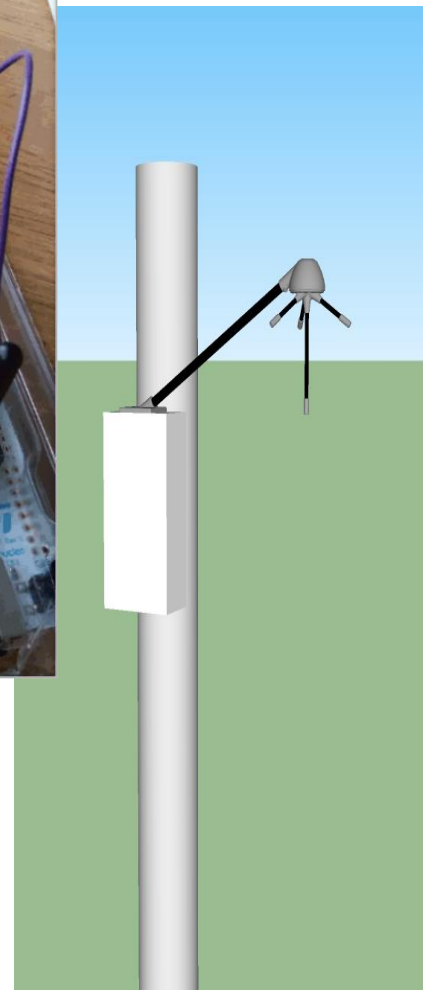


Code Generation Case Study : Bruitparif Medusa

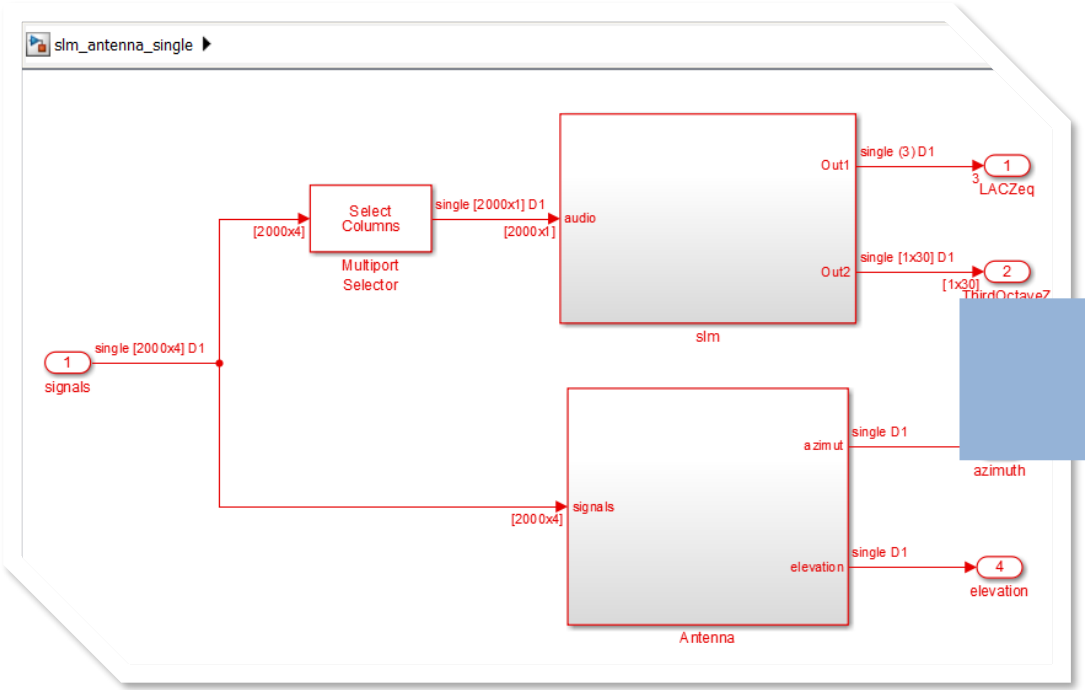
- **Requirements**
  - Monitor noise levels and directions
  - Send live data to a central server
  - Low-power consumption device (< 5 W)
  - Minimal network traffic (< 5 kbps)

- **Solution**
  - Low-power microcontroller (STM32F4)
  - UDP communication over cellular network
  - Algorithm development with MATLAB/Simulink
    - Design and feasibility/performance analysis
    - Preparation for embedded deployment
    - Automatic Production Code Generation with Embedded Coder
    - Low memory and CPU utilization





Bruitparif - Software



Total time (seconds × 1e-09)	1583320256
Measured time display options	('Units', 'Seconds', 'ScaleFactor', '1e-09', 'NumericFormat
Timer frequency (ticks per second)	1.68e+08
Profiling data created	19-Mar-2016 18:38:53

2. Profiled Sections of Code

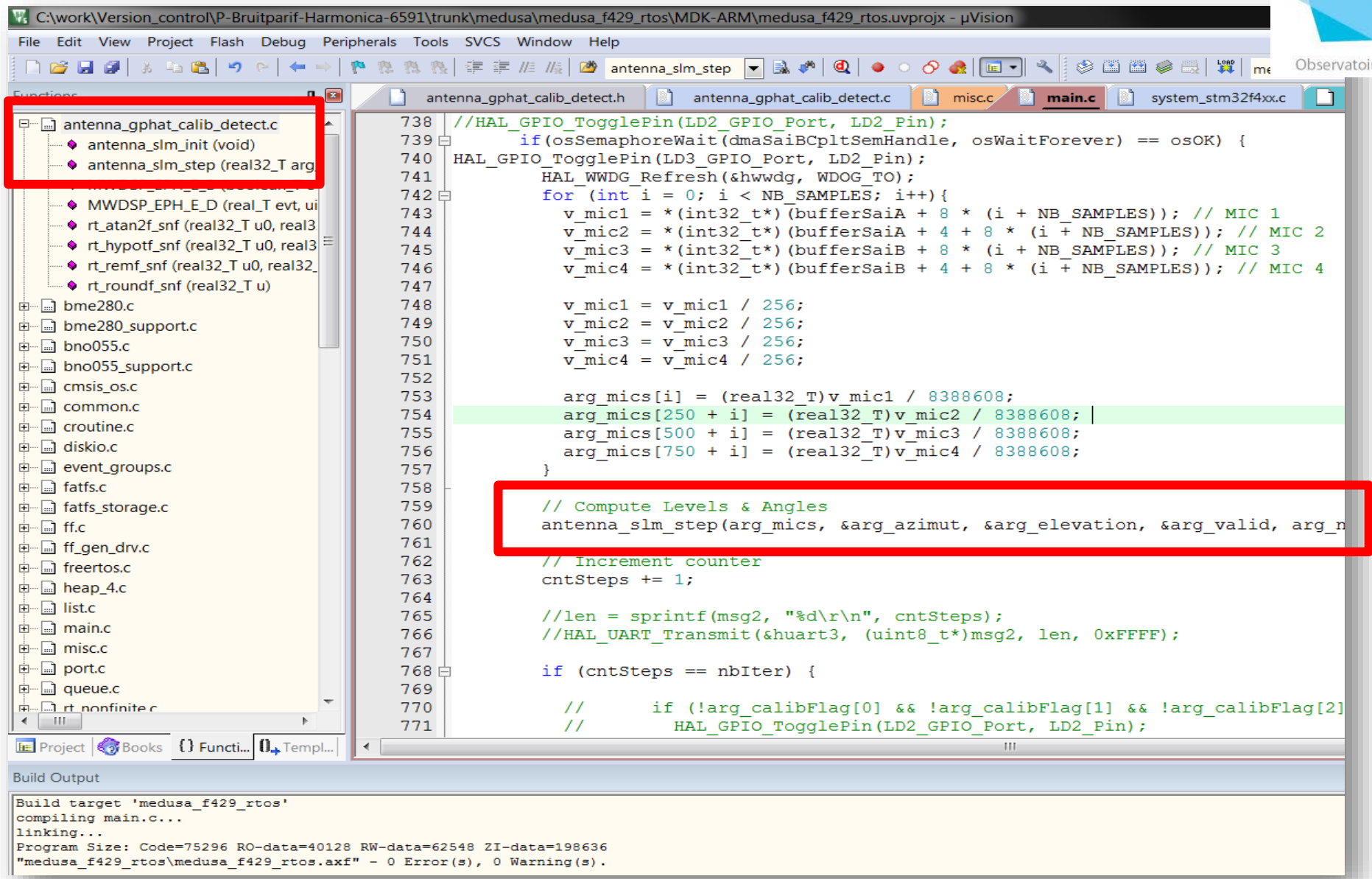
Section	Maximum Execution Time	Average Execution Time	Maximum Self Time	Average Self Time	Calls
bot_initialize	1060	1060	1060	1060	1
[+] bot_Init	47048	47048	32869	32869	1
[+] bot [0.015625 0]	5405875	5373712	1575119	1568924	129
Select mic	42530	42530	42530	42530	129
Generated Filter Block	85125	84842	85125	84842	129
Generated Filter Block	57113	57105	57113	57105	129
Math Function	26042	23352	26042	23352	129
Math Function1	26161	23760	26161	23760	129

1. Function replacements in bot [hide]

The following table provides a mapping from the functions used from the selected Code Rep
blocks in the model that triggered the replacement.

Function	Block
arm_biquad_cascade_df2T_f32	<S3>/Generated Filter Block <S4>/Generated Filter Block
arm_cfft_radix2_f32	<S8>/IFFT <S9>/IFFT

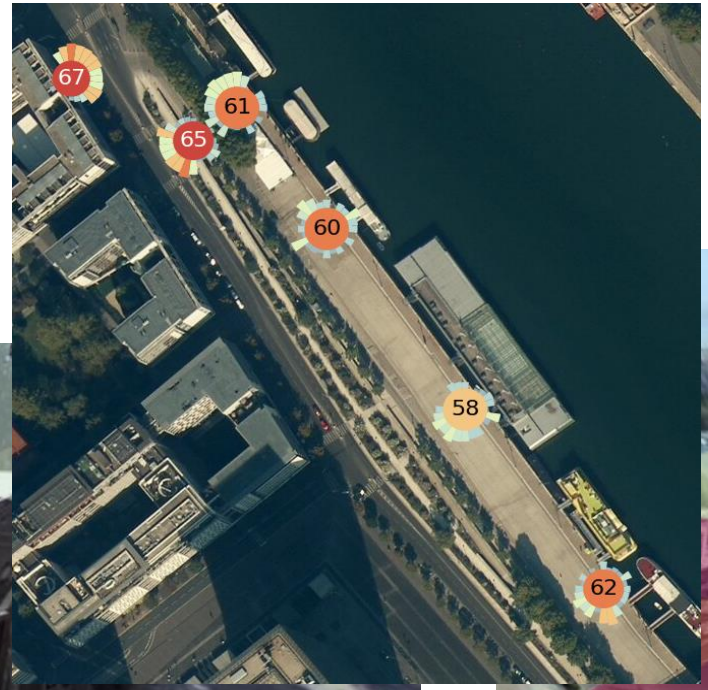
Bruitparif – Software (continued)

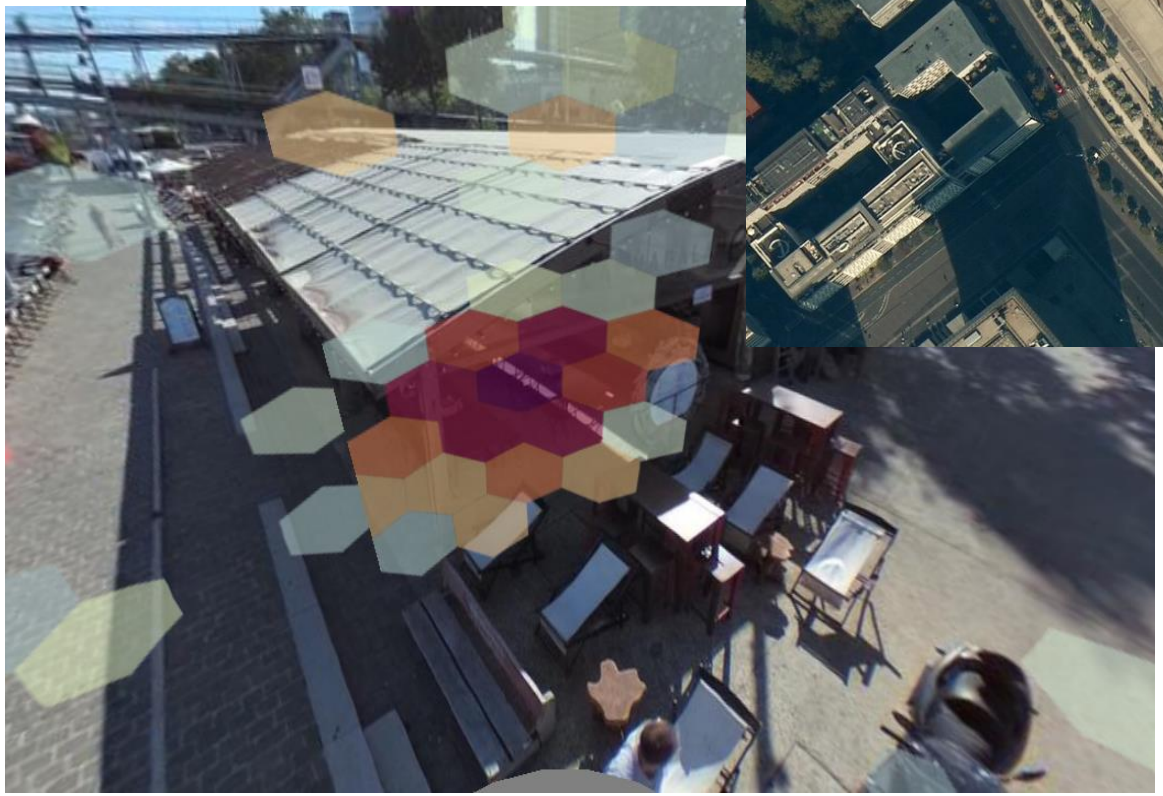


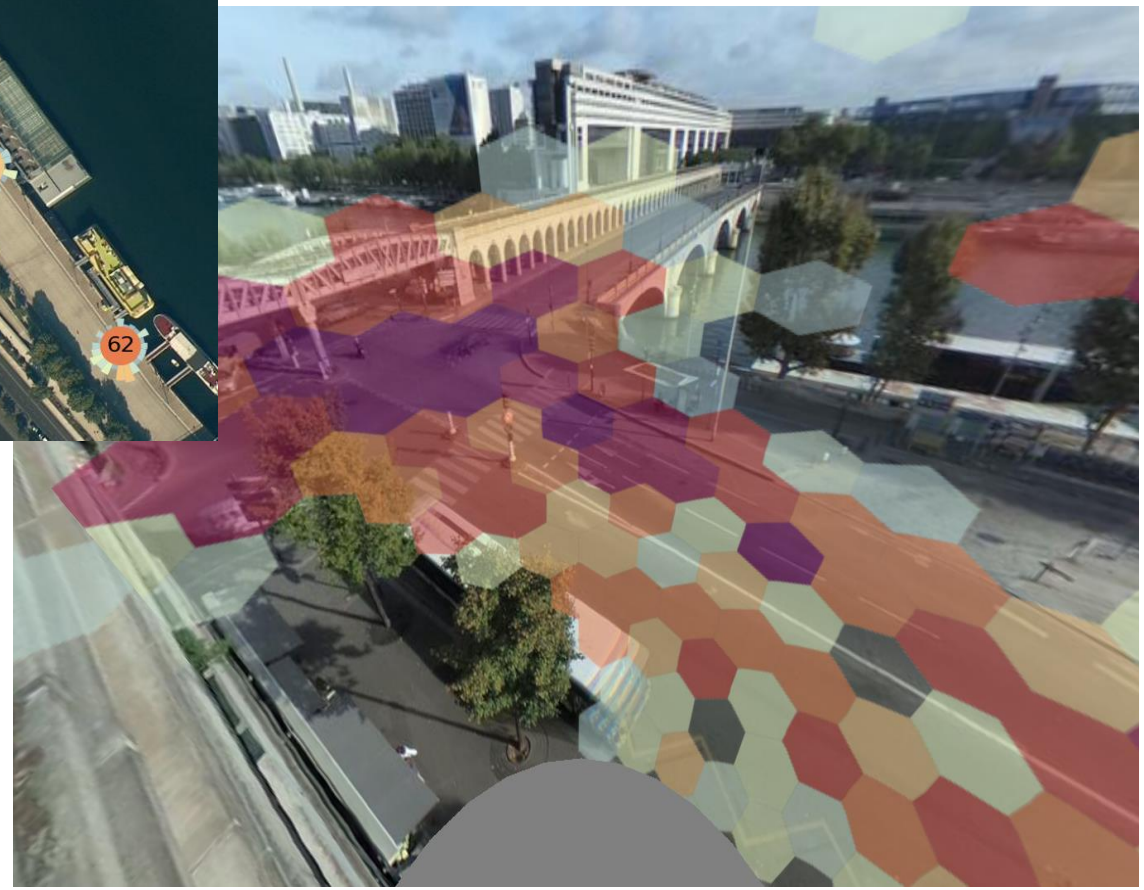
Automatic code generation in IoT network nodes

Source: Le Parisien

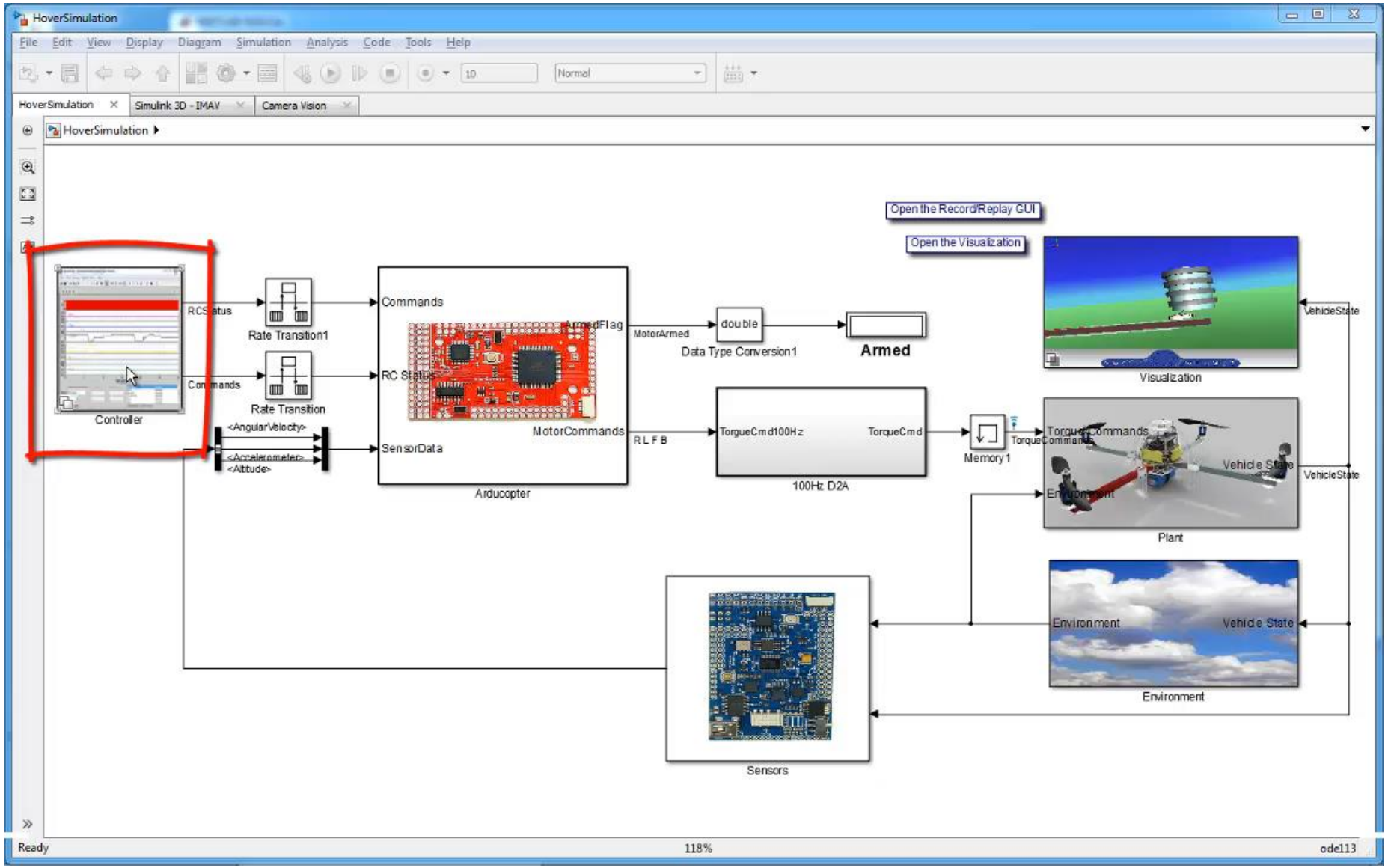
Bruitparif – Pilot Project Results



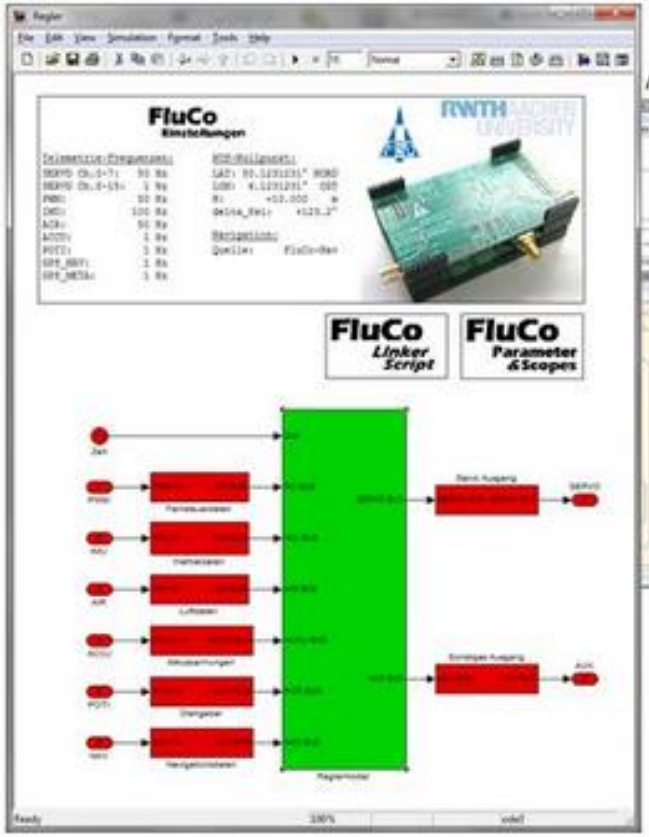


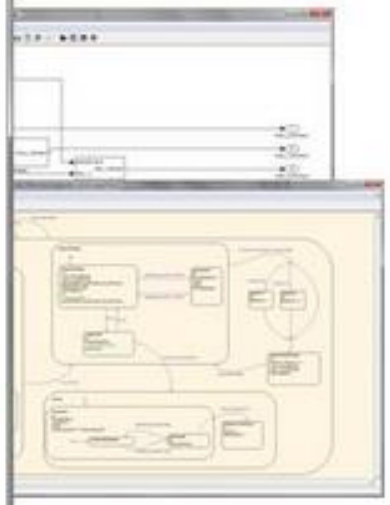


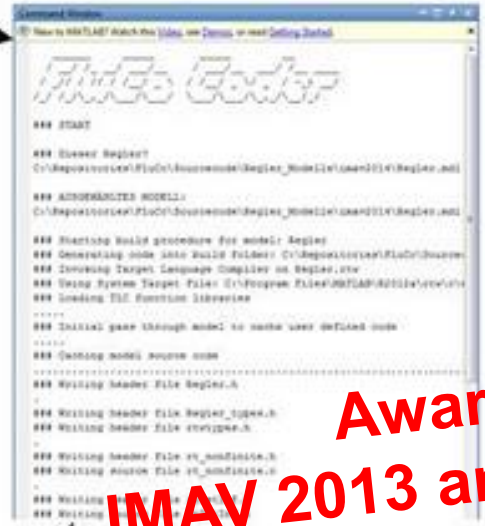
Before Code Generation: Modeling and Simulation

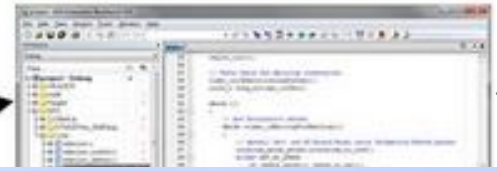


Code Generation for UAV Team MAVerix at student competition





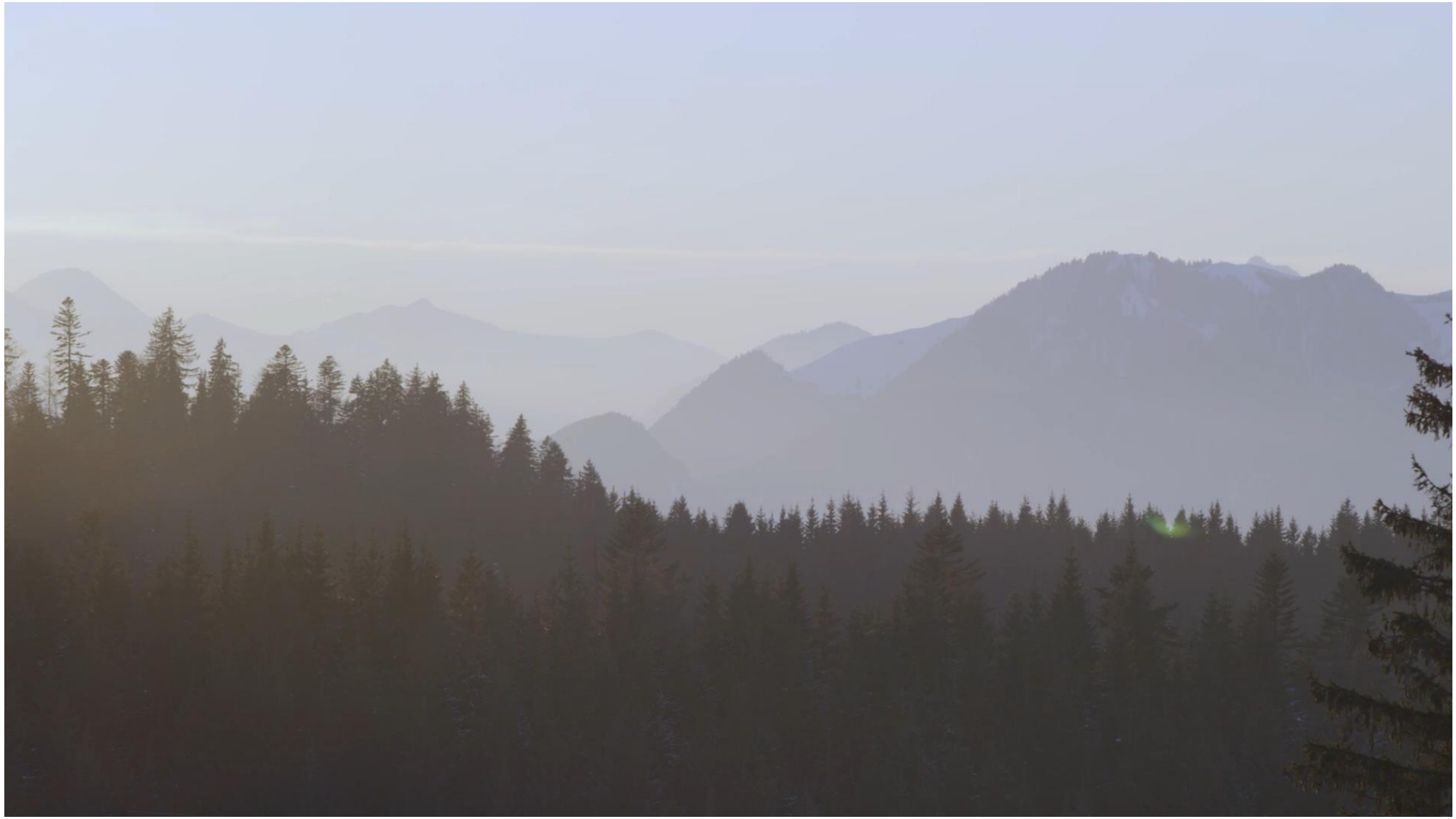




Awarded at
IMAV 2013 and IMAV 2014 !

2016: 8 km
DHL flight
tests !

MAVERIX
RWTH Aachen University



http://www.dpdhl.com/en/media_relations/specials/parcelcopter.html

Video source: Deutsche Post AG

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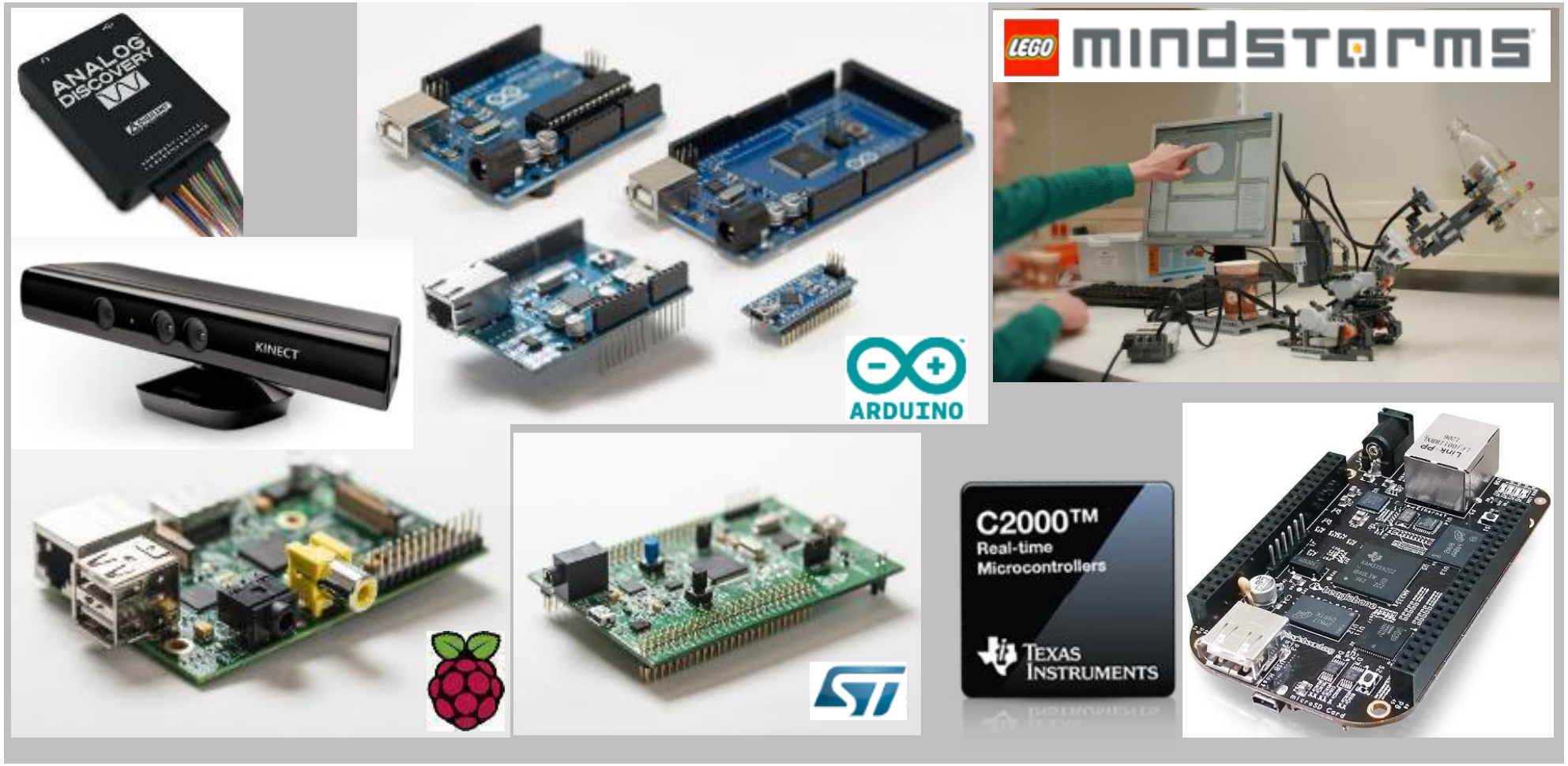
How do I connect MATLAB to hardware?

Since 2012: Hardware Support Packages!



C Code Generation-based Hardware Support Packages

- Texas Instruments C2000 200+ user installs / month!
- STmicroelectronics STM32**F4**07 and STM32**F7**46 Discovery boards
- Beaglebone Black
- Raspberry Pi 1, 2, 3 500+ user installs / month!
- Arduino (Uno, Due, Nano, Mini, Mega, too many to list!) 2000+ user installs / month!
- NXP FRDM, STM32 Nucleo boards
- Android, iOS, and **more**! 250+ user installs / month!

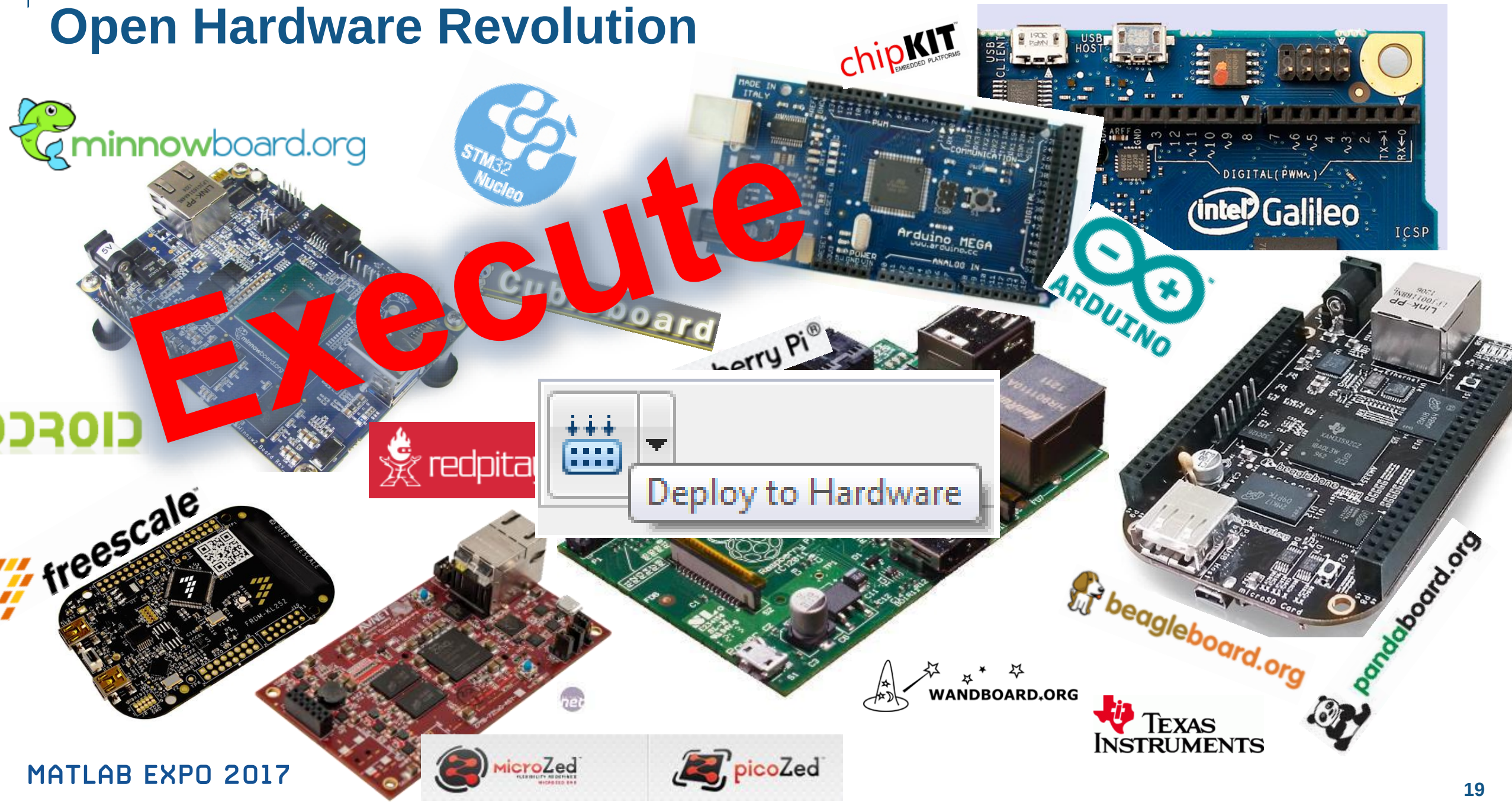
Includes: **Simulink-based HSP**

- Compiler Toolchain
- Peripheral configuration I/O Blocks
- External mode
- Processor-In-the-Loop PIL framework
- Example models and documentation

Includes: **MATLAB-based HSP**

- Connectivity API
- Coming Soon: Code Generation

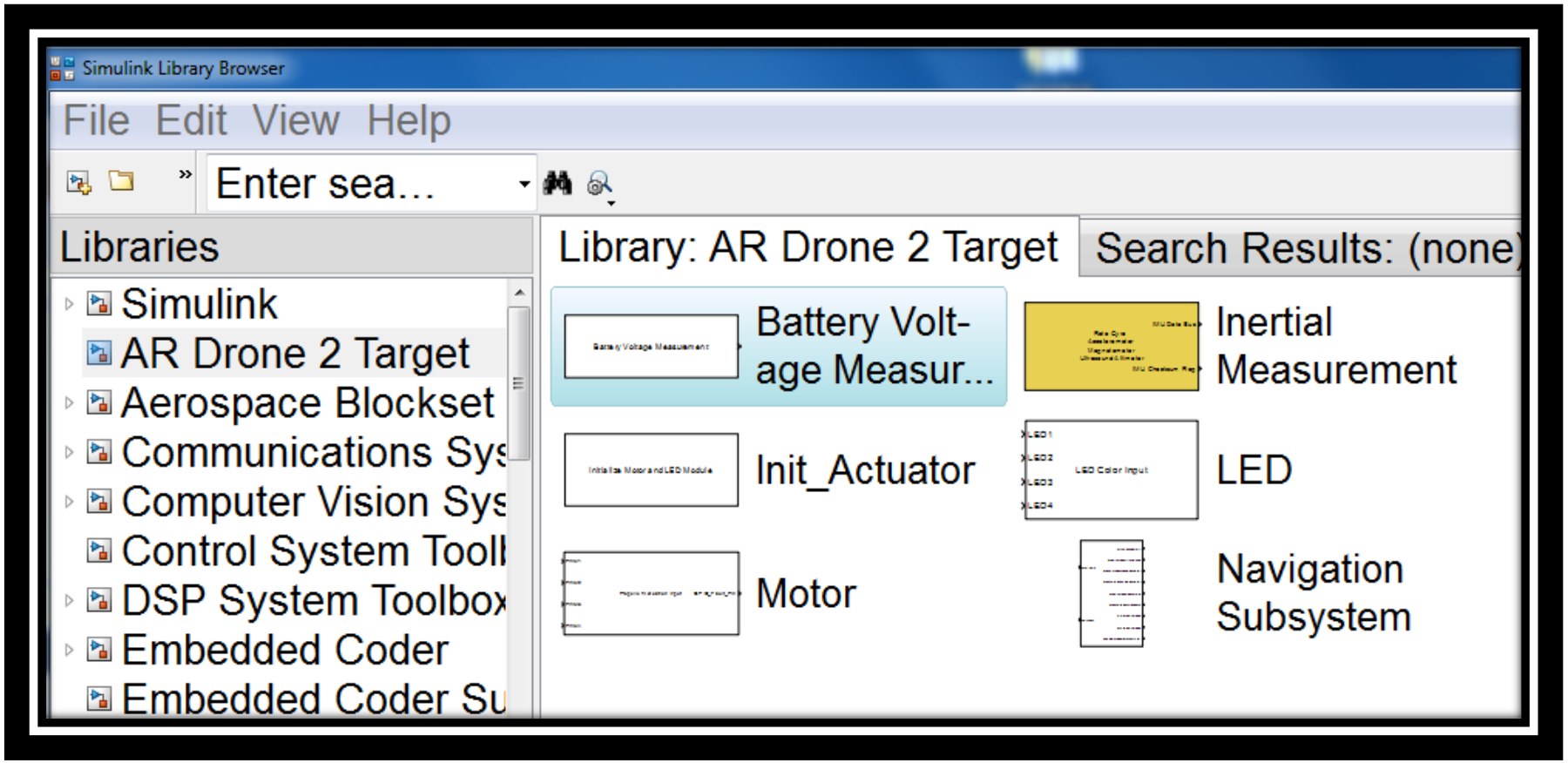
Open Hardware Revolution



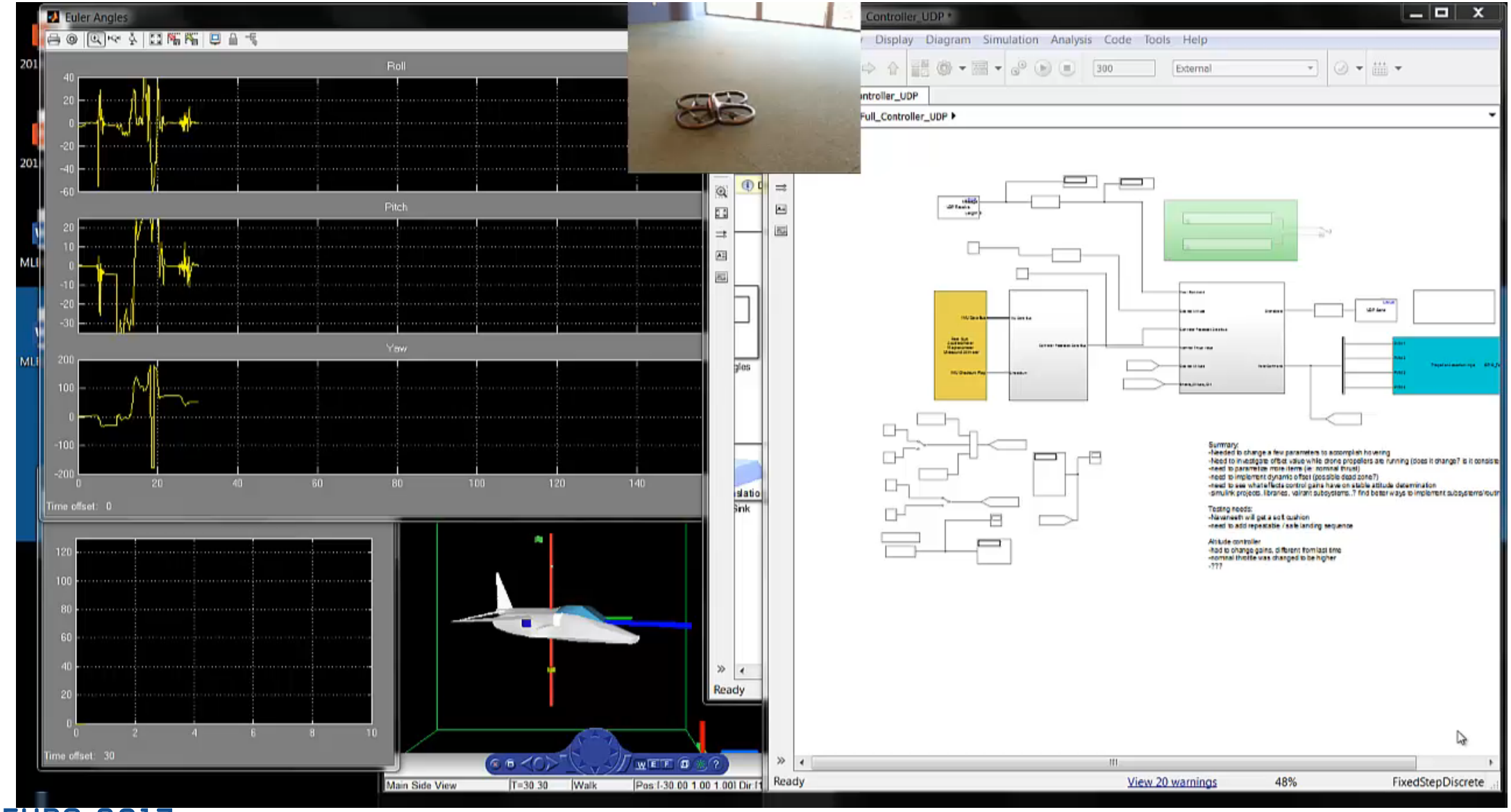
Parrot AR Drone

Execute

Parrot AR Drone Hardware Support in Simulink



Deploying Simulink Model to Parrot AR Drone

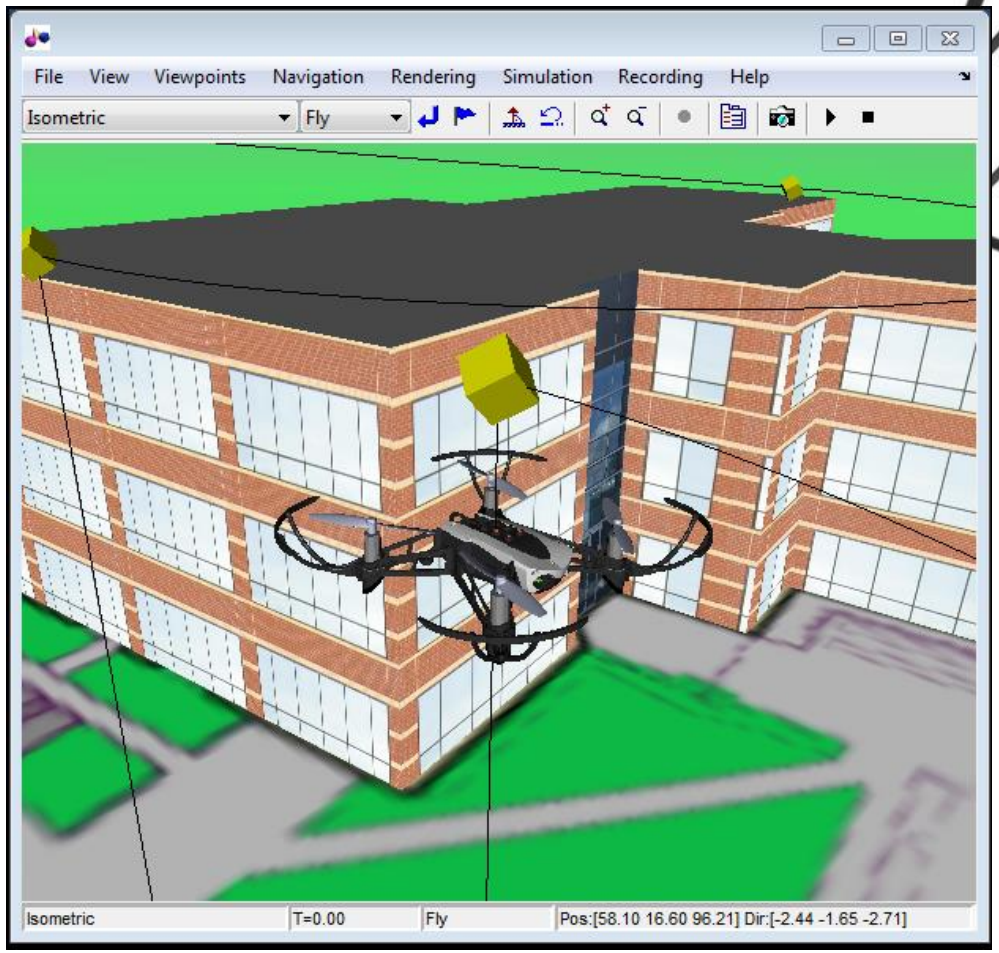


Parrot Mini Drone Support in Simulink

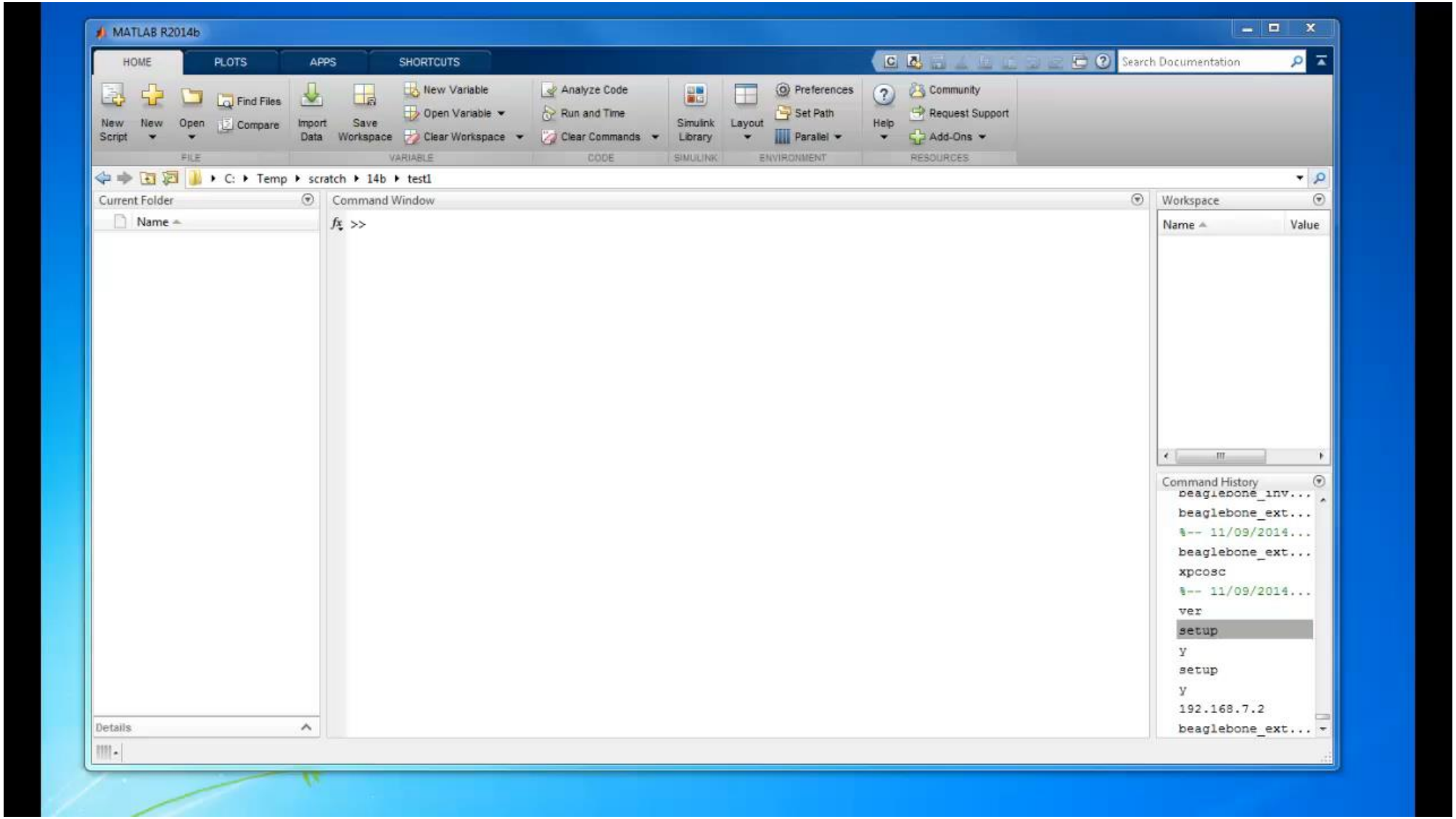
16.30 Feedback Control Systems

An MIT Feedback Control Systems Class that Teaches with Palm-size Drones

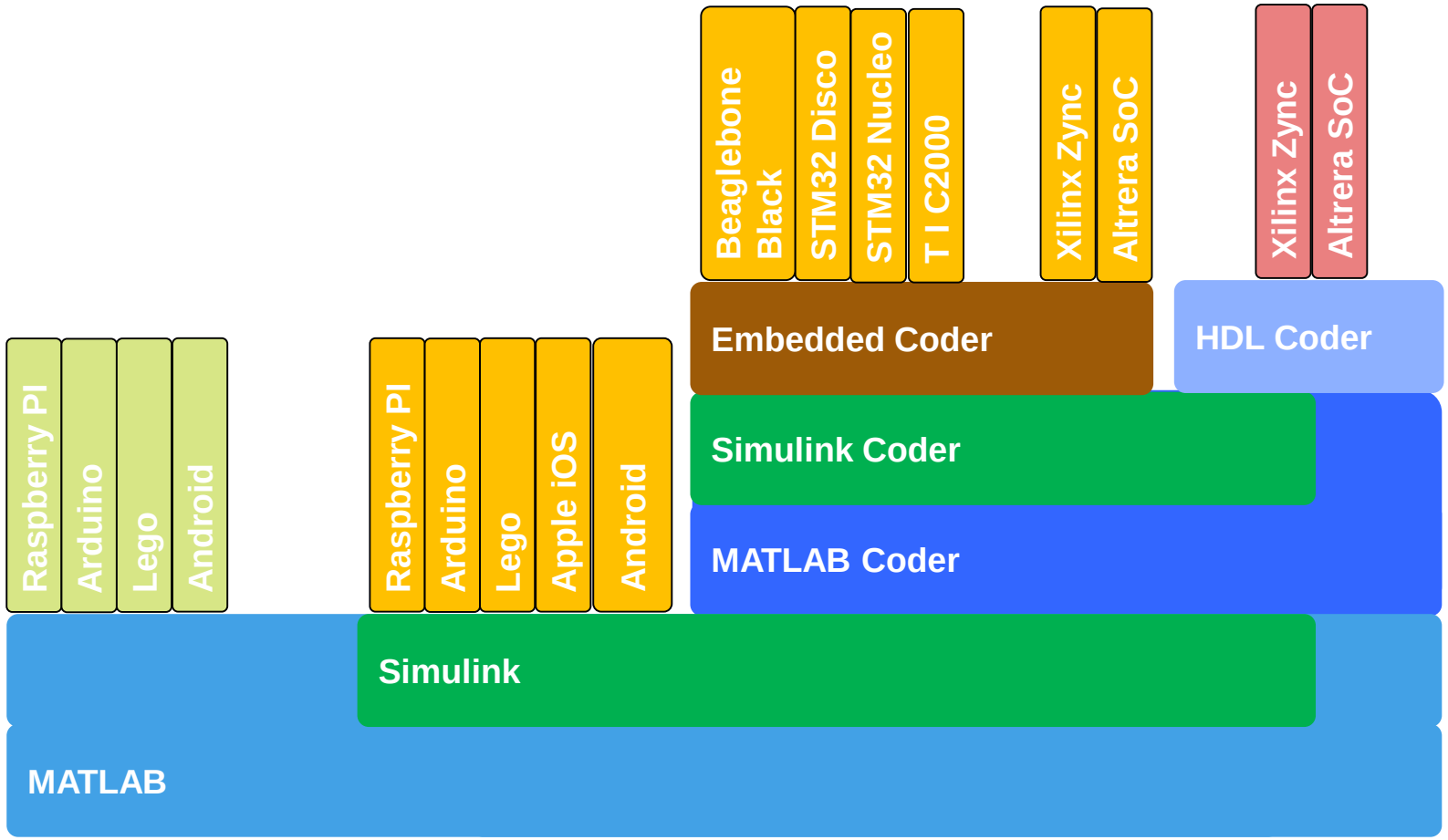
http://fast.scripts.mit.edu/dronecontrol/



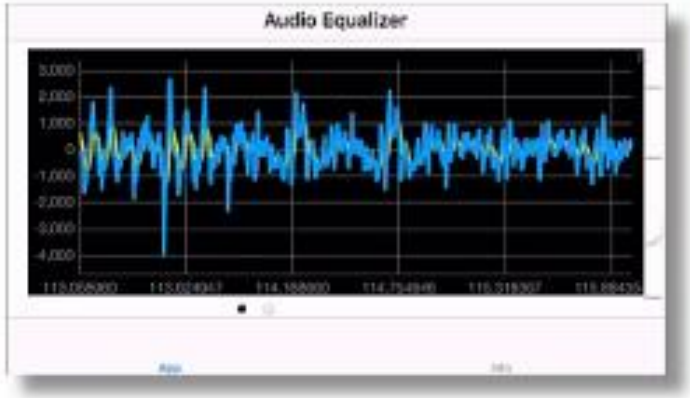
Using the Support Package Installer is Easy!



MathWorks Hardware Support Packages



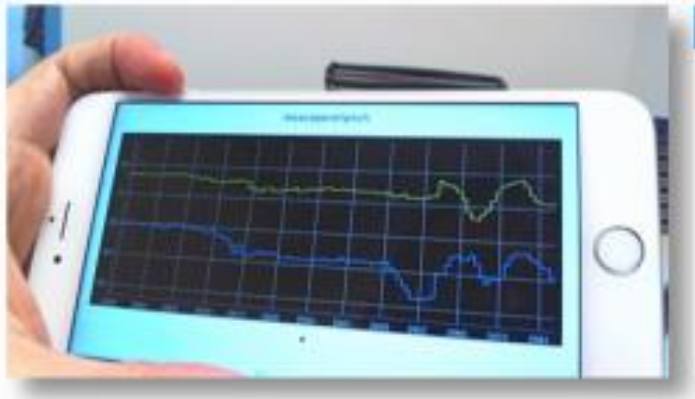
iPhone iPad and Android Support



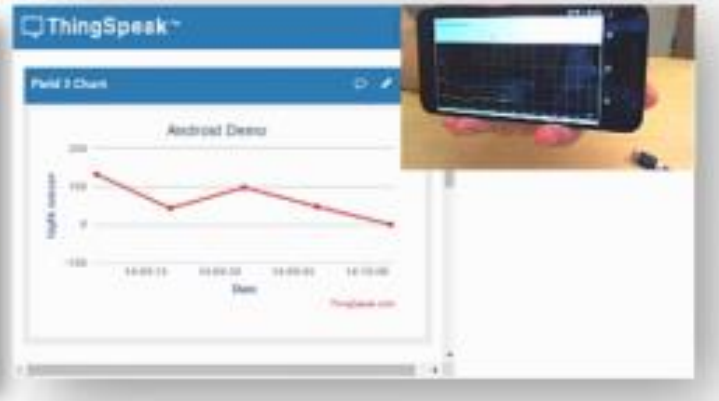
1) Audio processing

2) Image processing

3) Video processing



4) Mobile sensing



5) IoT with ThingSpeak

6) Wireless connectivity

Arduino board support from MATLAB and Simulink

2012b

UNO

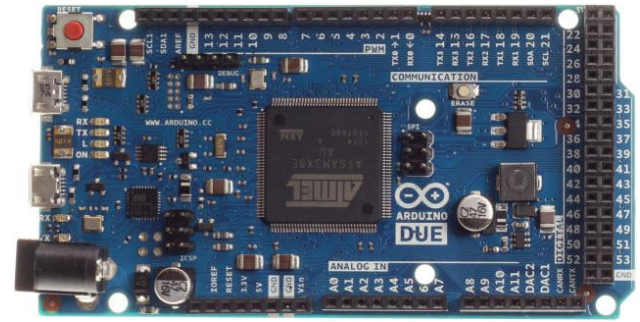
MEGA

2013b

NANO

2014a

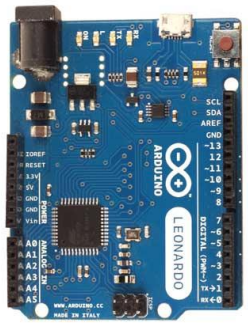
DUE



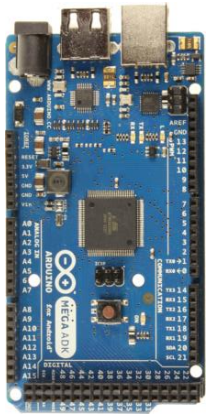
Mac OS X Support!

2014b

Leonardo



Mega ADK



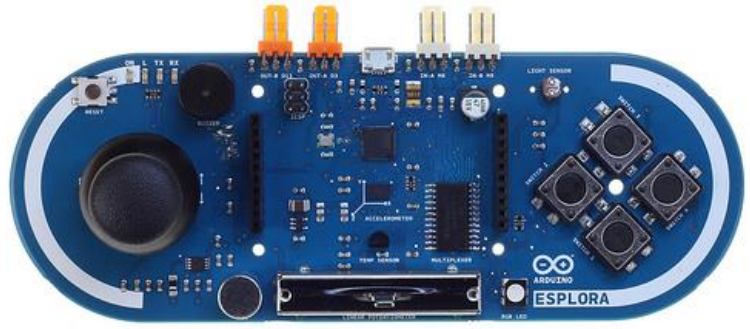
Mini

Fio

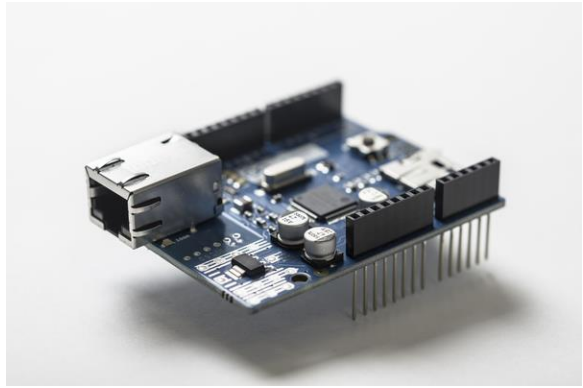
Pro

Micro

Esplora



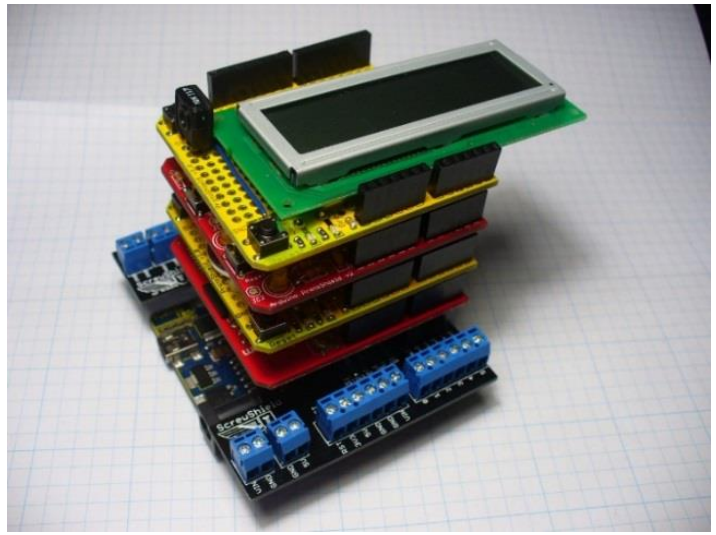
Arduino Shields



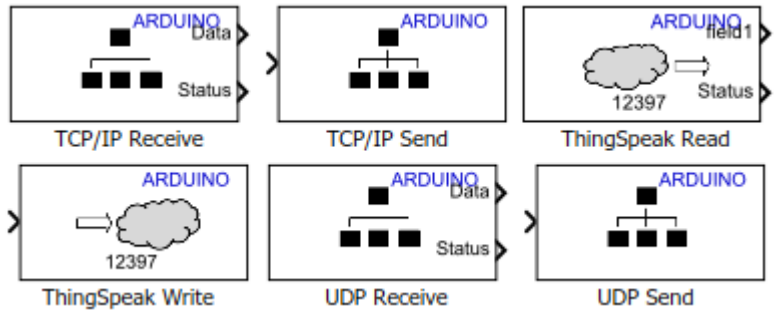
Ethernet Shield

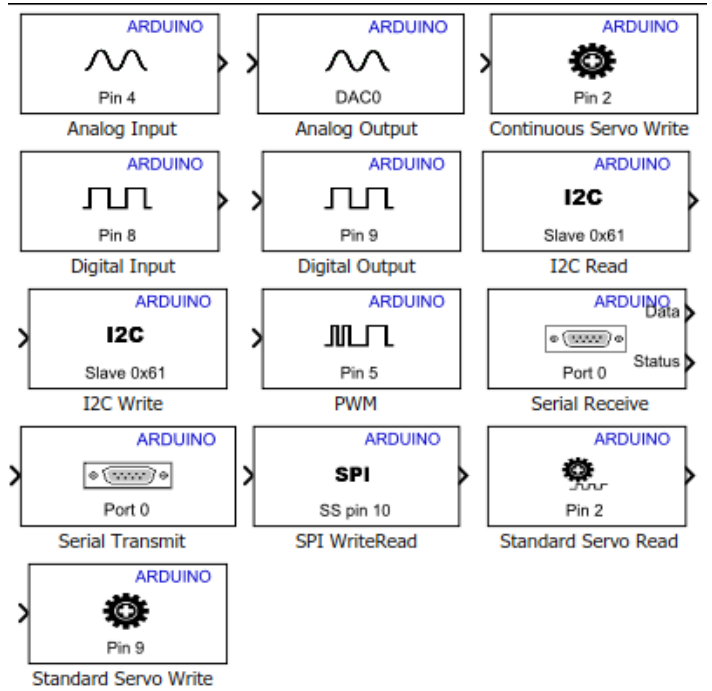
Wifi Shield

Motor Shield



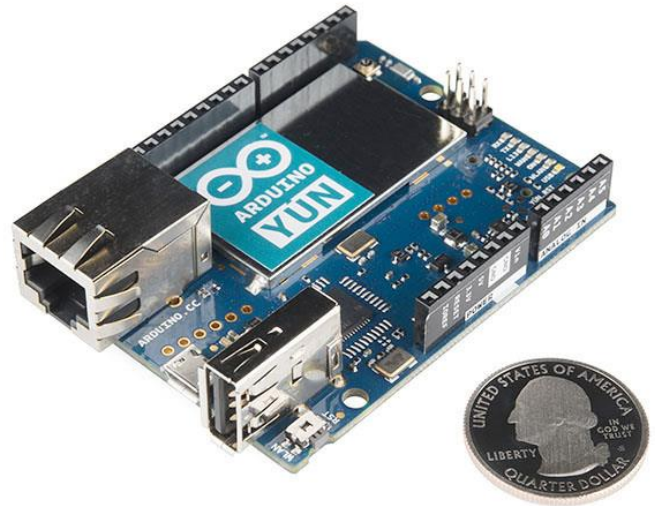
Simulink Blocks





Arduino

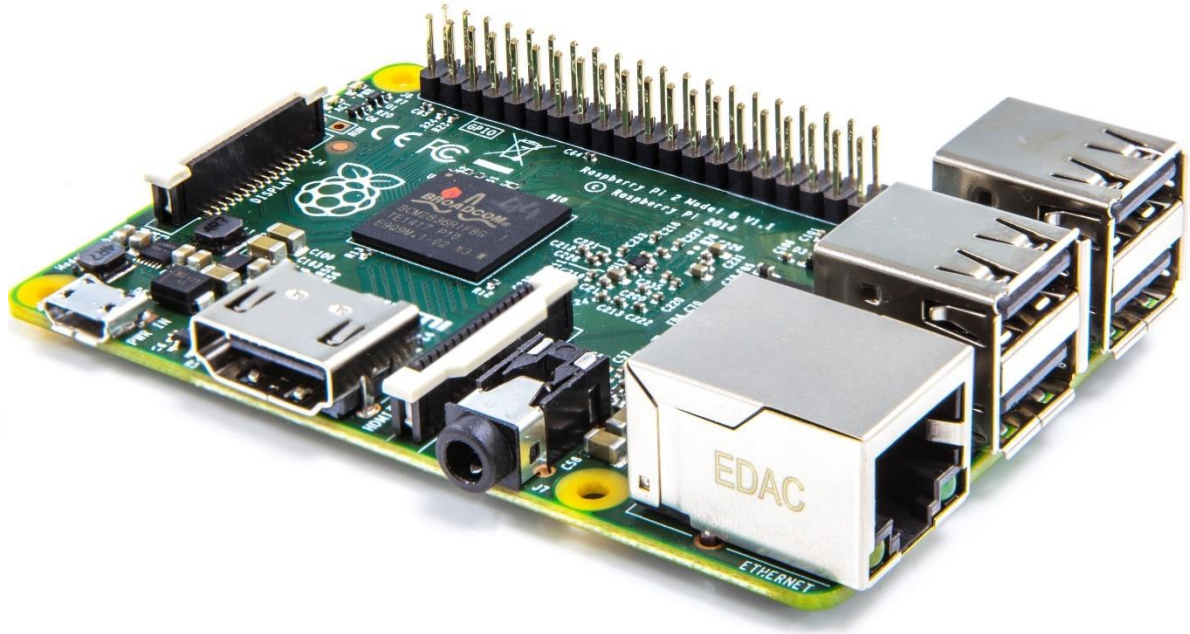
- **17a** – print/println support
- **16b** – Thingspeak read, PIL, enhanced external mode
- **15a** – Support from Linux
- **New IO Block support**:
  - I2C, SPI
  - UDP/TCP to LEGO, Raspberry Pi, and Android/iPhone
- **New boards:** Yun



Raspberry Pi

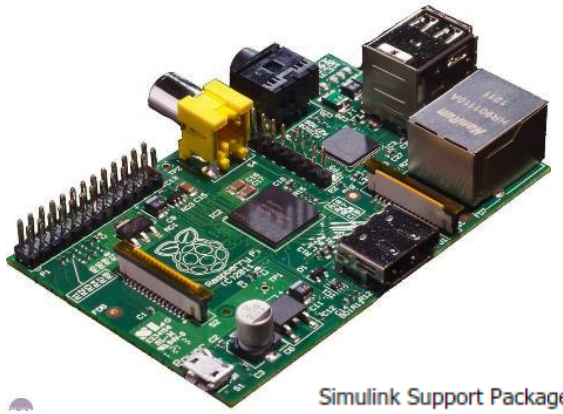
- 17a – New blocks: I2C, SPI, UART, TCP/IP, IMU, Pressure, Humidity, etc
- 16b - Support from Linux PC
- 16a – Pi 3 support
- 15b – Support from Mac
- 15a – Pi 2 support

Thingspeak
Read/Write Support!

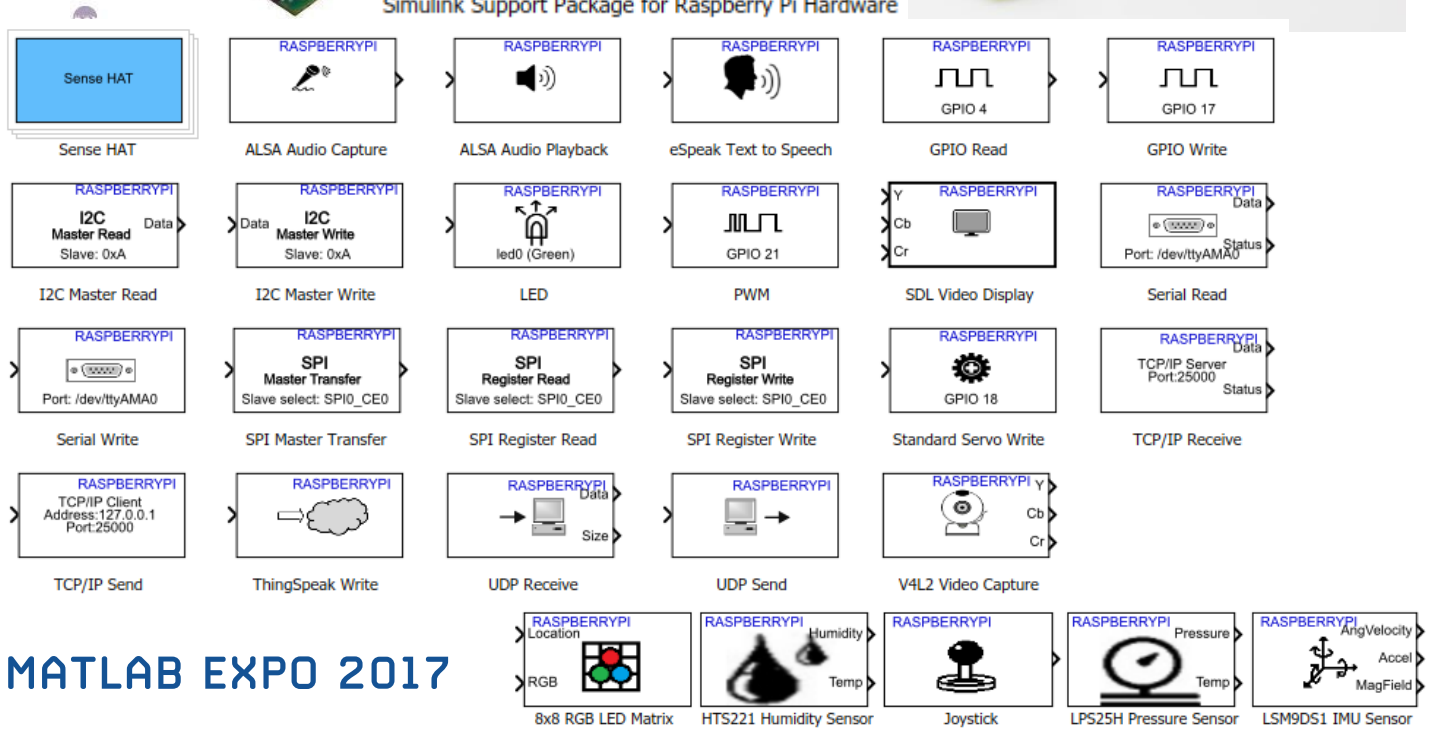


Linux Boards supported by MATLAB and Simulink

Raspberry Pi 1, 2, and 3

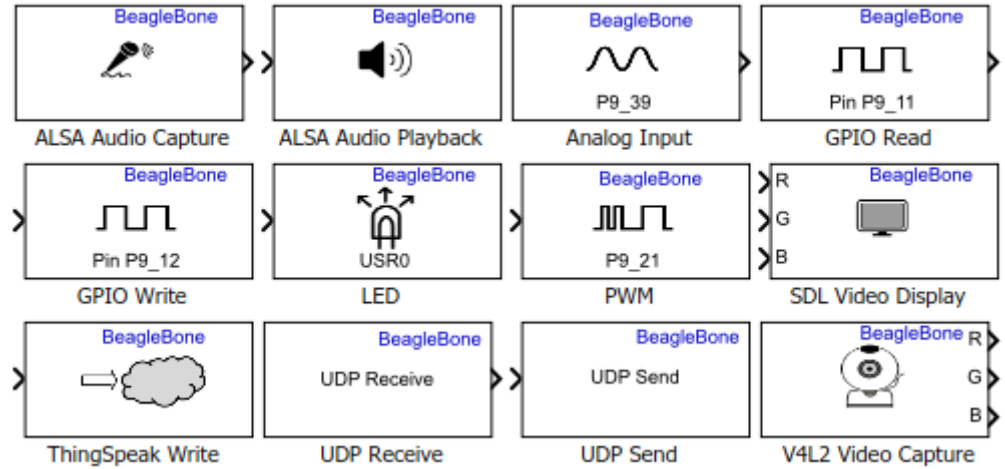


Simulink Support Package for Raspberry Pi Hardware



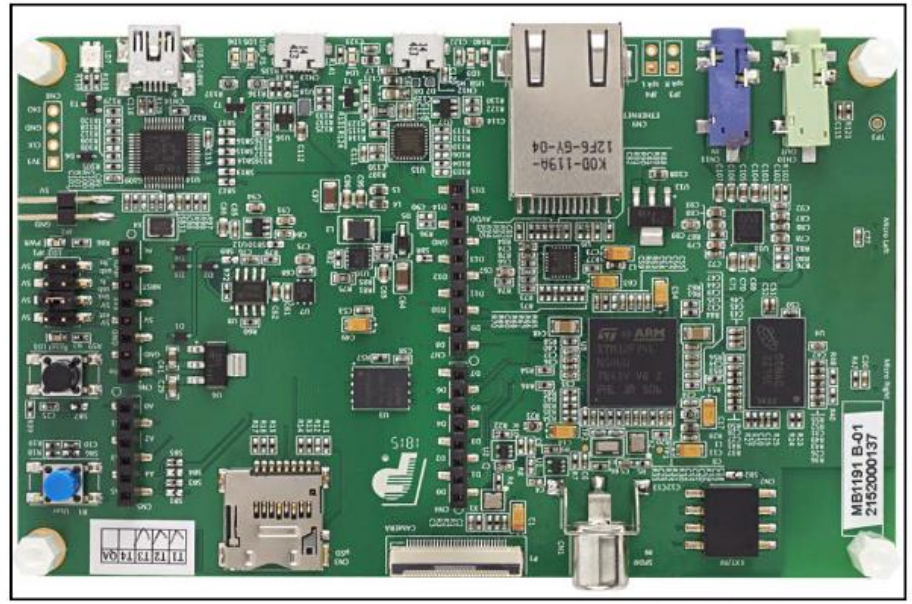
BeagleBone Black

Embedded Coder Support Package for BeagleBone Black Hardware

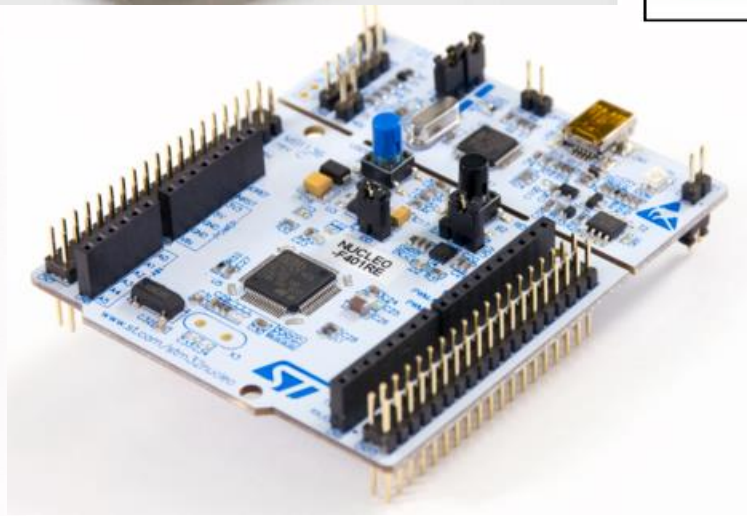


STM32 Board Support

- STM32 Discovery : F407 & F746



- STM32 Nucleo :
  - STM32F746
  - STM32F411
  - STM32F401
  - STM32F302
  - STM32F103
  - STM32F031
  - STM32L476
  - STM32L053



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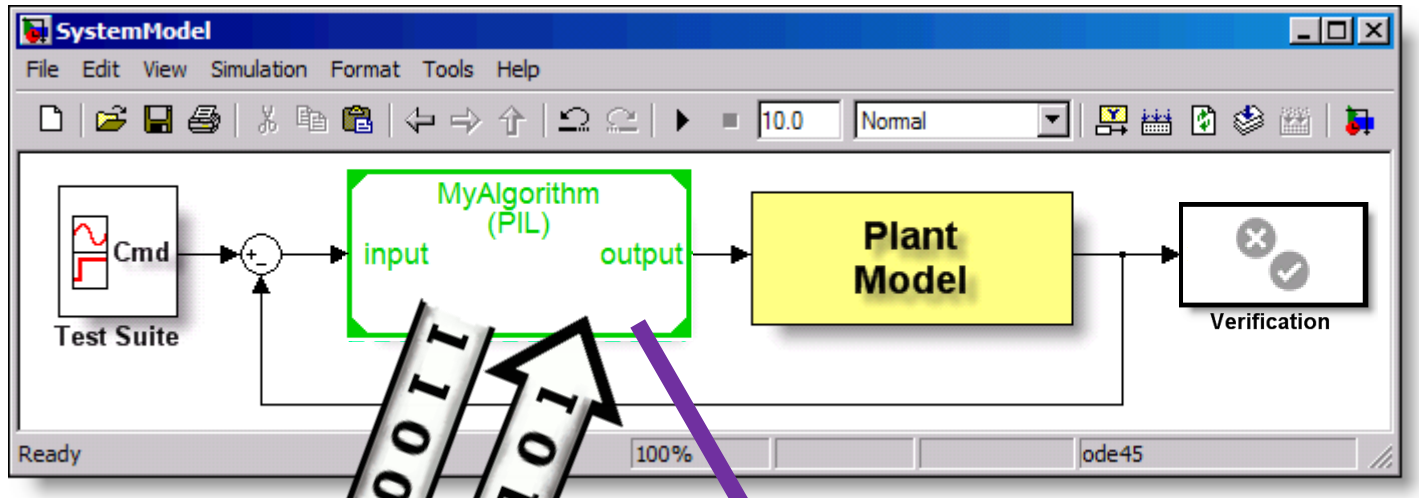
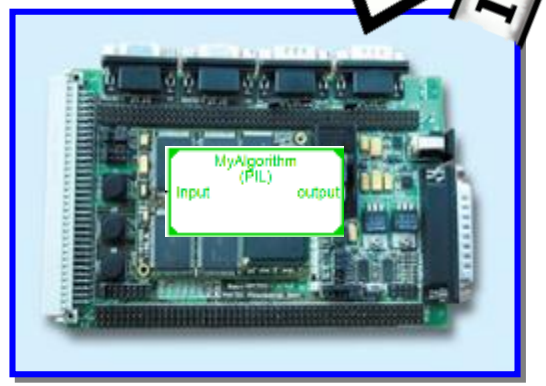
How SIL and PIL Work

On-Target Simulation



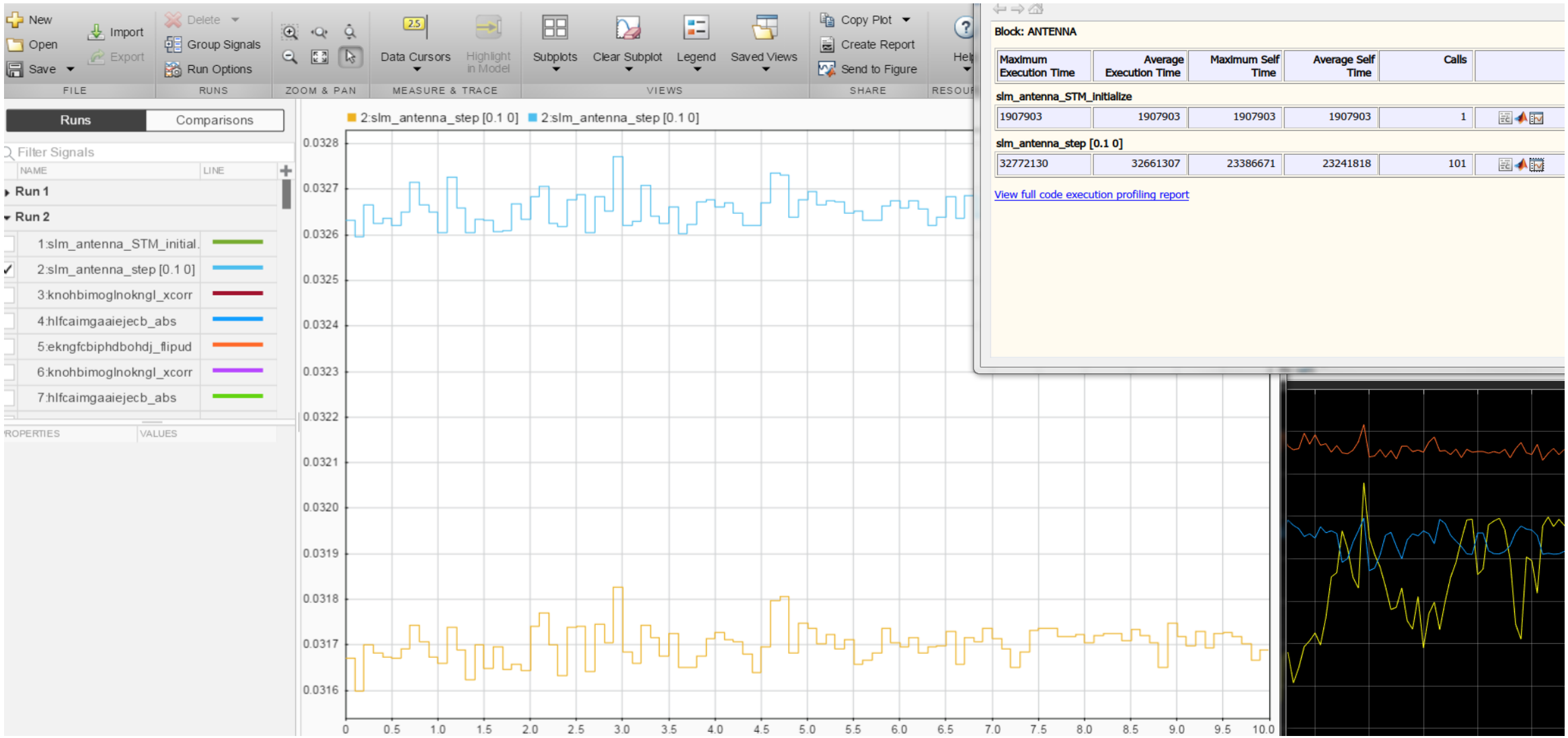
Non-Real-Time Synchronization with Host at Each Time Step



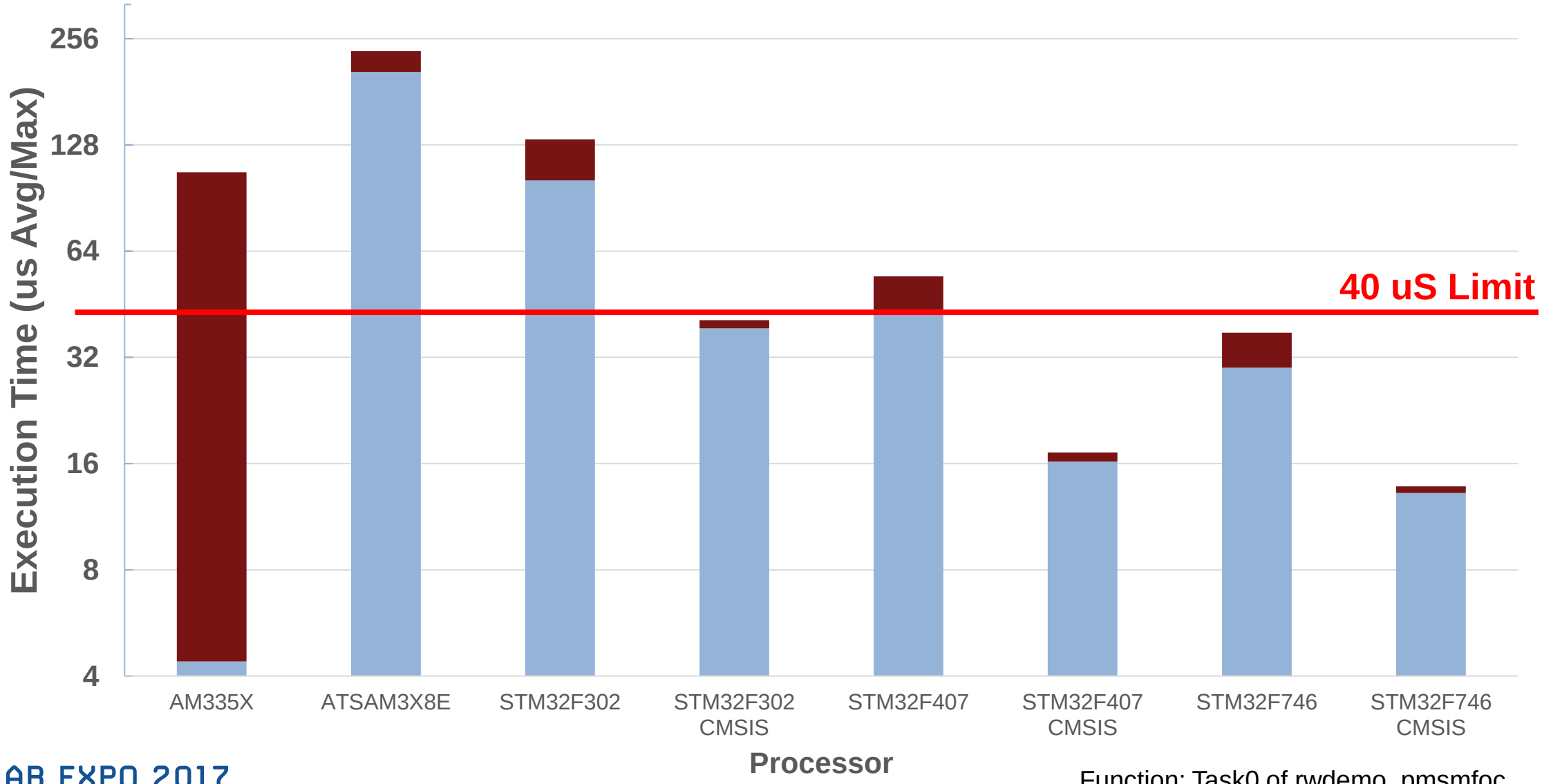
Execution History

- **Equivalence comparison**
- **Code coverage**
- **Execution timing (profiling)**

Processor-in-the-Loop (PIL) profiling

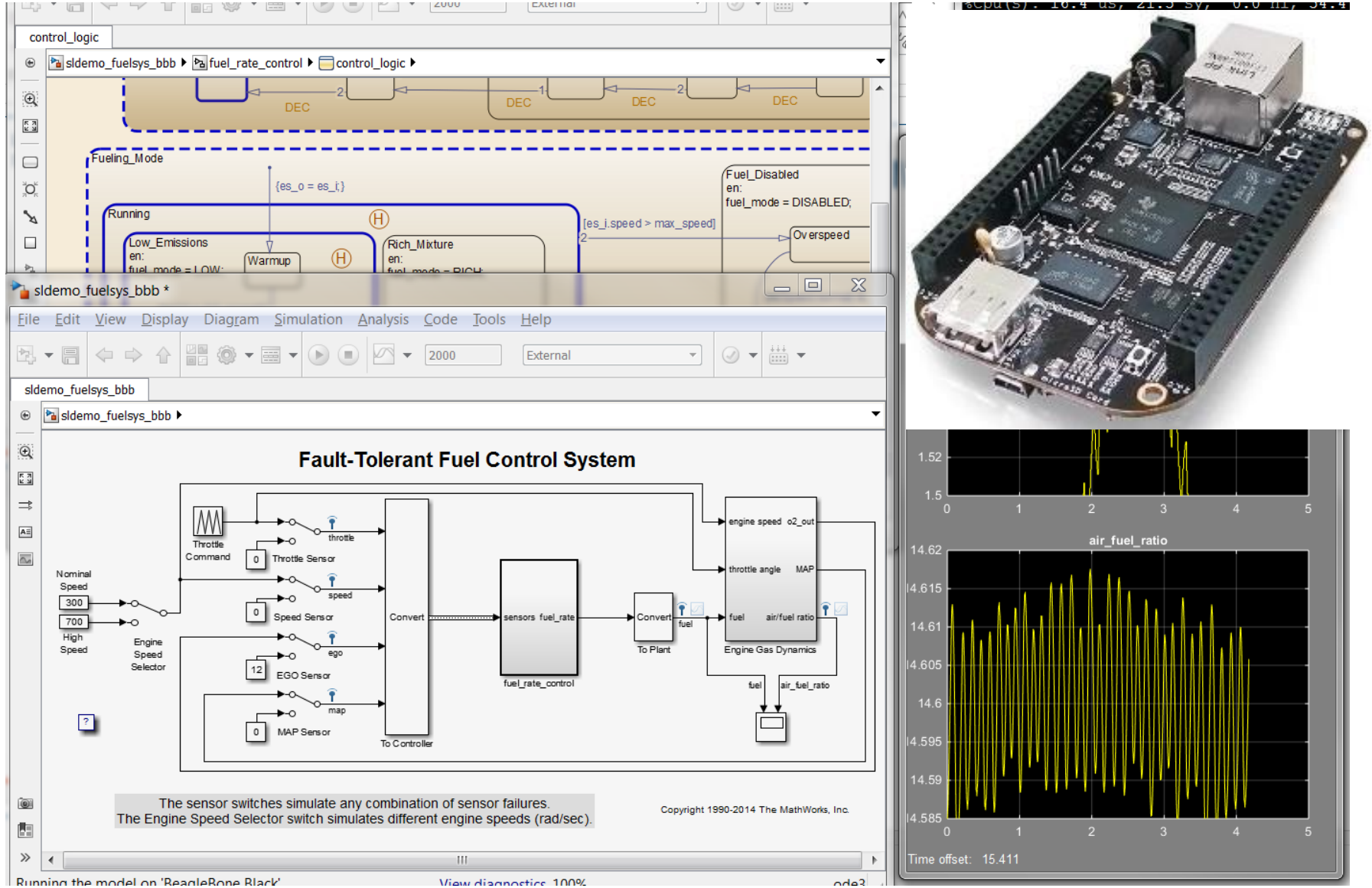


Processor Benchmarks on various ARM Cortex CPUs



Function: Task0 of rwdemo_pmsmfoc

Deploy Simulink Model to Beaglebone Black



Agenda

- Introduction
- Hardware Support Packages for MATLAB and Simulink
- Processor-in-the-Loop Execution
- **Code Generation within the Internet of Things (IoT)**
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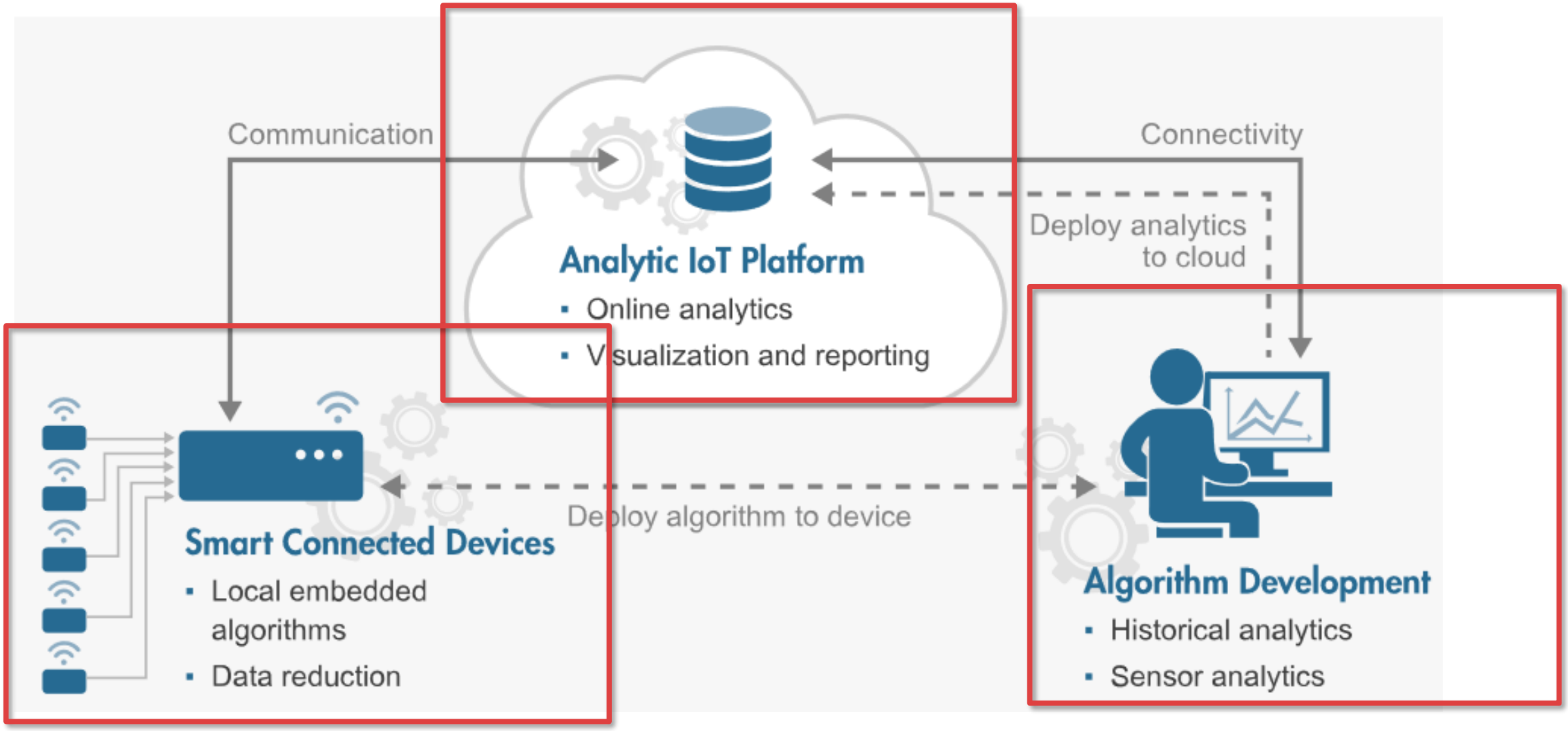
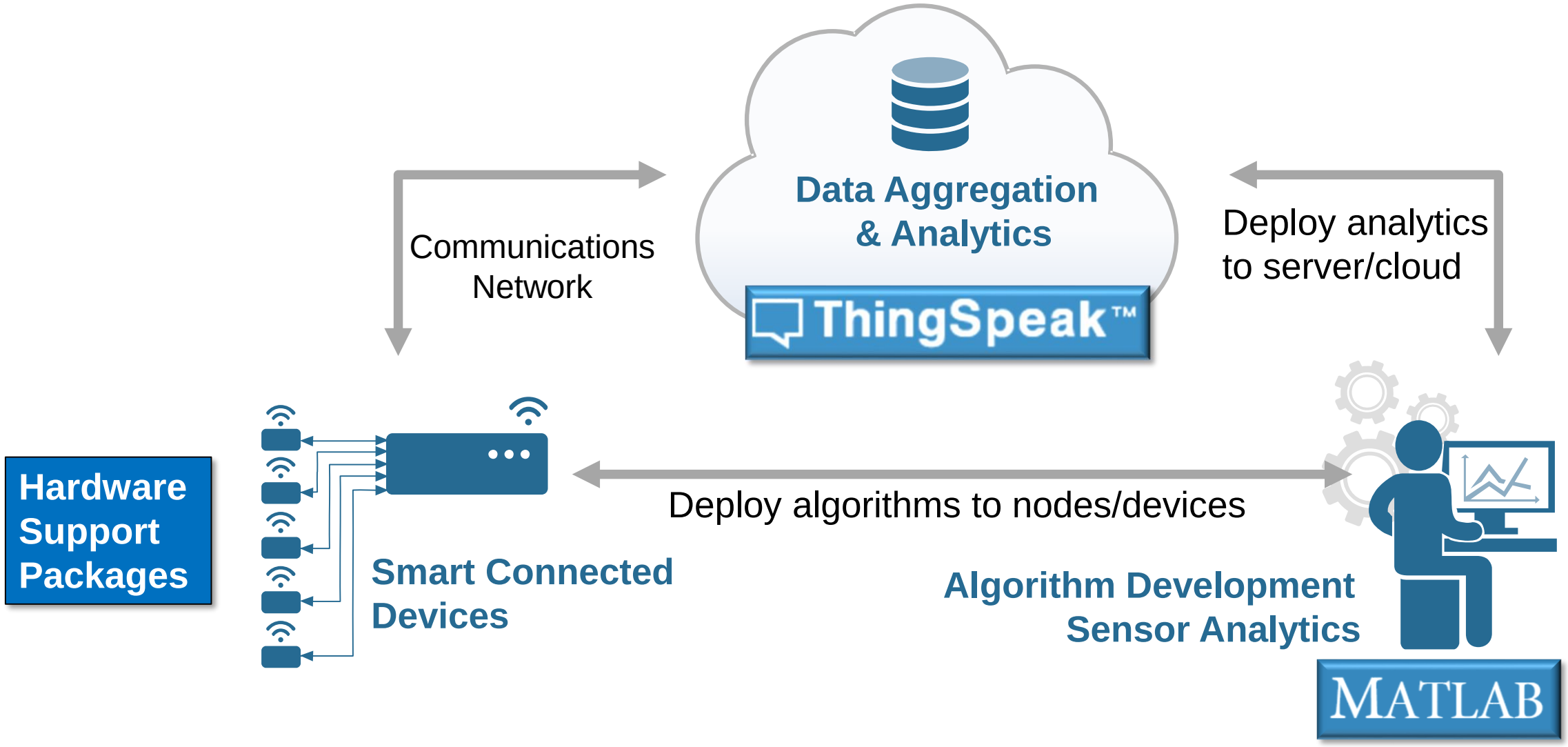
- Questions

IoT Analytics Challenges

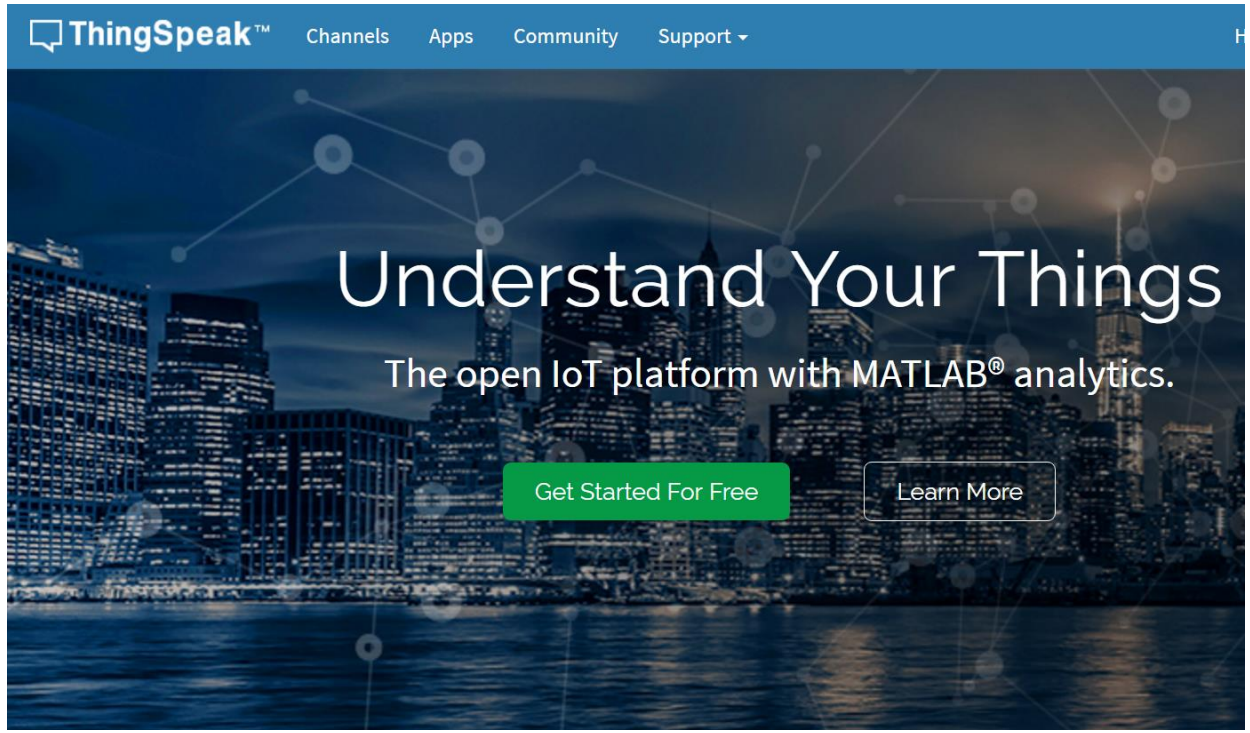


IoT Analytics Solutions



What Is ThingSpeak?

Web Site For People



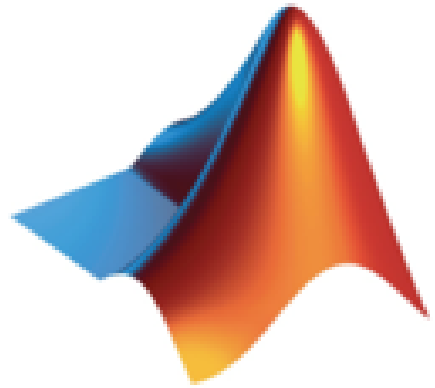
Web Service for Devices


```
{
  - 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"
        }
    ]
}
```

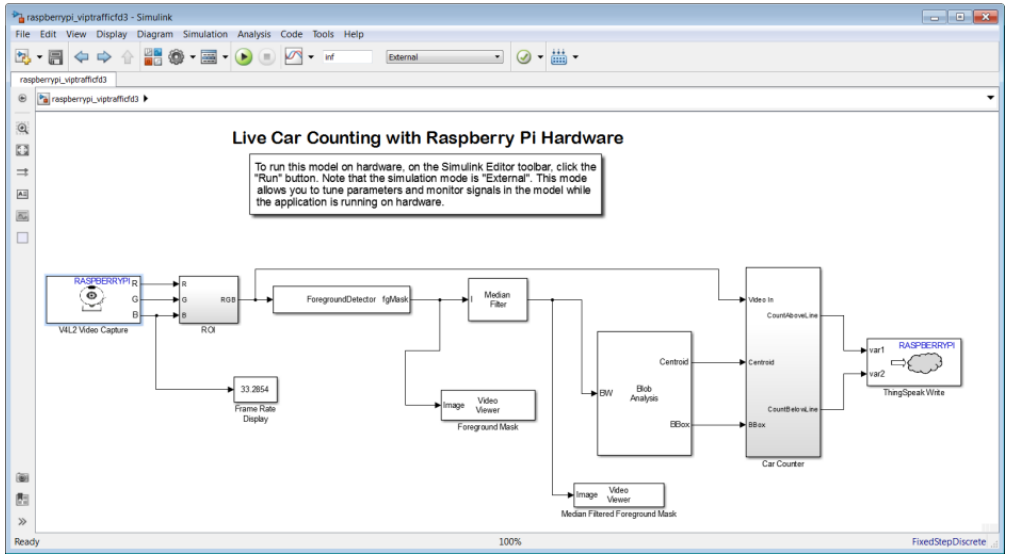
ThingSpeak

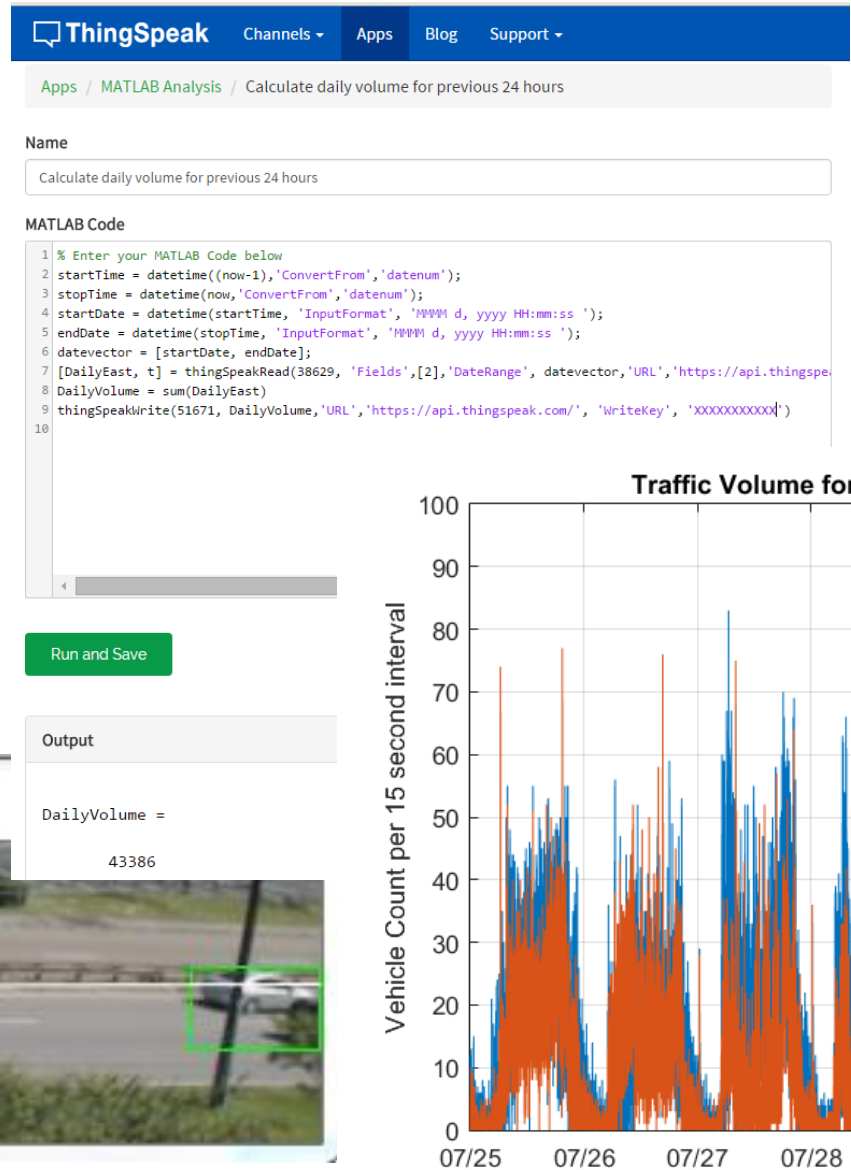
- New MathWorks web service hosted on AWS
- Lets you collect, analyze and act on data from “things”
- Over **130,000** users worldwide
- It has **MATLAB** for IoT Analytics
- It’s **free** to get started

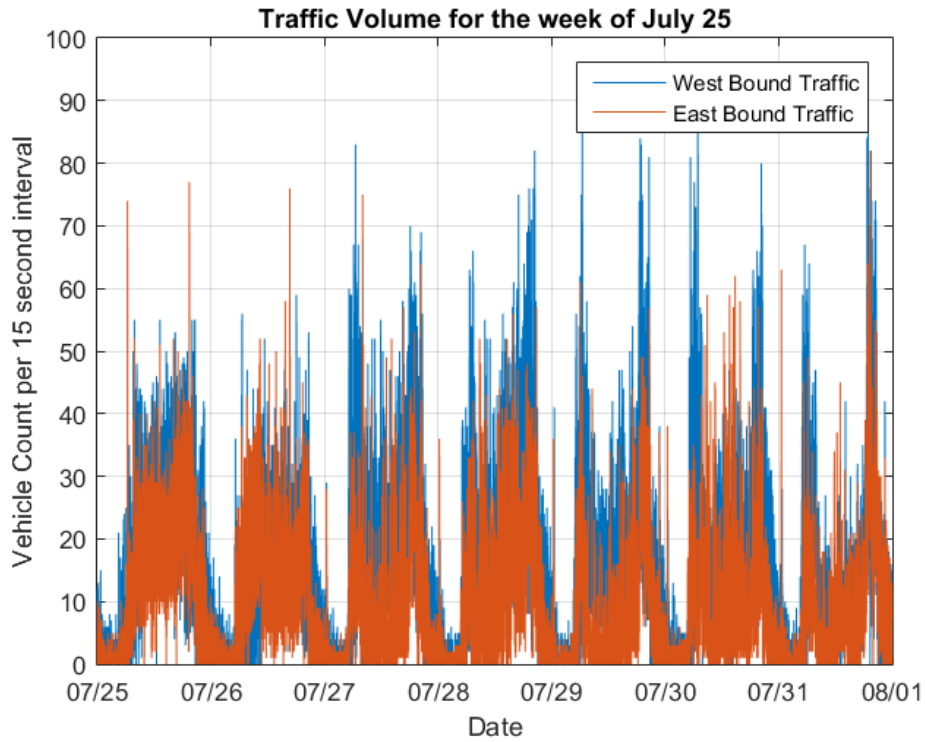
https://thingspeak.com



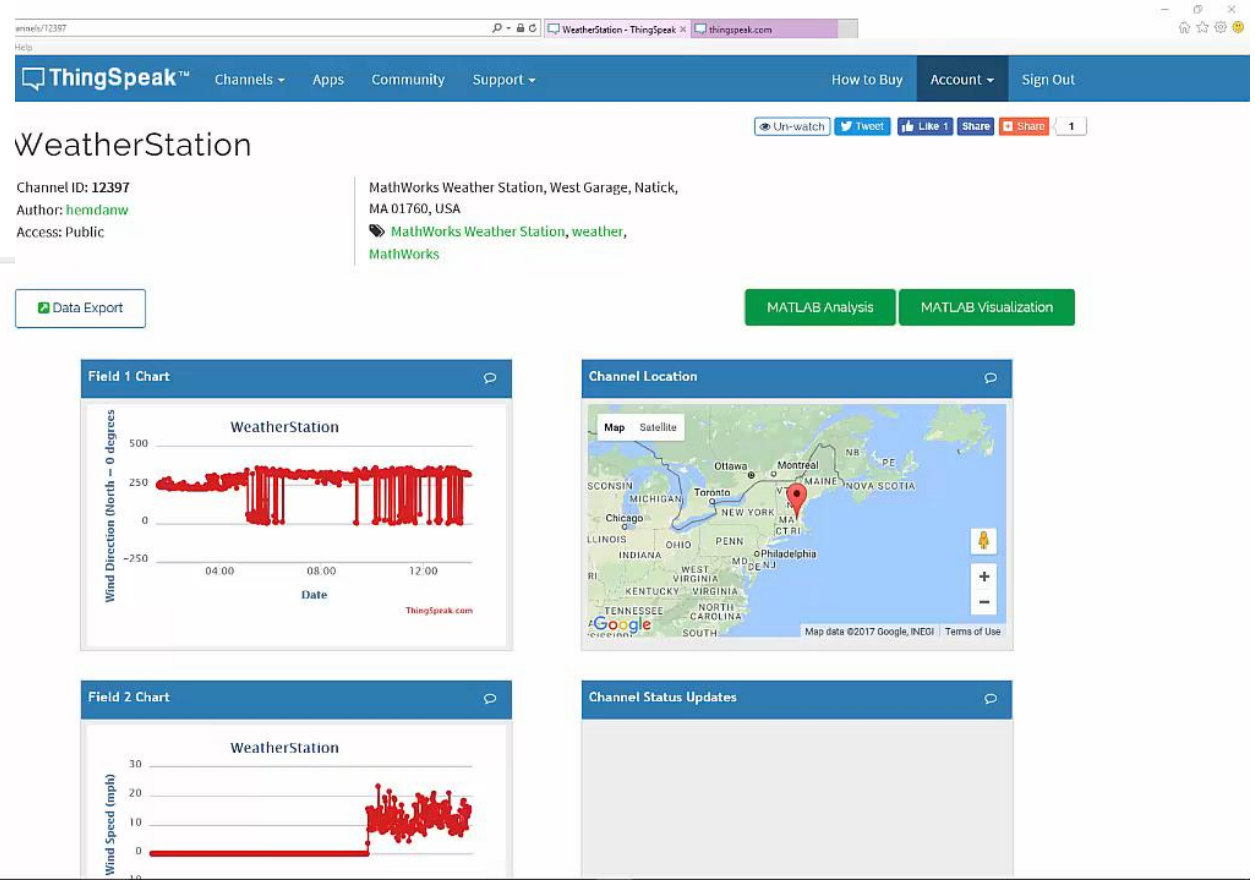
Car-counting camera IoT example



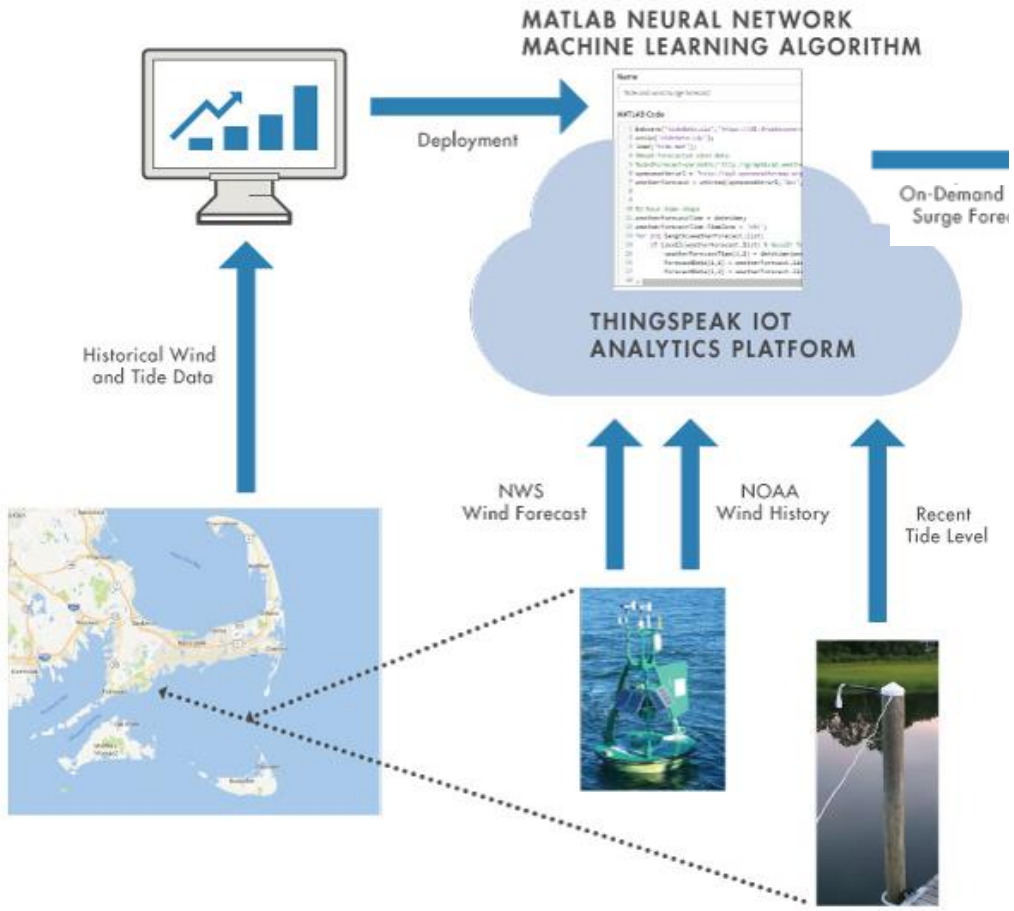




Custom Visualizations with ThingSpeak- Weather Station Example



Predictive Analytics Example with ThingSpeak



ThingSpeak™ Channels Apps Community Support How to Buy Account

Un-watch Tweet Like 0 Shar

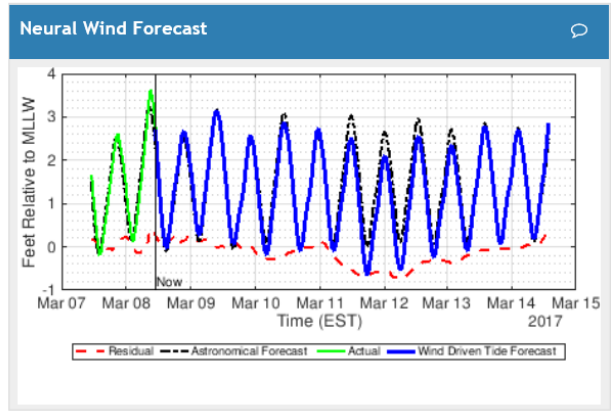
Predicted and Measured Ockway Bay Tide Chart

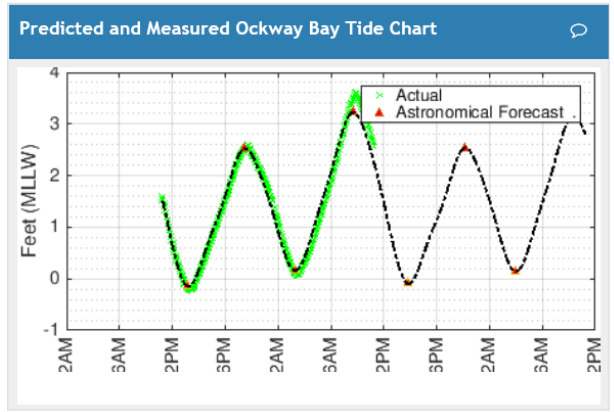
Channel ID: 137305
Author: mawrey
Access: Public

Tide measurement and forecasting with the effect of wind predicted using neural networks.

tide, wind surge, neural network

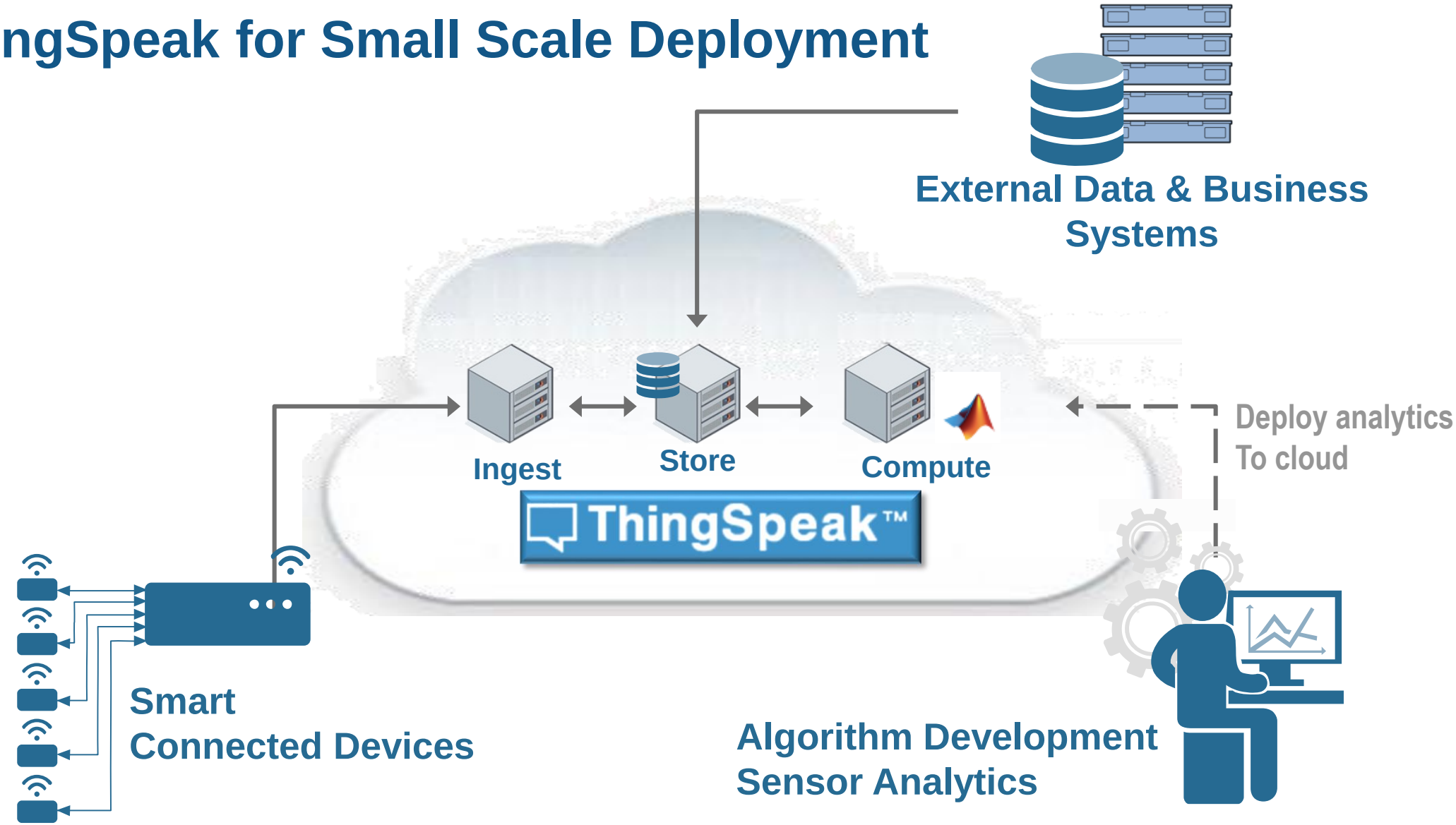
Data Export More Information MATLAB Analysis MATLAB Visualiz



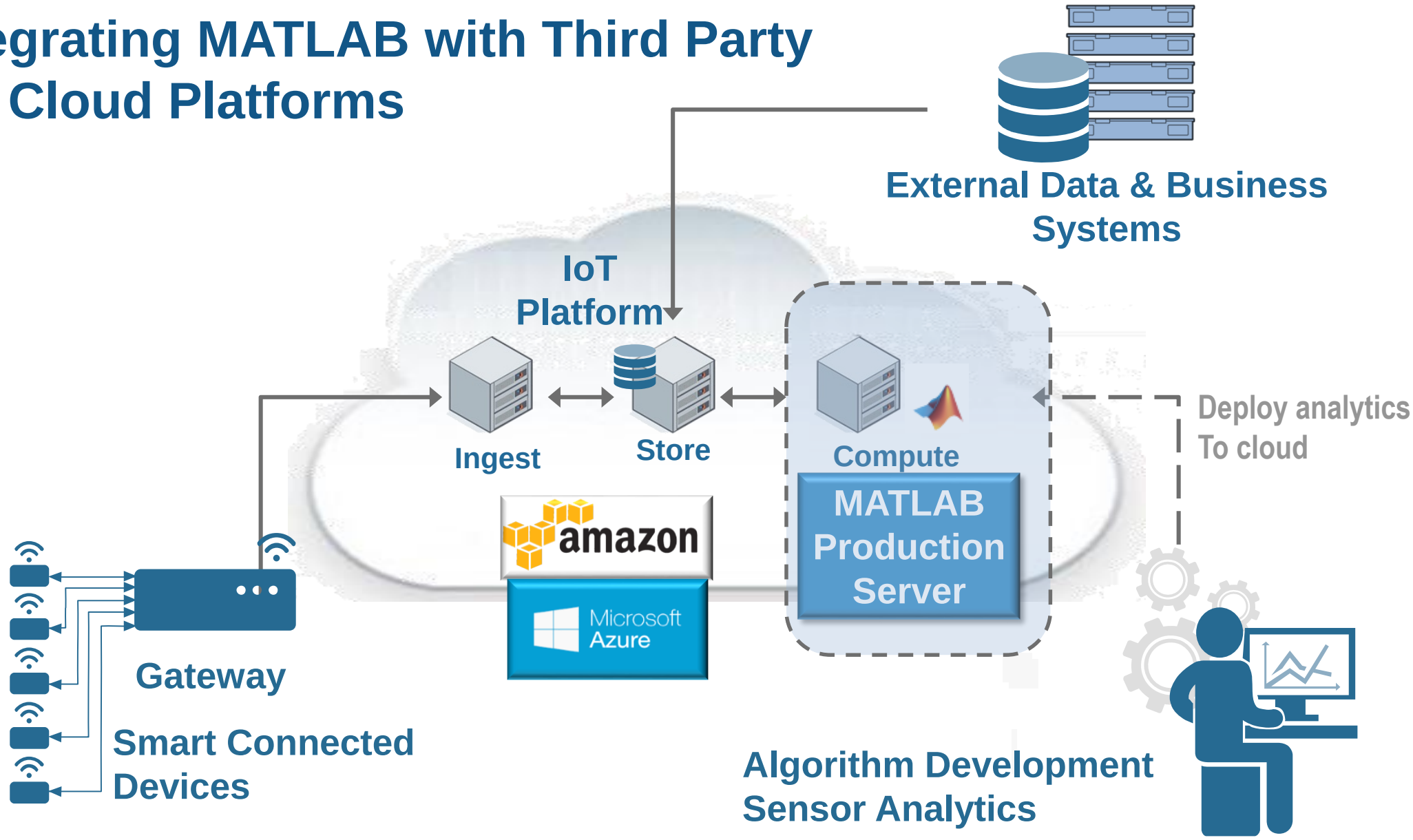



```
netWind.divideFcn = 'dividerand';  % Divide data randomly
netWind.divideMode = 'sample';  % Divide up every sample
netWind.divideParam.trainRatio = 70/100;
netWind.divideParam.valRatio = 15/100;
netWind.divideParam.testRatio = 15/100;
```

ThingSpeak for Small Scale Deployment



Integrating MATLAB with Third Party IoT Cloud Platforms



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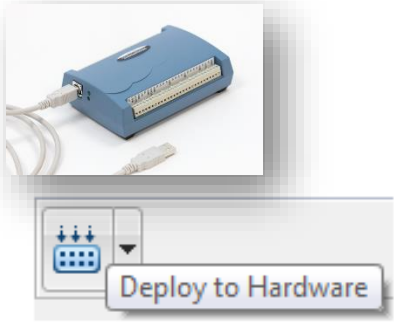
Key takeaways

Hardware support in MATLAB and Simulink …



- Code generation for prototype or production workflows

- Hardware Support Packages make it **easy to install and configure** the necessary software

- Supports many **Open Hardware Revolution** boards and mobile devices (iOS, Android)

- Enables smart sensors for the Internet of Things

Q&A

Déploiement embarqué et connectivité hardware avec MATLAB et Simulink