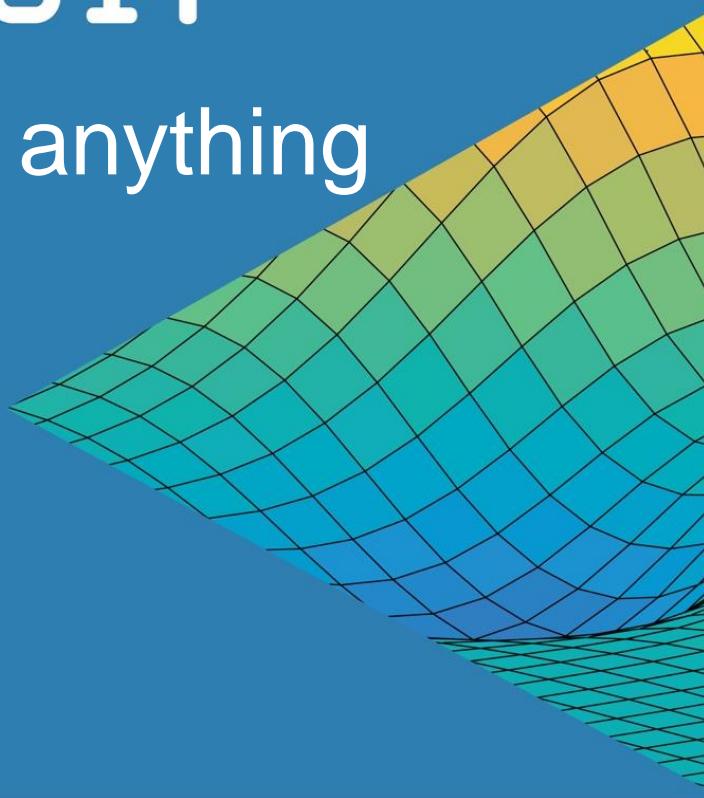


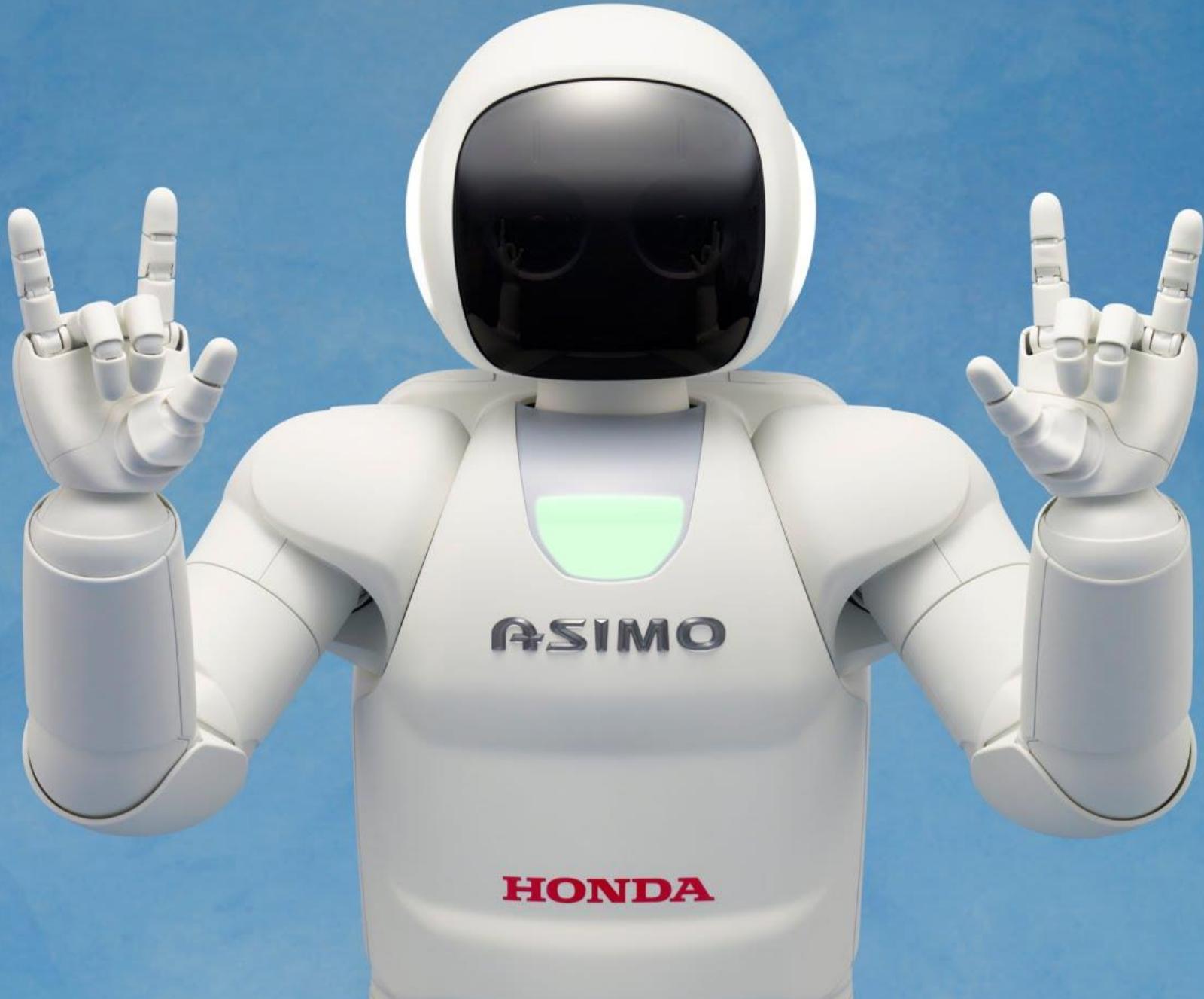
MATLAB EXPO 2017

How to build an **autonomous** anything

Jim Tung
MathWorks Fellow
MathWorks



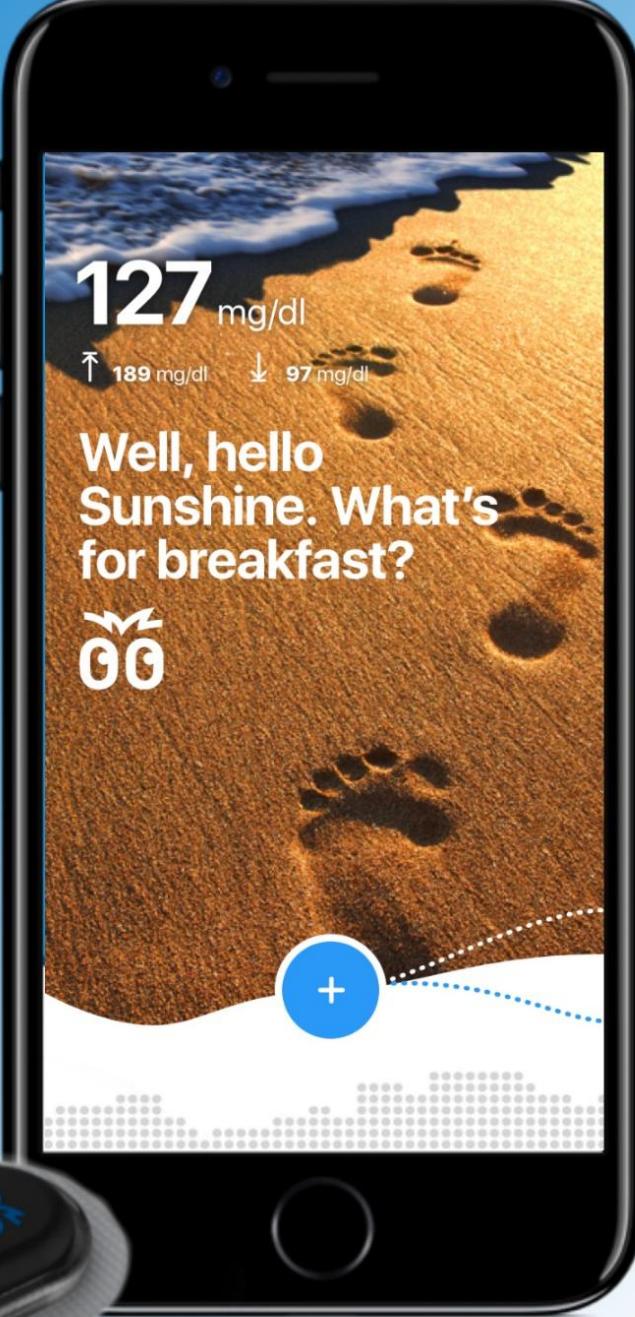












Autonomous Technology

Autonomous

Acting independently

Autonomous Technology

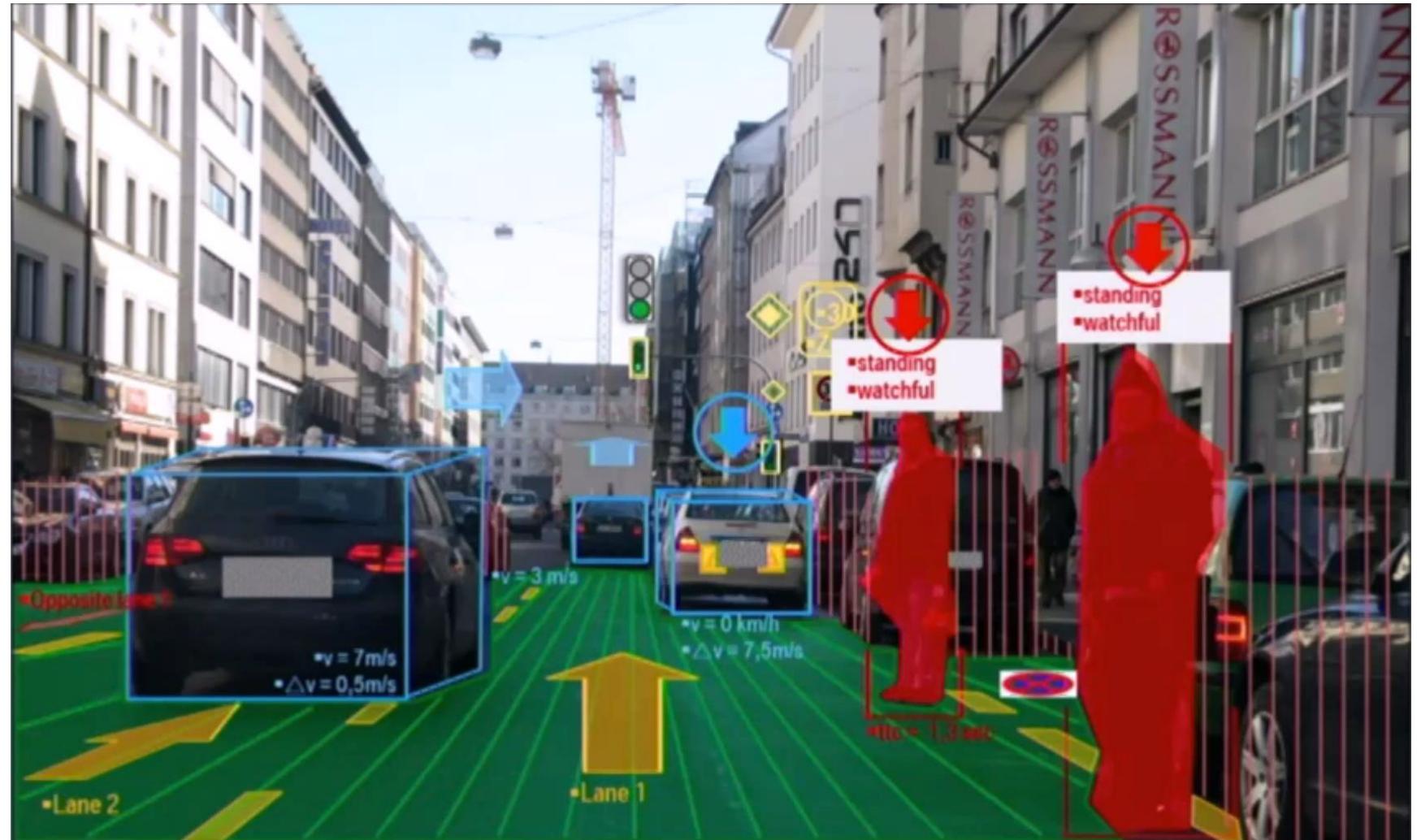
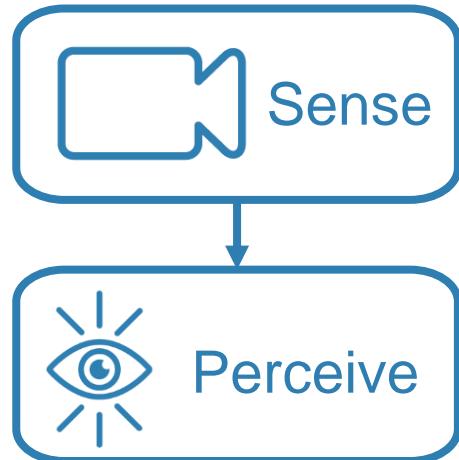
*Provides the ability of a system to act
independent of direct human control
under **unrehearsed** conditions*



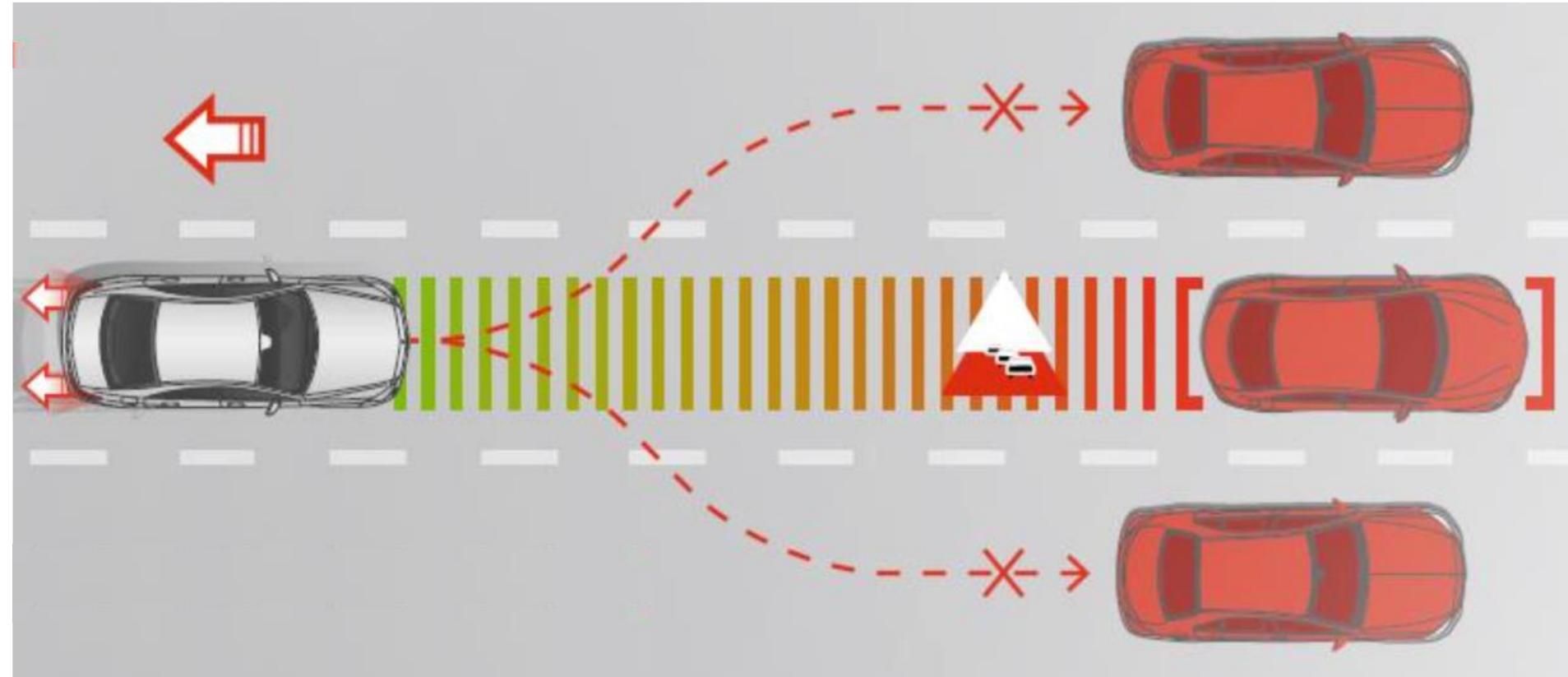
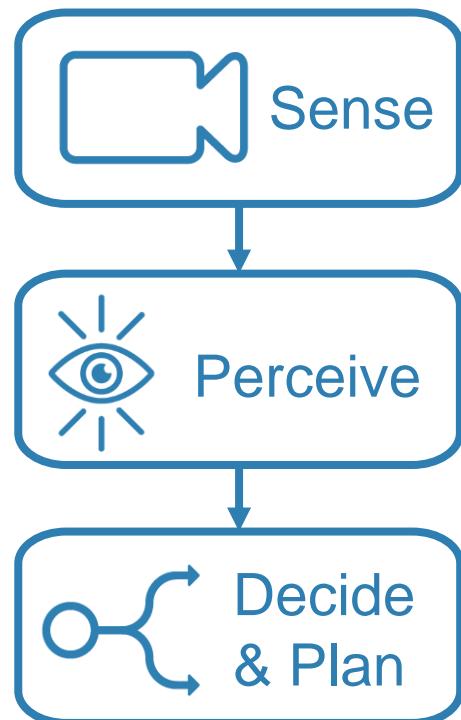
Capabilities of an Autonomous System



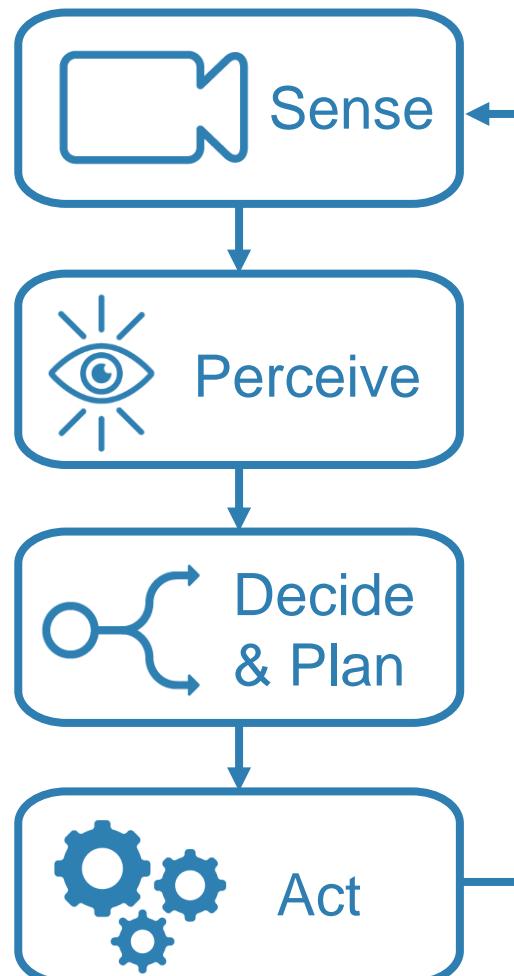
Capabilities of an Autonomous System



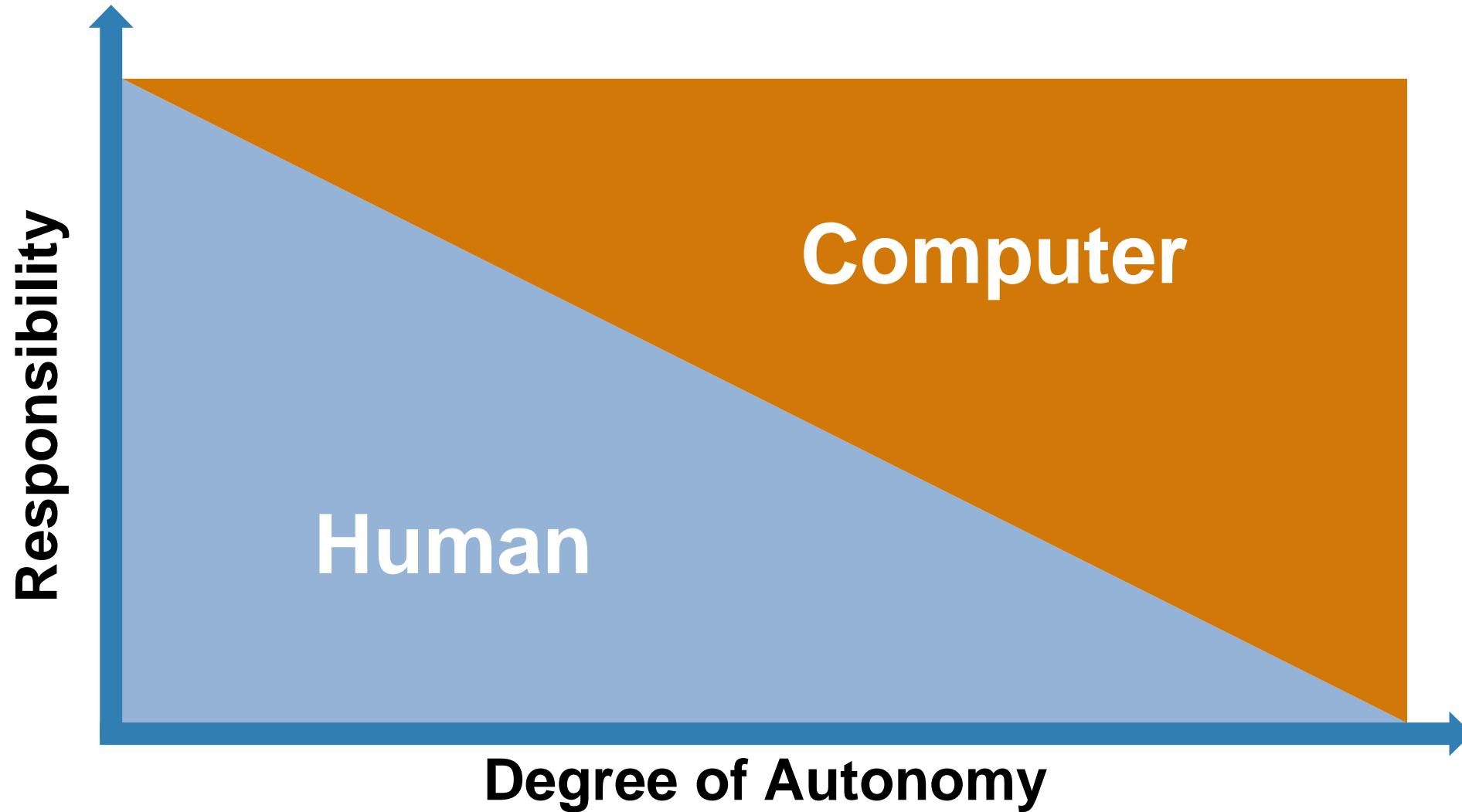
Capabilities of an Autonomous System



Capabilities of an Autonomous System



Autonomous Technology – Balancing Responsibility



Cost of rig: \$1,000,000+

Repair cost: \$100,000

Cost of valve: \$200

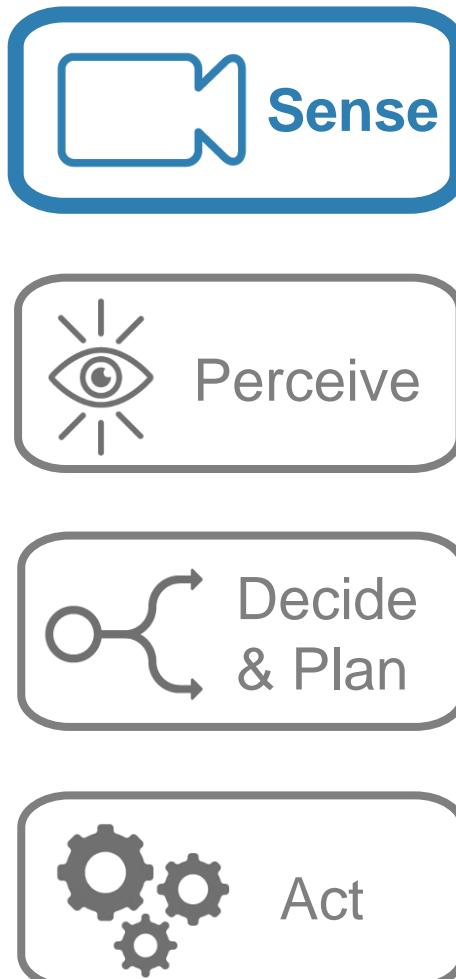




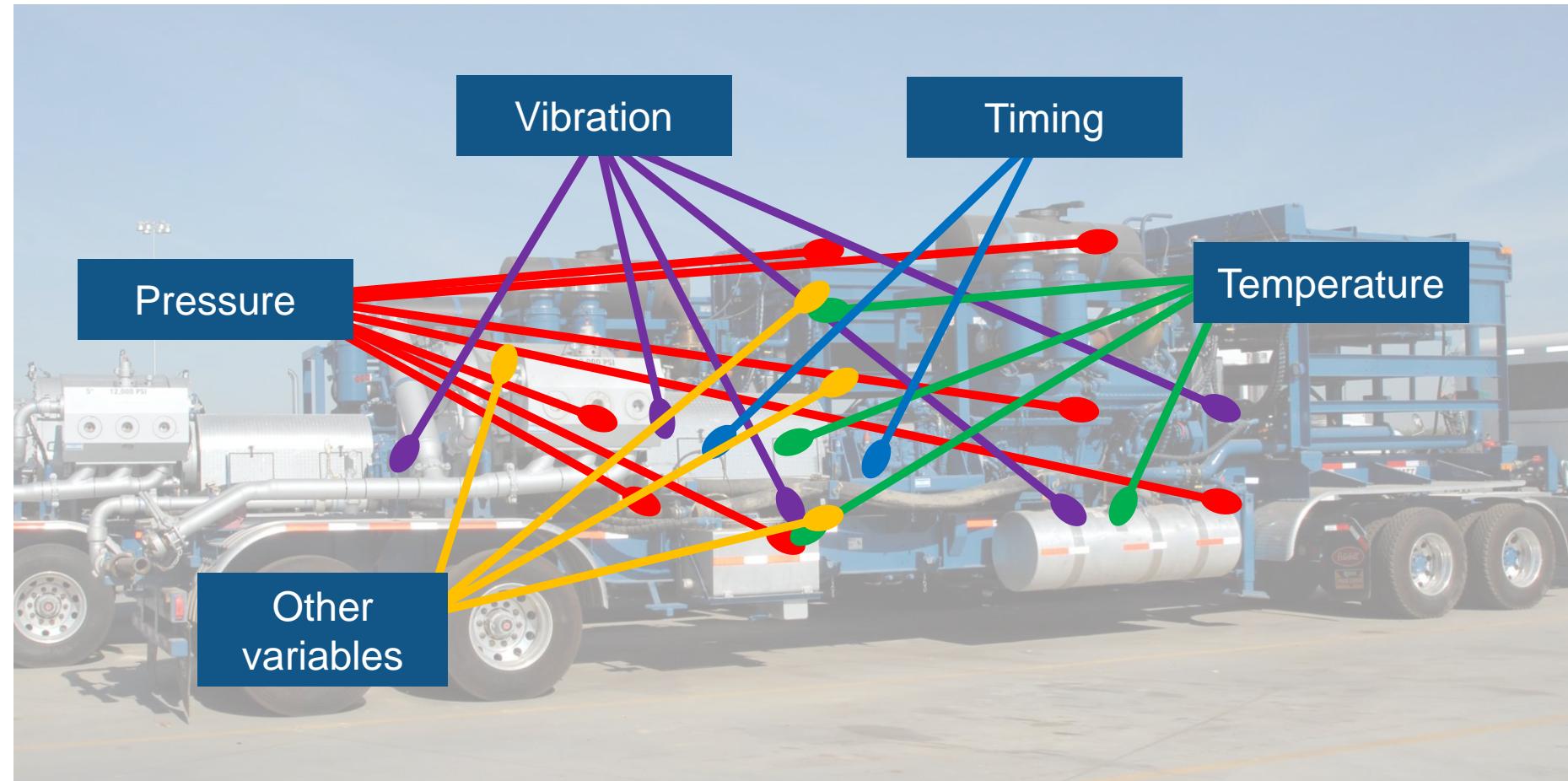




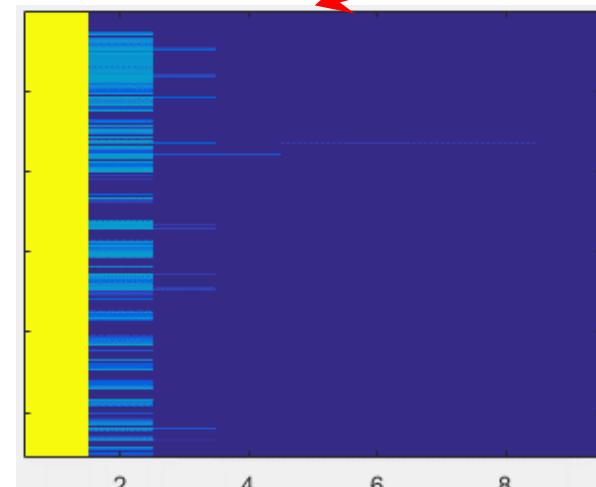
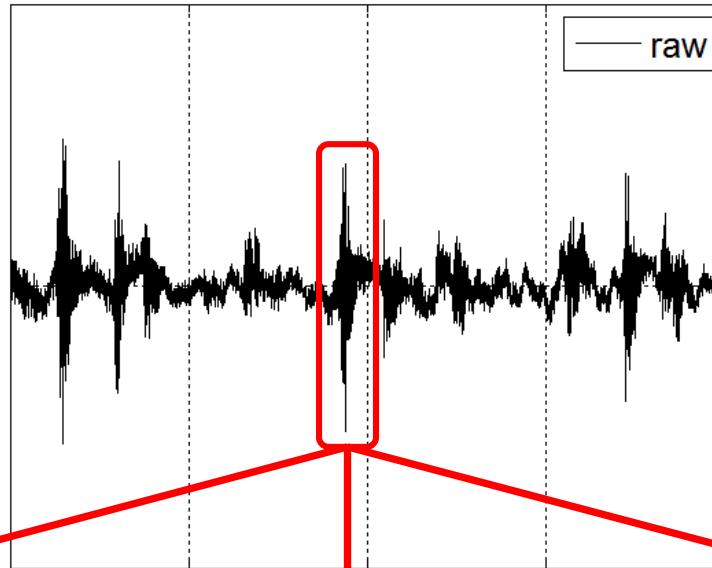
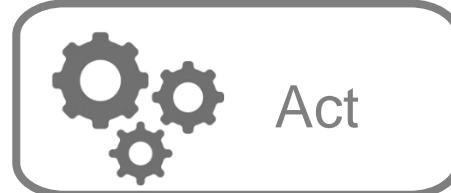
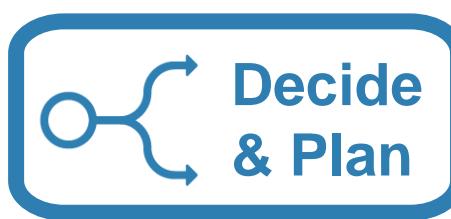
Autonomous Service for Predictive Maintenance



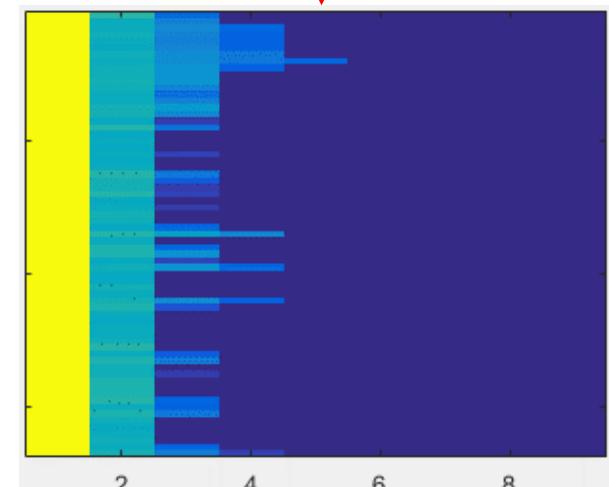
Which sensor values should they use?



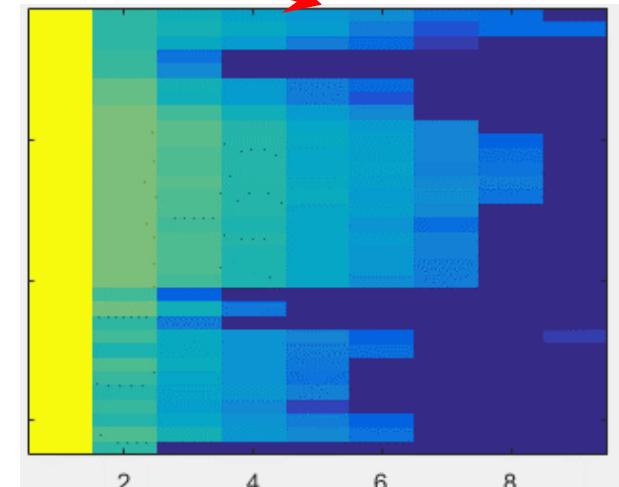
Autonomous Service for Predictive Maintenance



Normal Operation



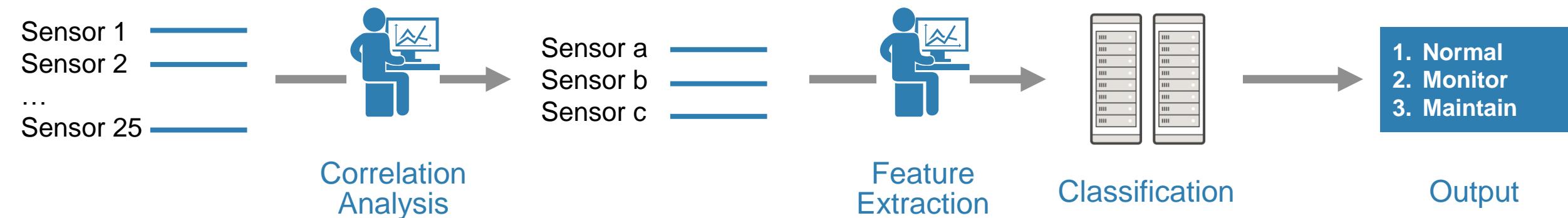
Monitor Closely



Maintenance Needed

Machine Learning or Deep Learning?

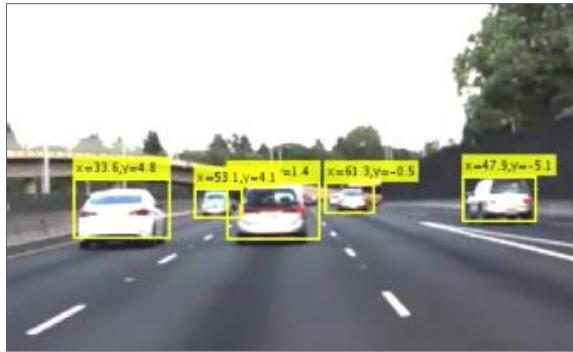
Machine Learning Approach



Deep Learning Approach



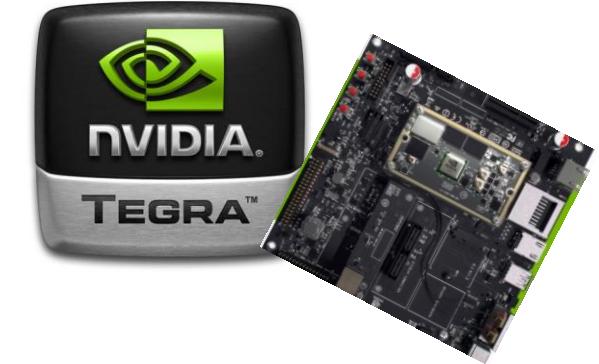
R2017b Mega Release of Deep Learning Capabilities



Design Deep Learning
& Vision Algorithm



Accelerate and Scale
Training



High Performance
Embedded Implementation

Deep learning design is **easy**
in MATLAB

Apps for Ground Truth Labeling,
Pixel Labeling
Pre-trained **model importer**
Training Visualization

Parallel Computing Toolbox

7x faster than pyCaffe
2x faster than TensorFlow

GPU Coder

14x faster than pyCaffe
4x faster than TensorFlow
1.6x faster than C++ Caffe

What are the best predictors?

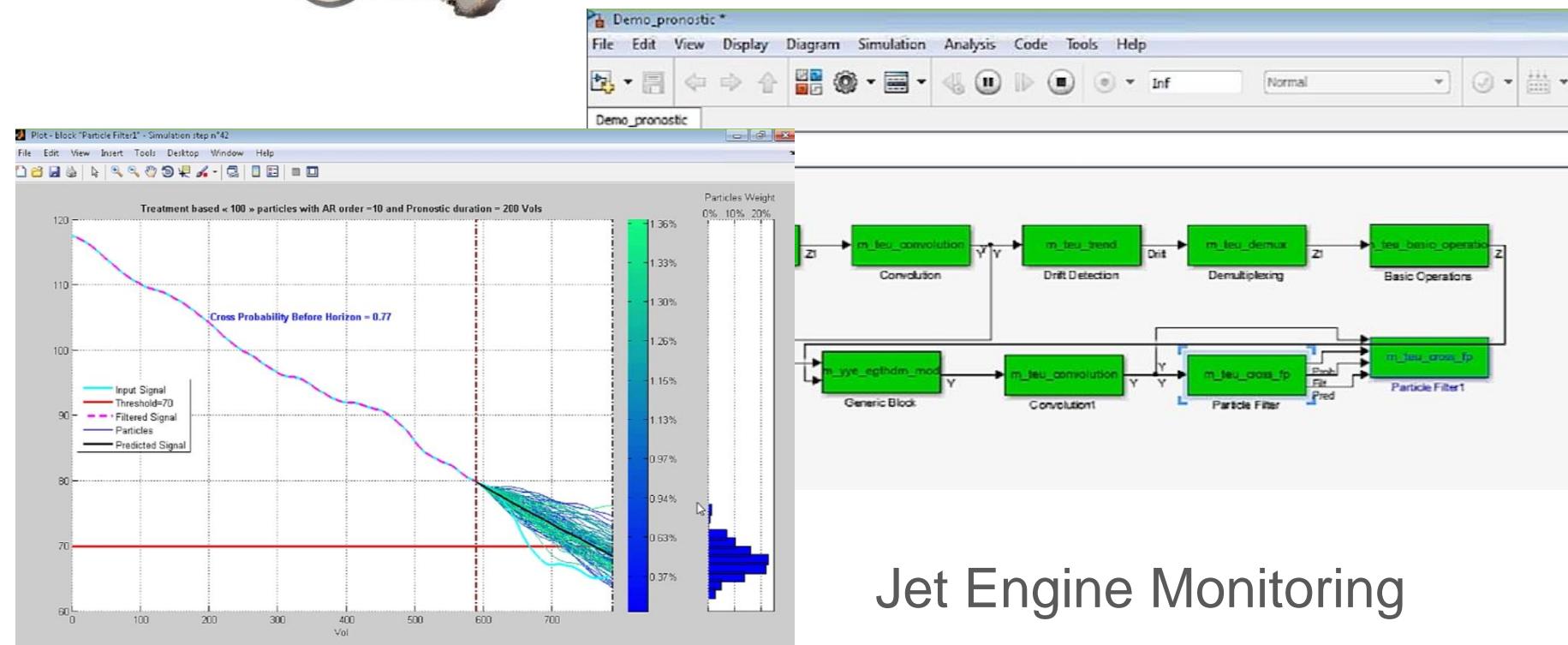
- Data-driven

What are the best predictors?

- Data-driven
- Model-driven



SAFRAN
Sneecma



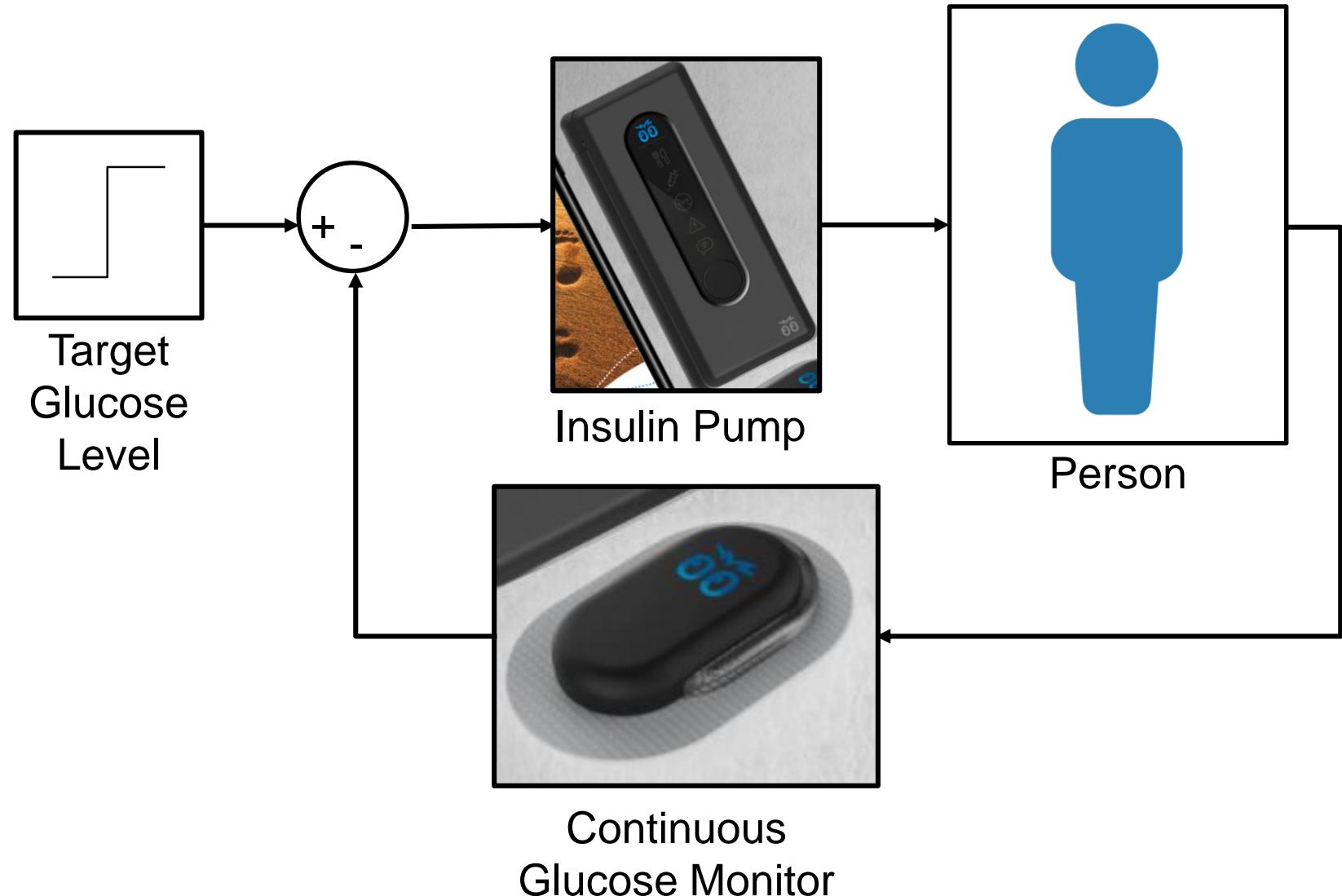
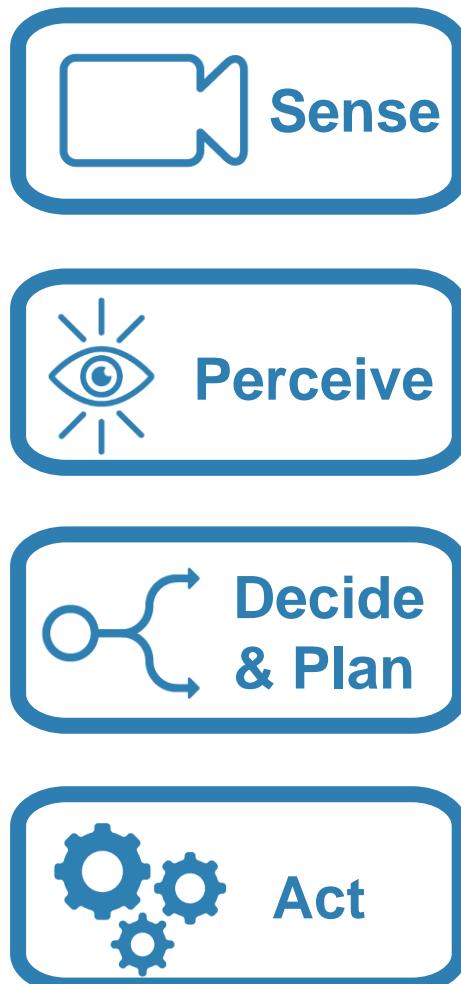
Jet Engine Monitoring

Autonomous Glucose Level Management



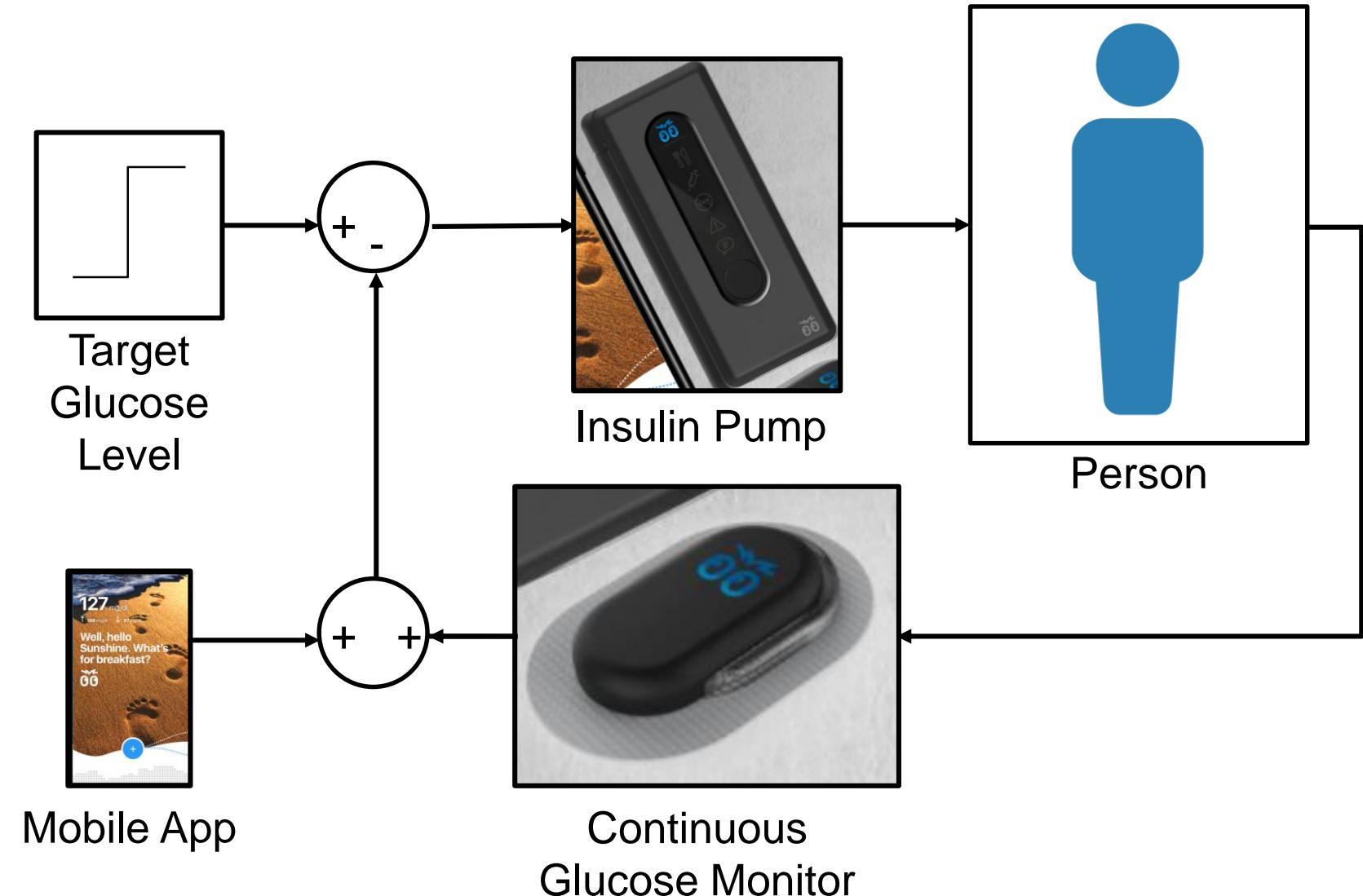
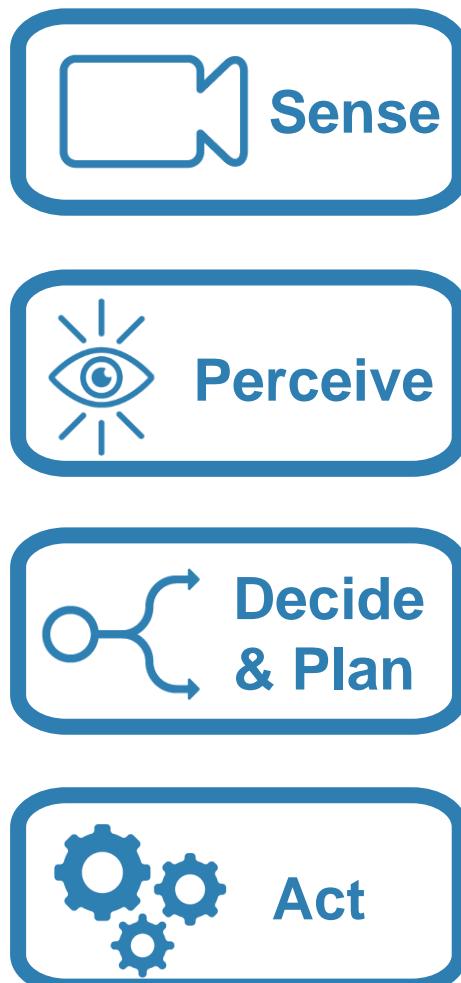
Autonomous Glucose Level Management

Bigfoot Biomedical



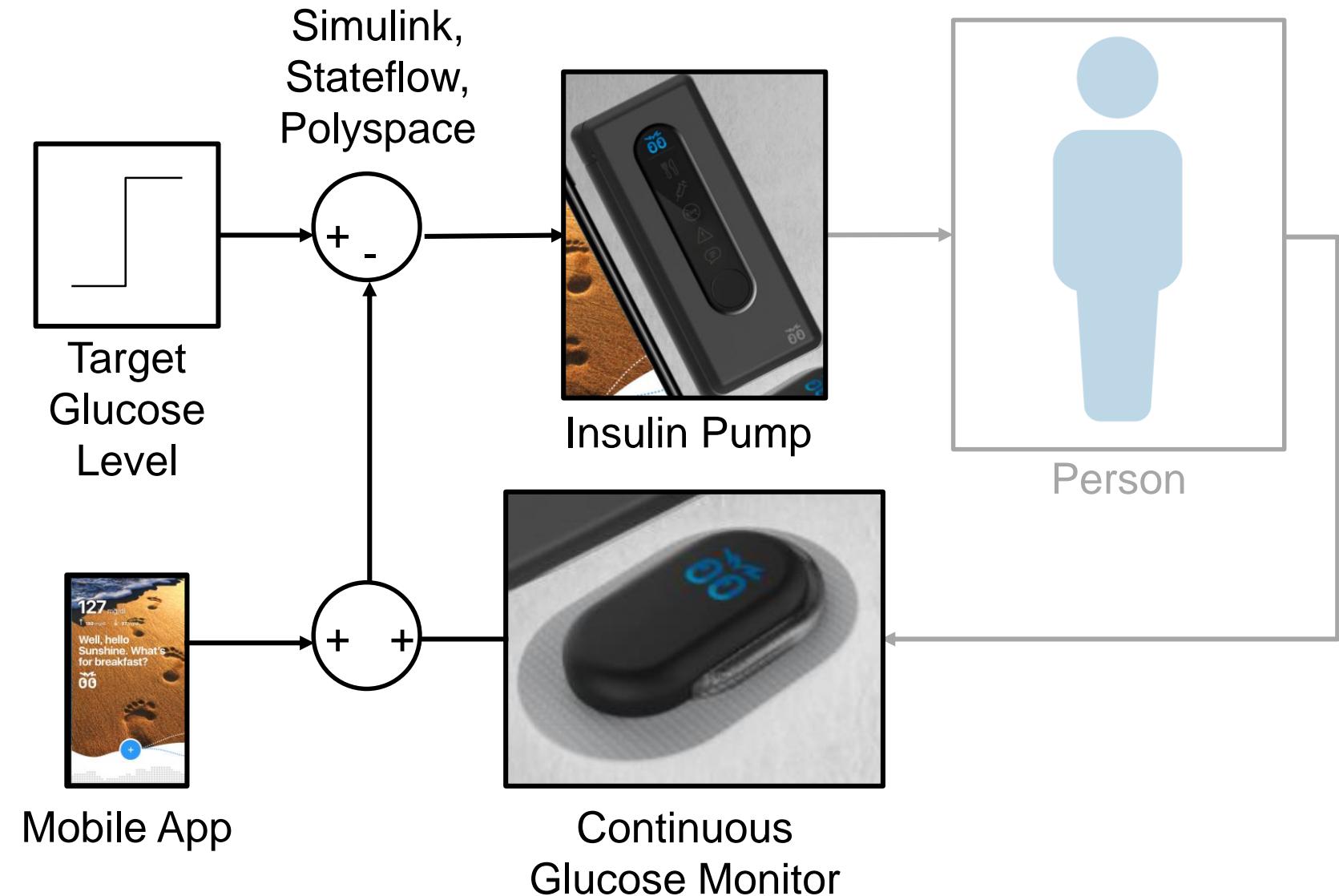
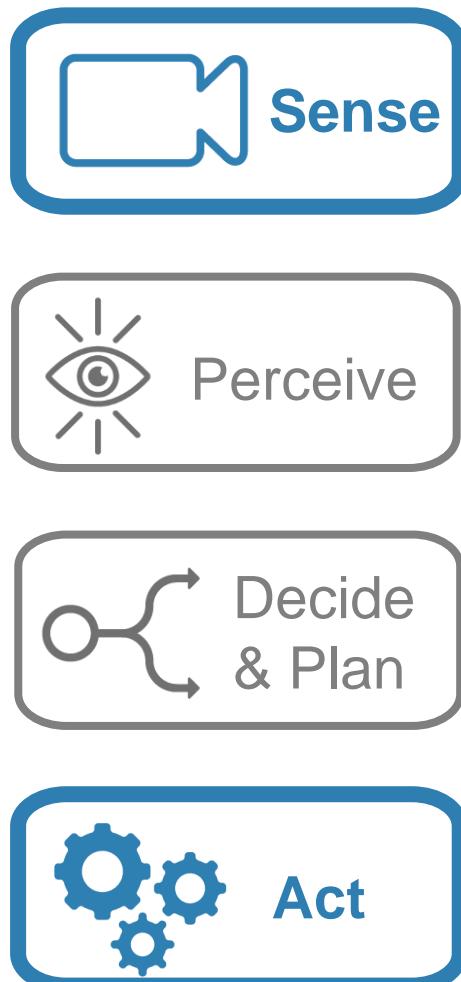
Autonomous Glucose Level Management

Bigfoot Biomedical



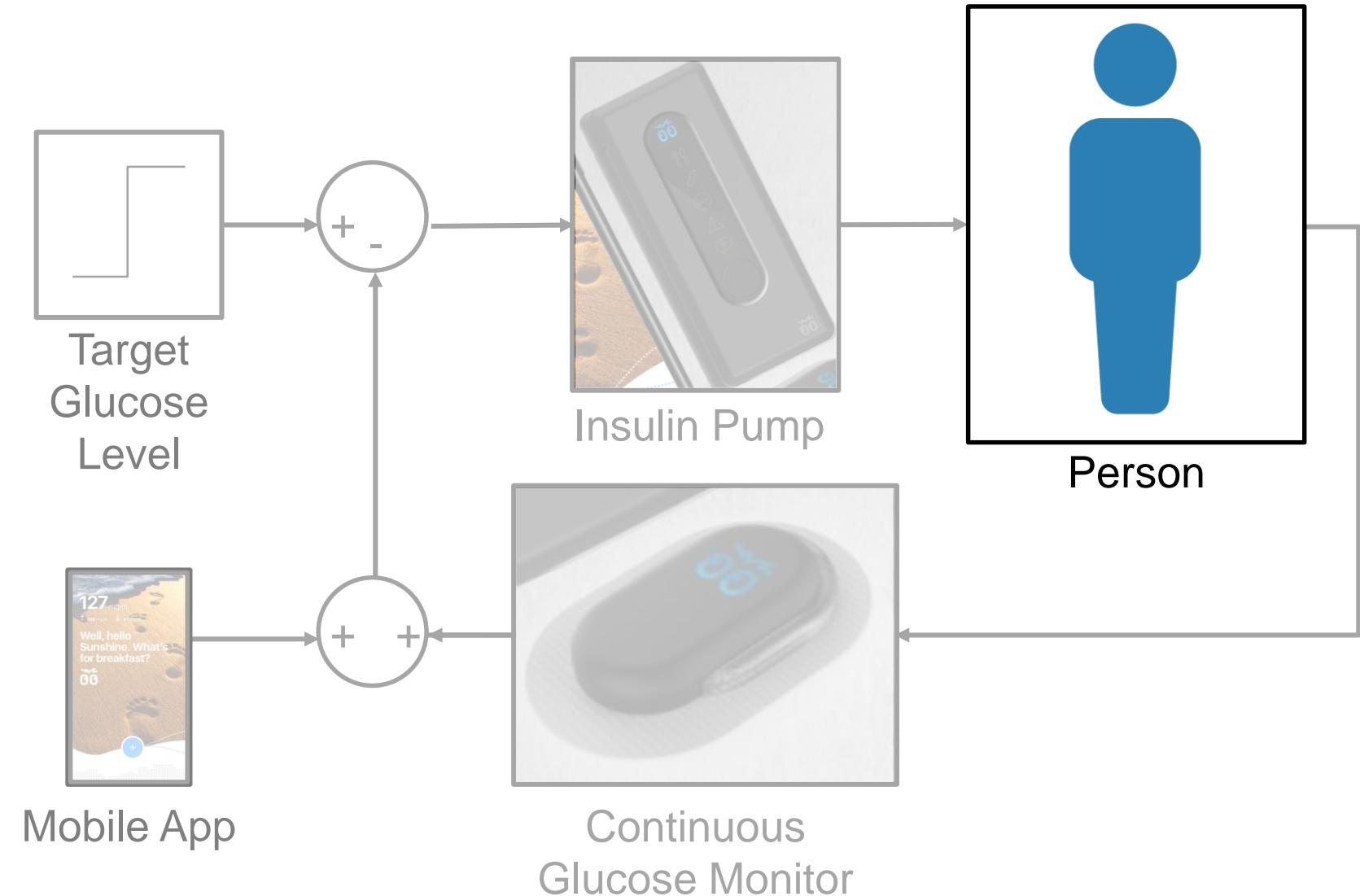
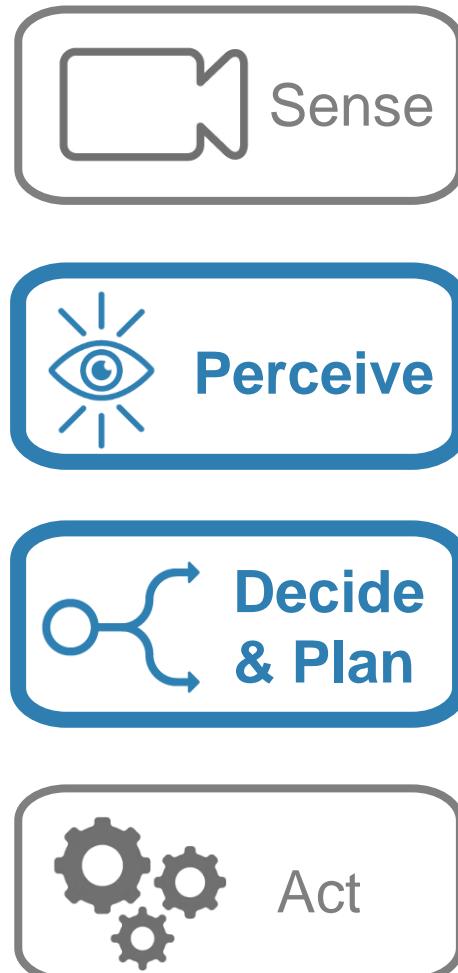
Autonomous Glucose Level Management

Bigfoot Biomedical



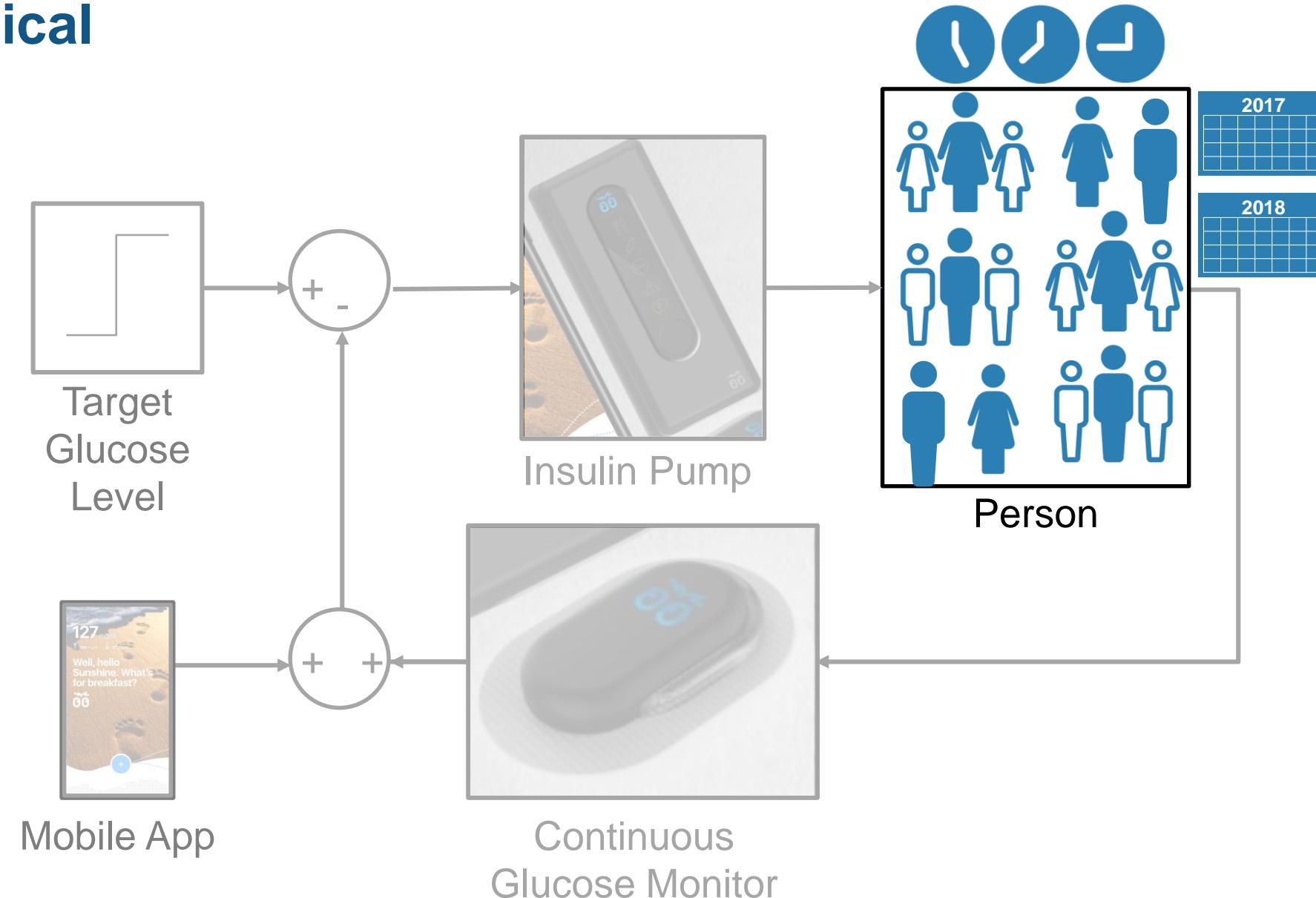
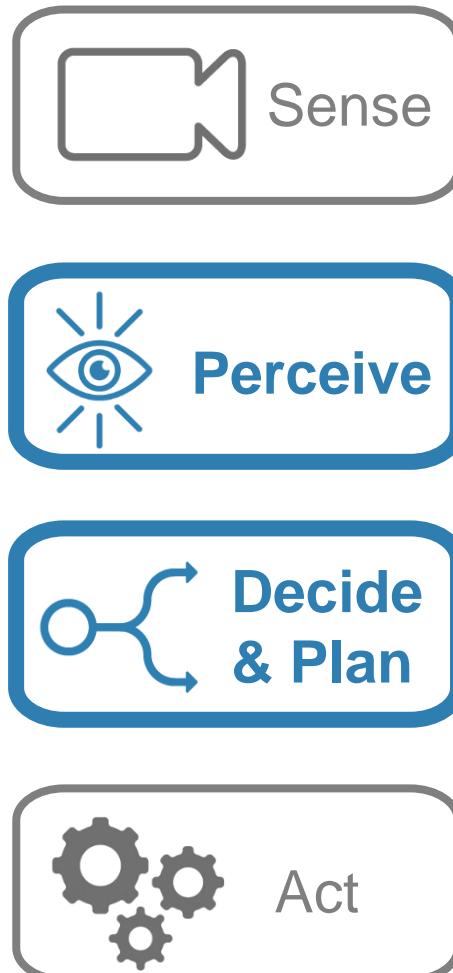
Autonomous Glucose Level Management

Bigfoot Biomedical



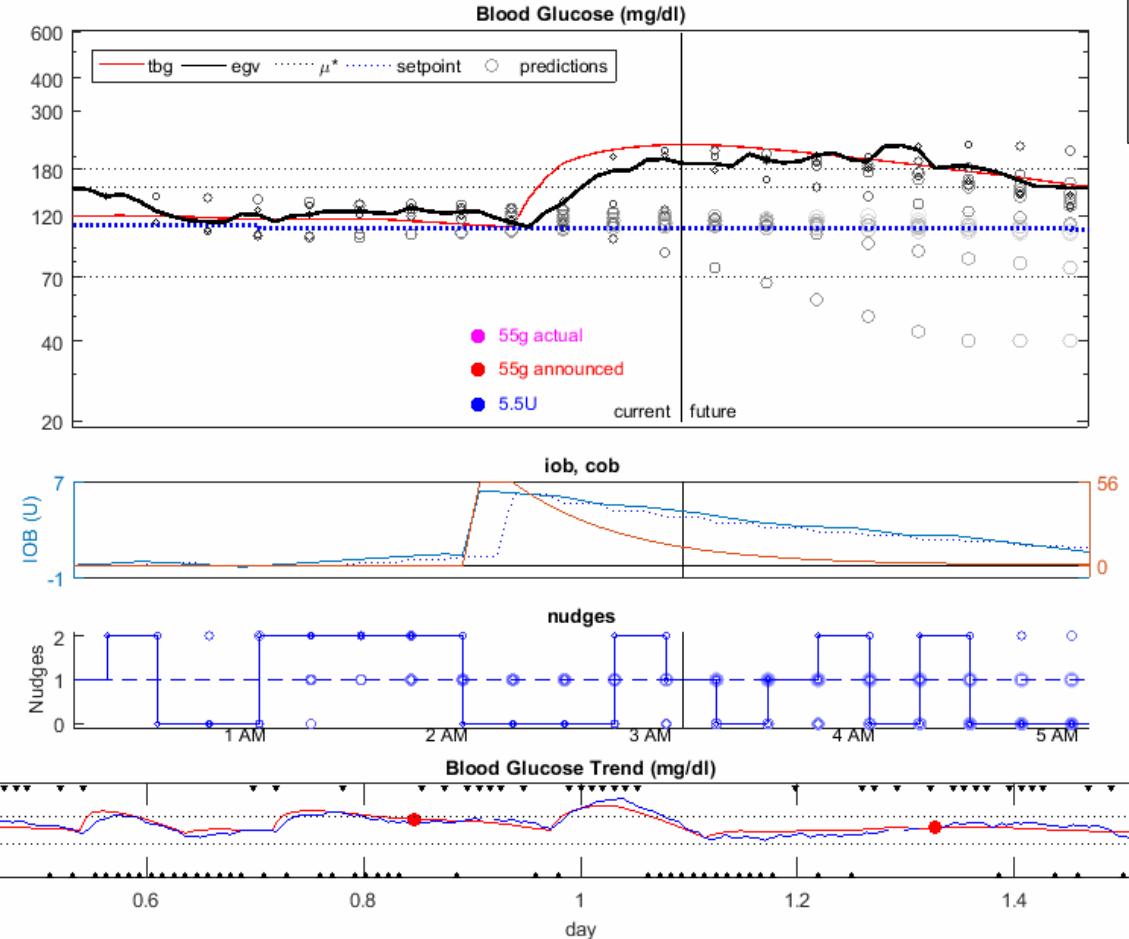
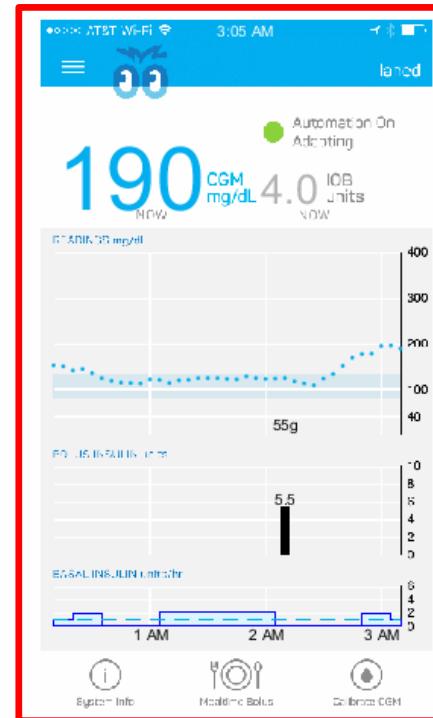
Autonomous Glucose Level Management

Bigfoot Biomedical



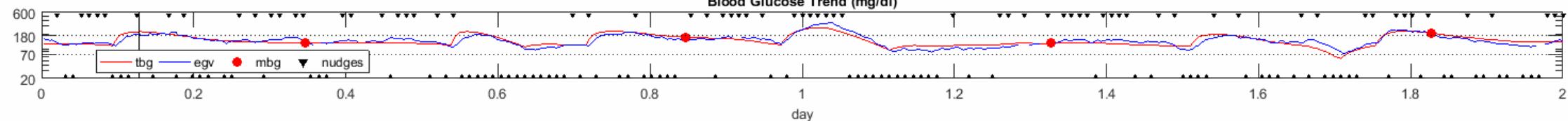
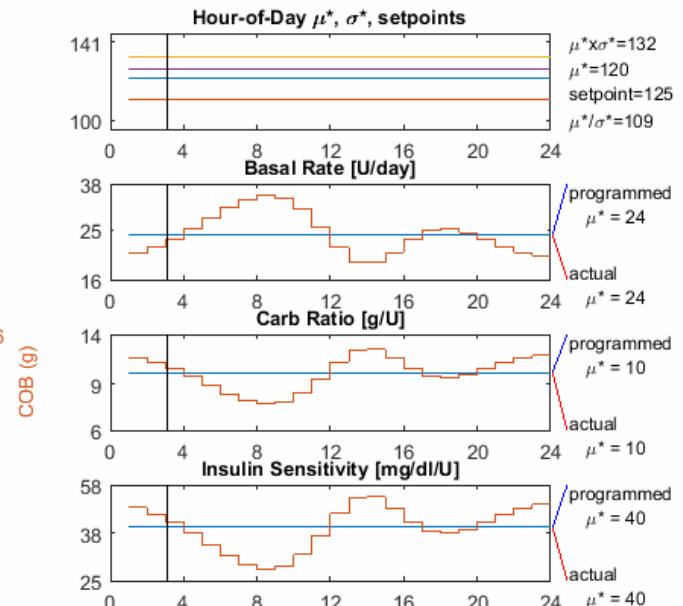
Virtual Clinic

Generating data through simulation



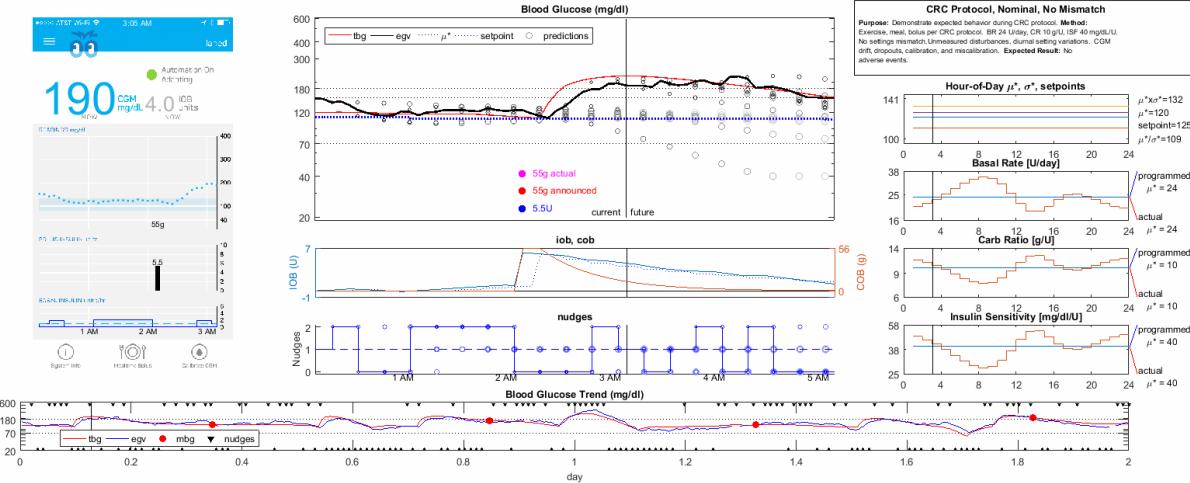
CRC Protocol, Nominal, No Mismatch

Purpose: Demonstrate expected behavior during CRC protocol. **Method:** Exercise, meal, bolus per CRC protocol. BR 24 U/day, CR 10 g/U, ISF 40 mg/dL/U. No settings mismatch. Unmeasured disturbances, diurnal setting variations. CGM drift, dropouts, calibration, and miscalibration. **Expected Result:** No adverse events.



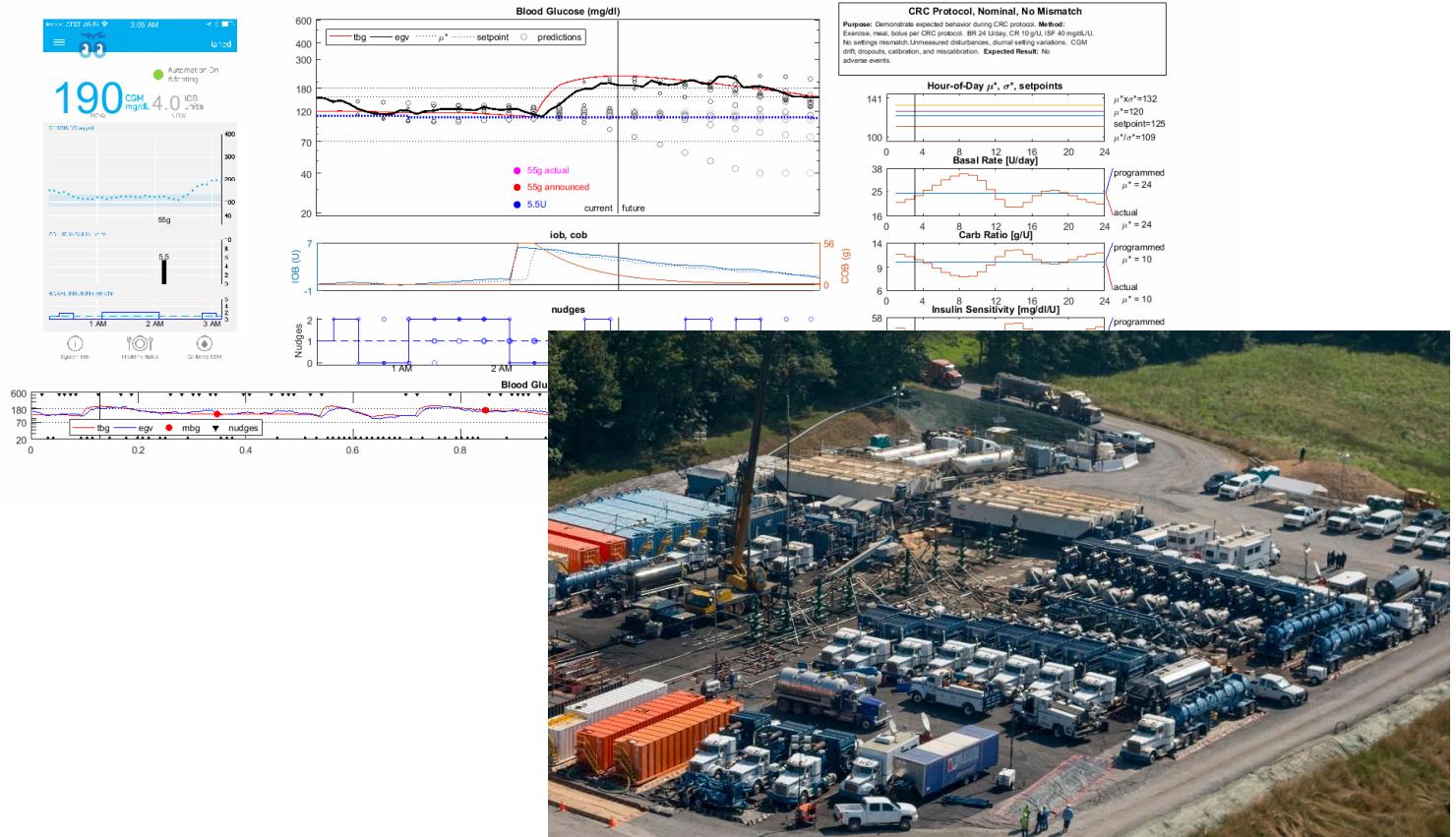
Virtual Clinic

Scaling computations to simulate 50 million patients a day



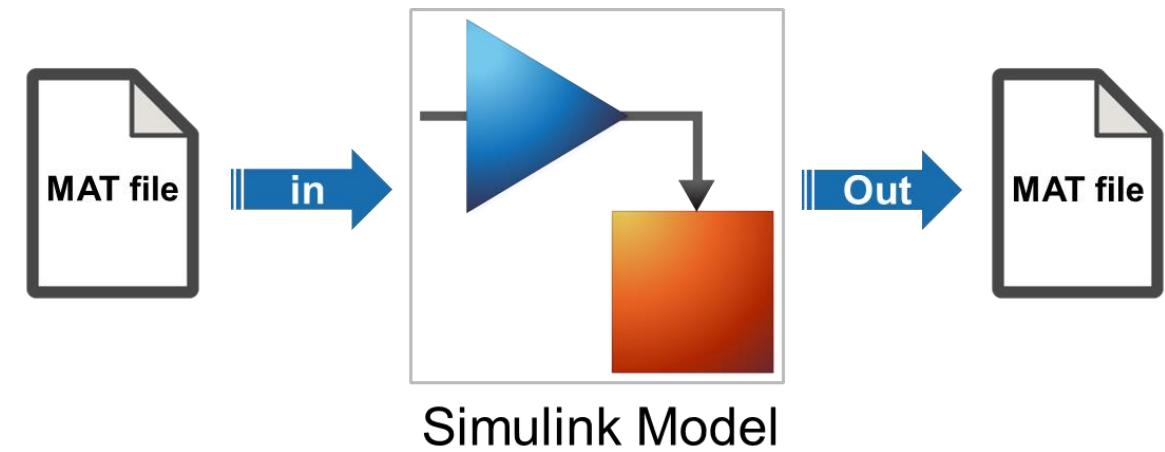
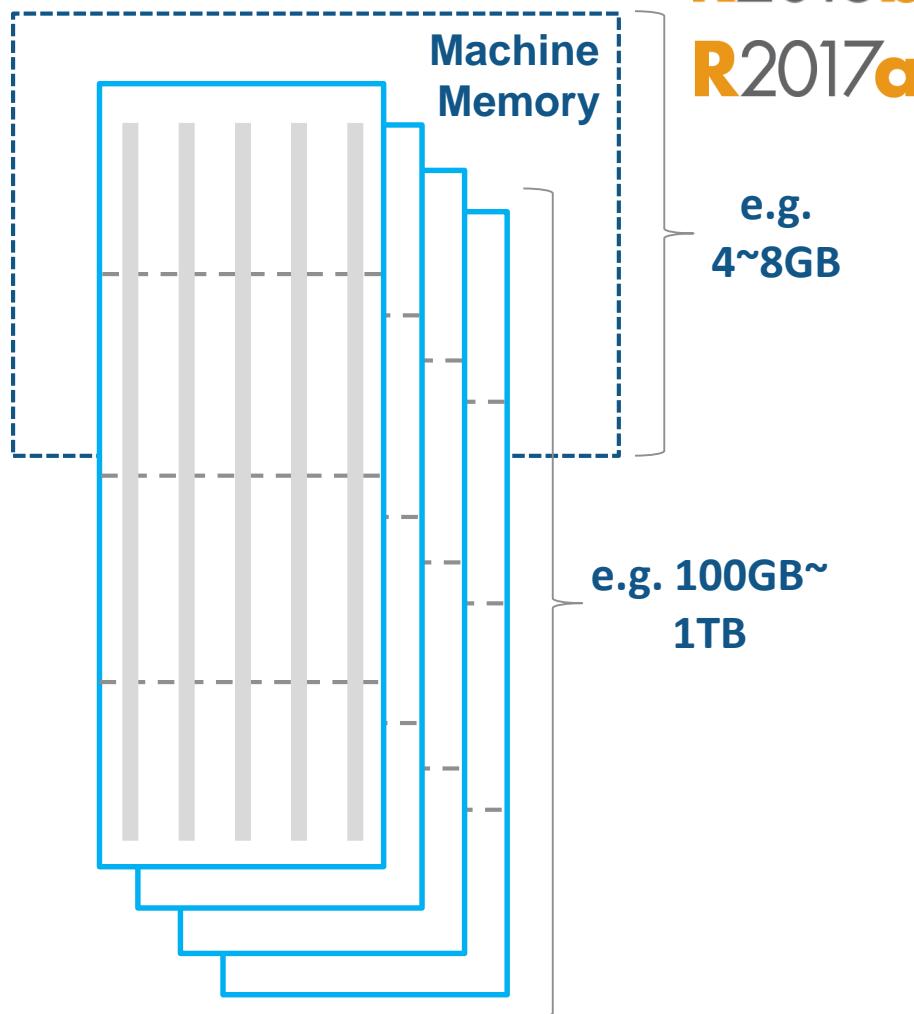
Where will you get your data?

- Simulation
- Public repositories
- In the lab
- In the field
- Internet of Things (IoT)



Working with Big Data Just Got Easier

Tall arrays in MATLAB



Stream large input signals from MAT-files

R2017a

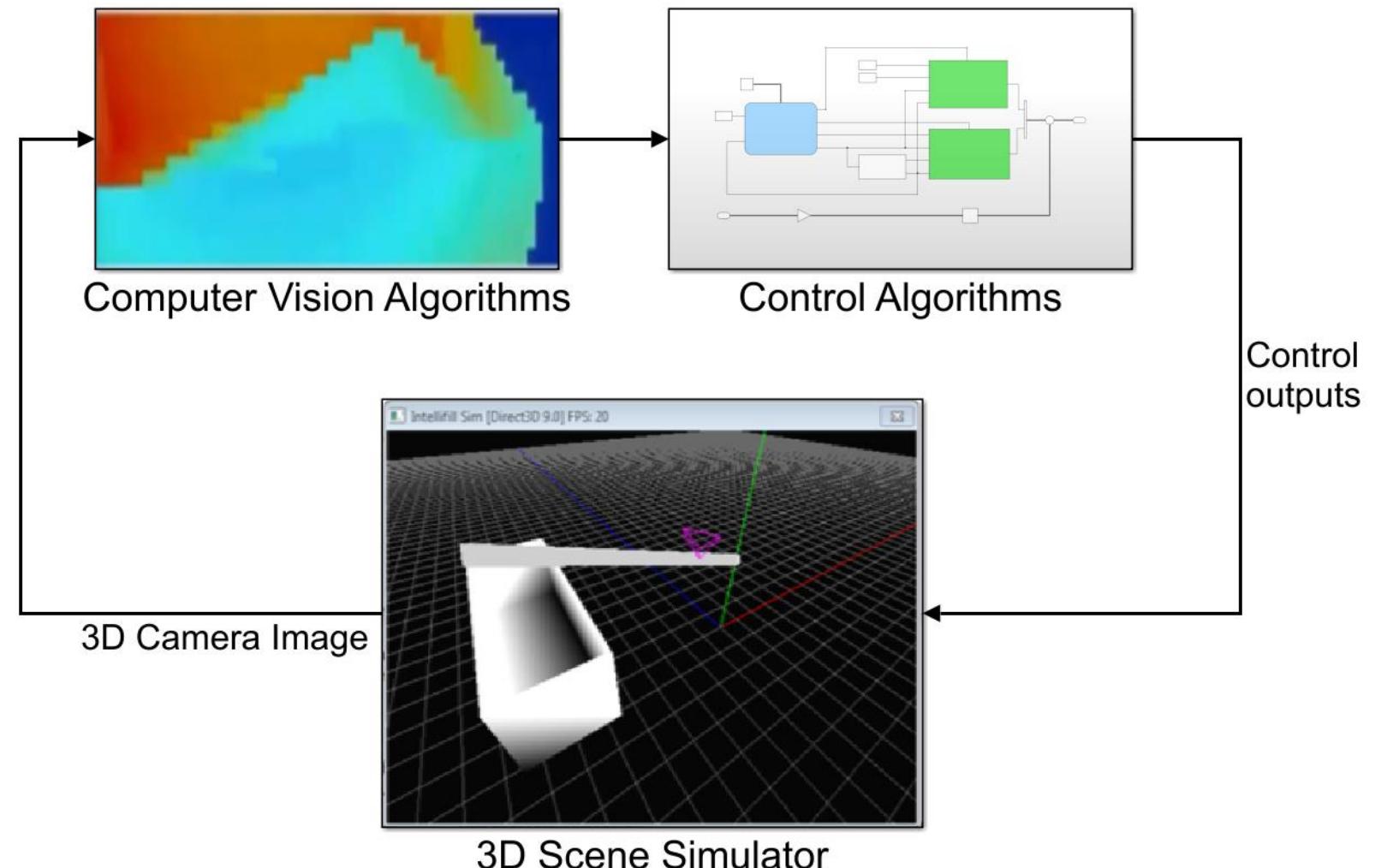
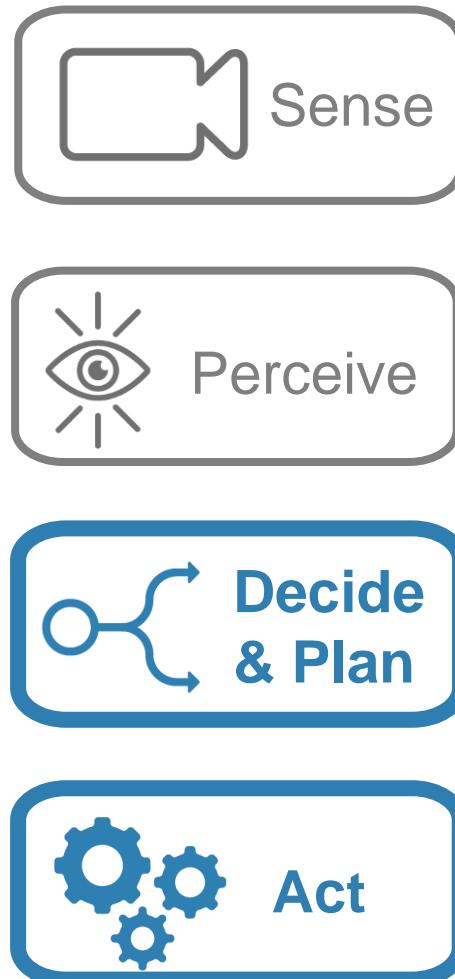


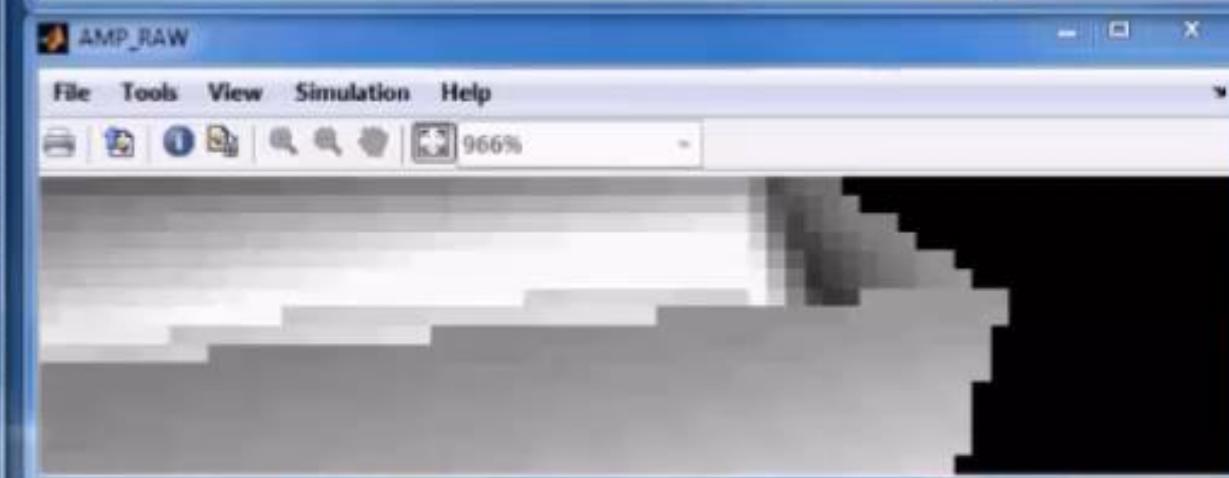
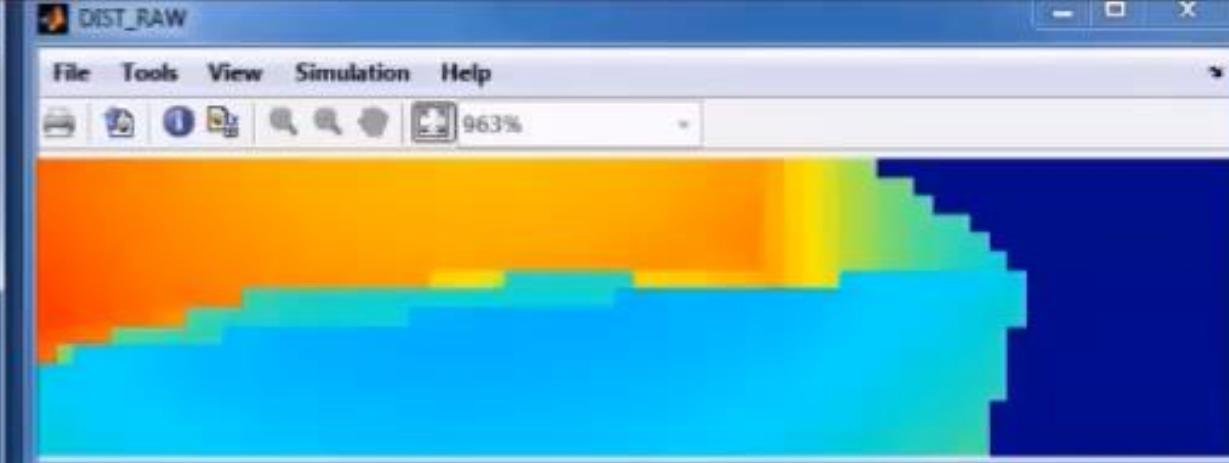
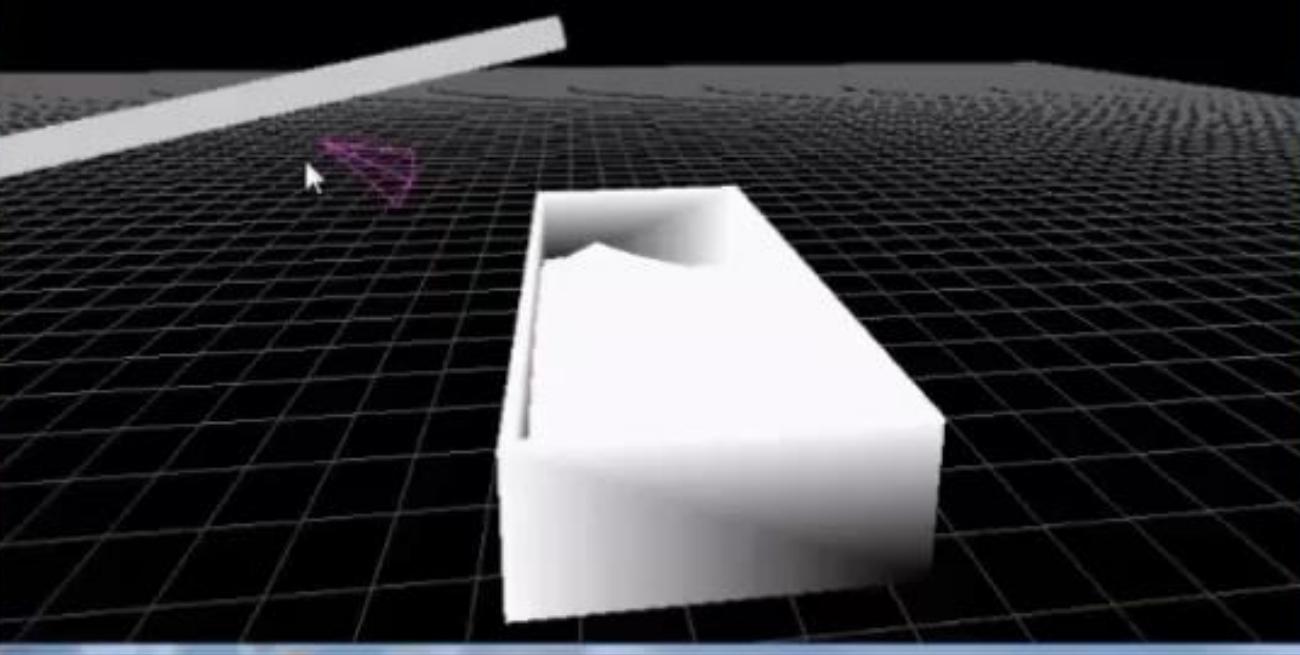


Autonomous Trailer Filling

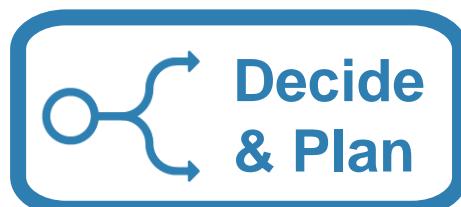


Autonomous Trailer Filling





Autonomous Trailer Filling



3D Cameras



Computer vision and controls algorithms

CAN

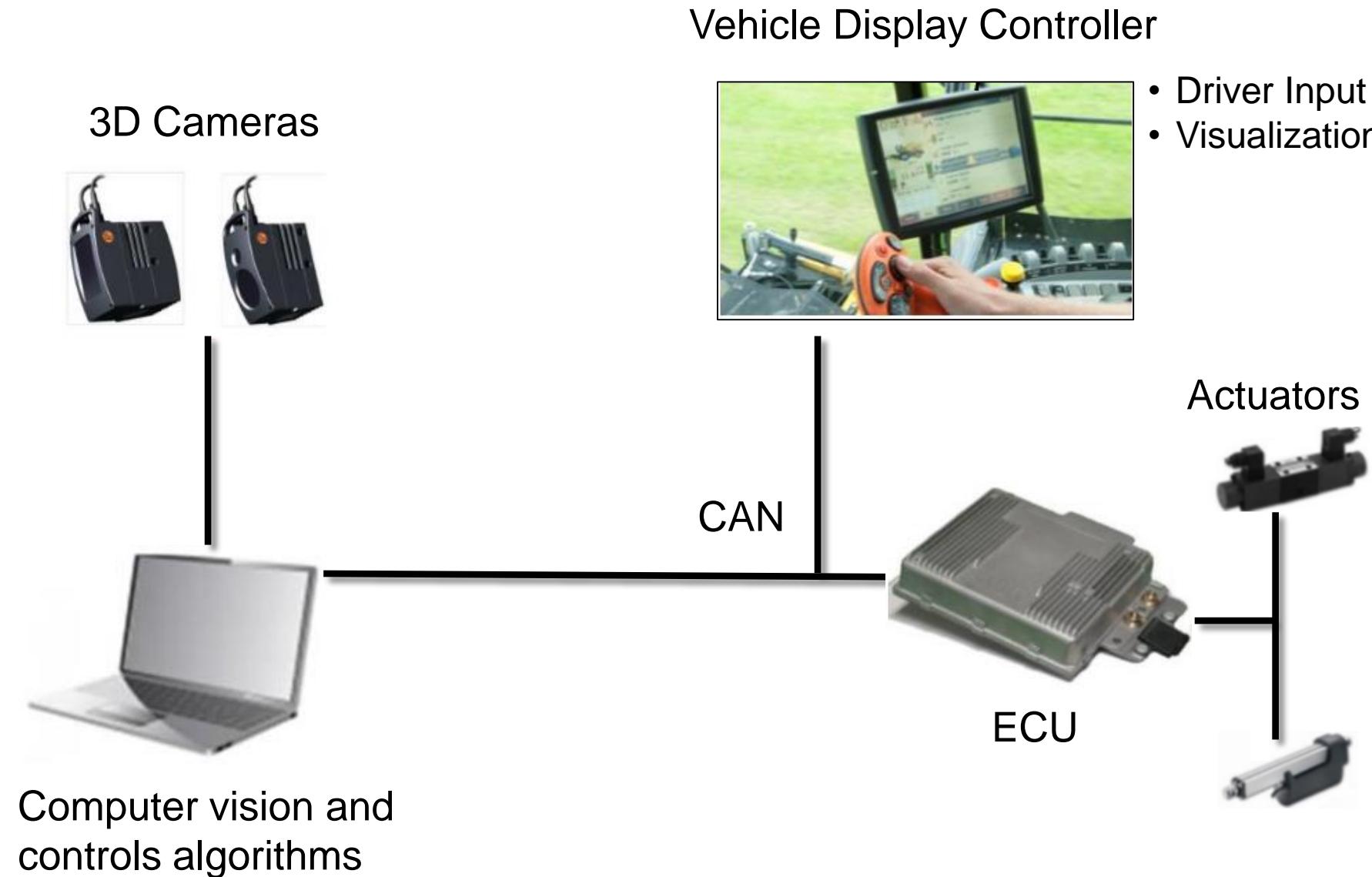
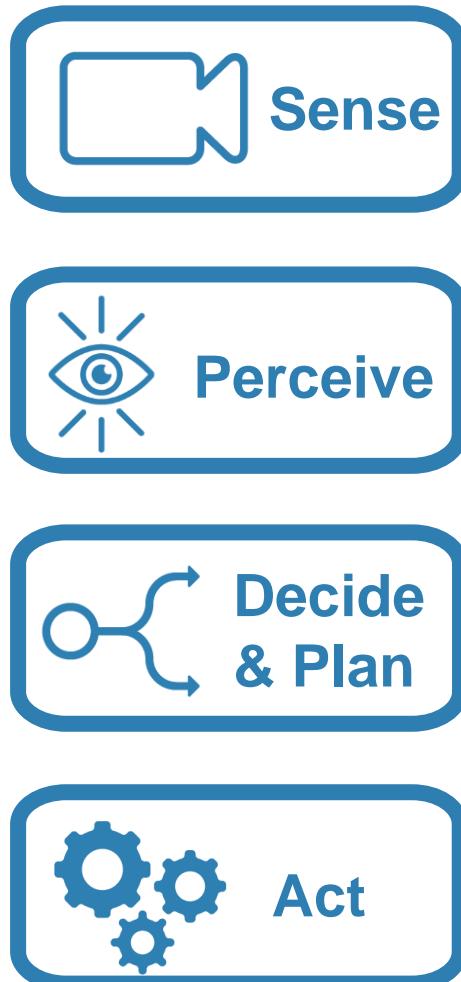


ECU

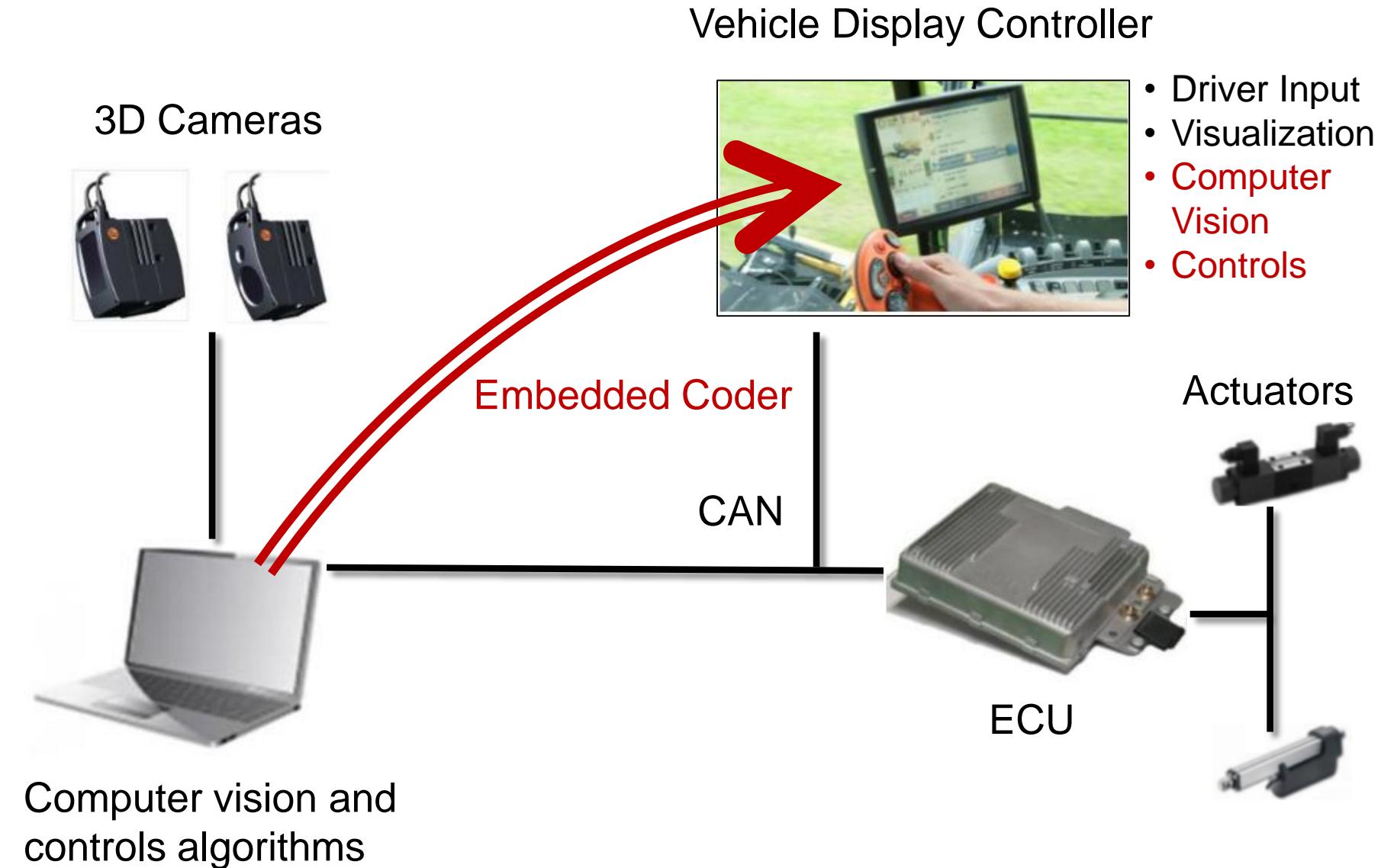
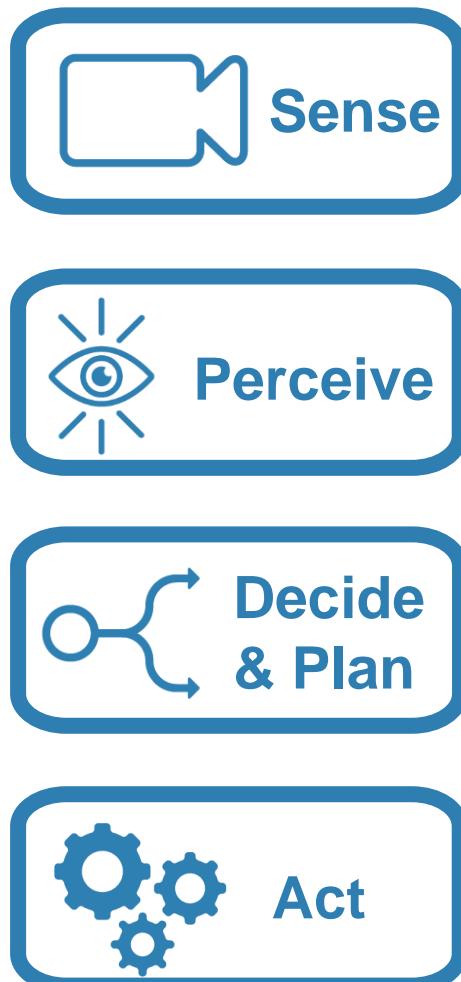


Actuators

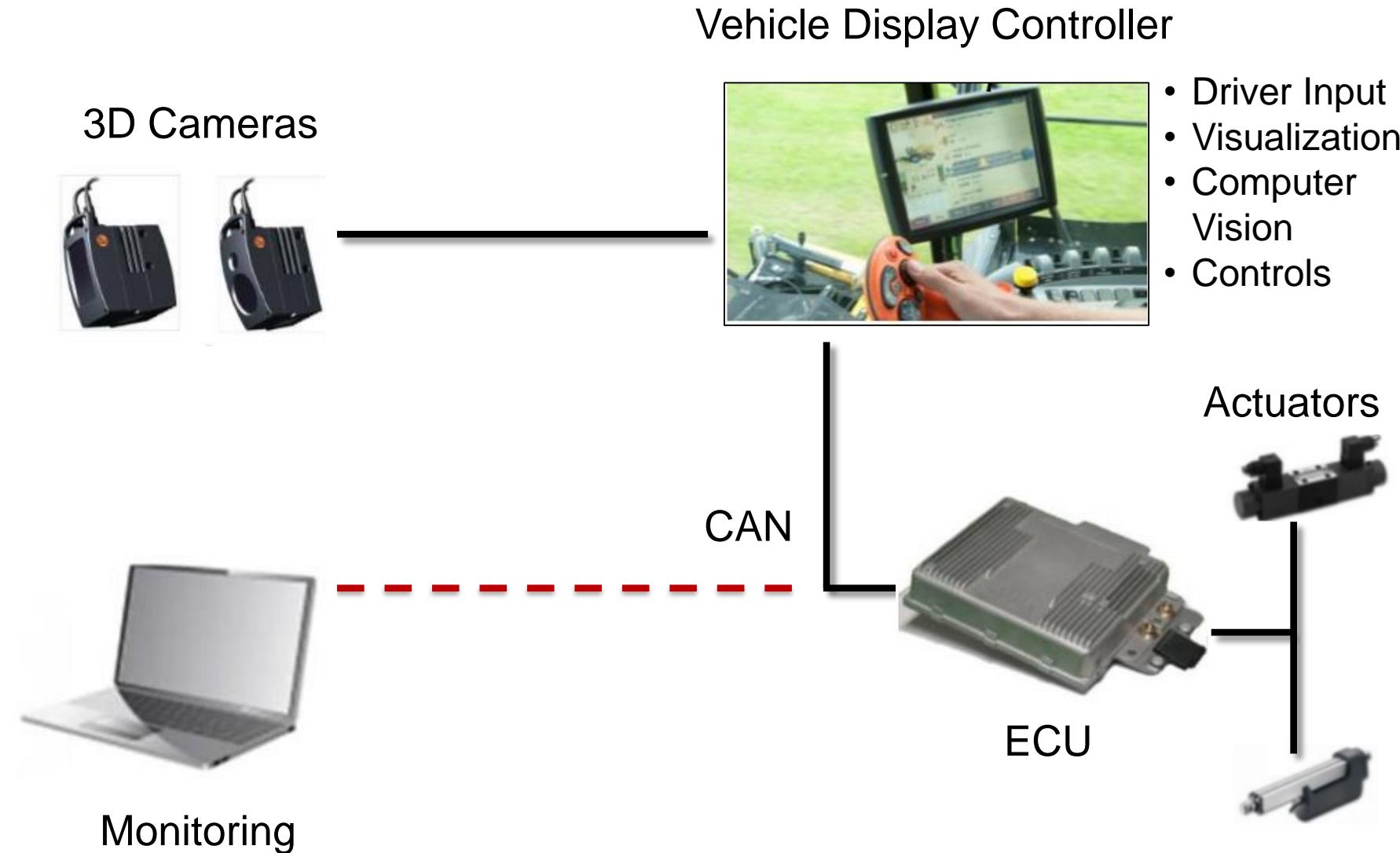
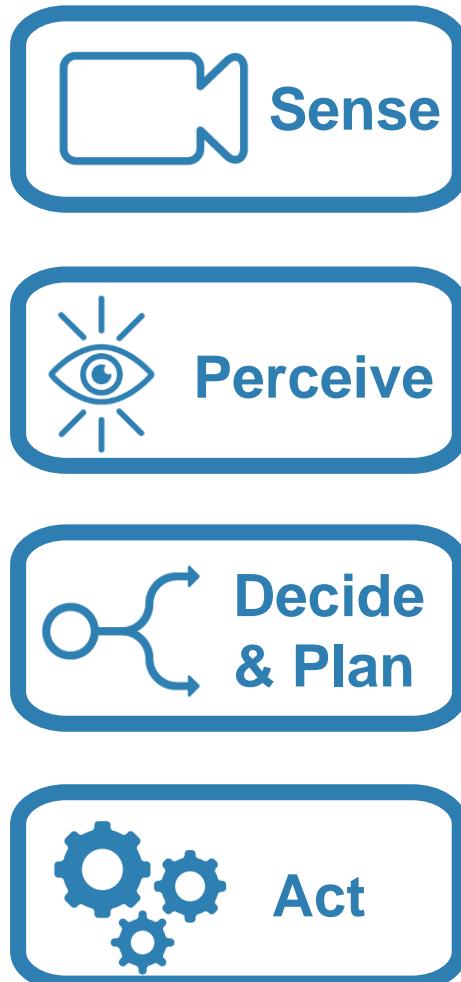
Autonomous Trailer Filling



Autonomous Trailer Filling

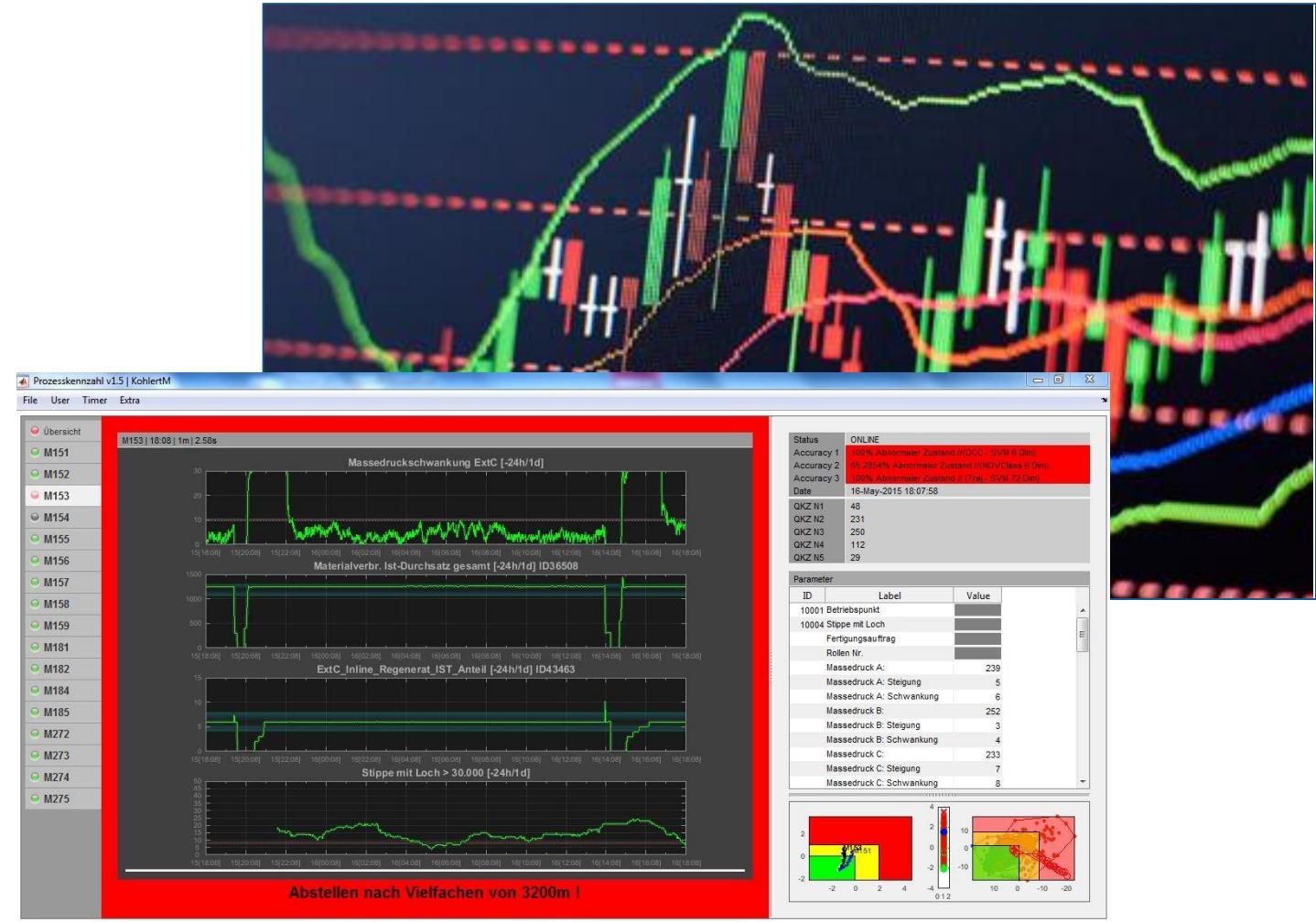


Autonomous Trailer Filling



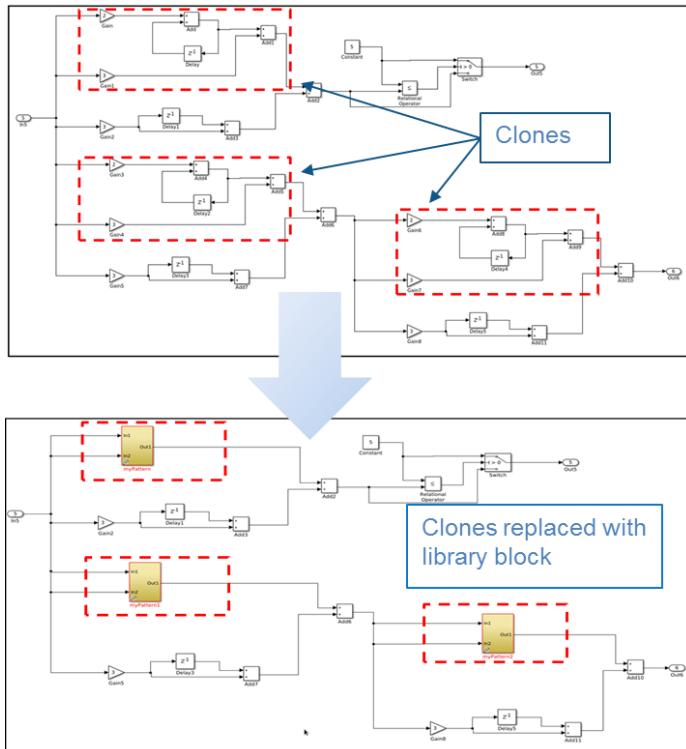
How will you put it into production?

- Embedded Systems
- IT Systems
- Cloud
- Desktop Apps



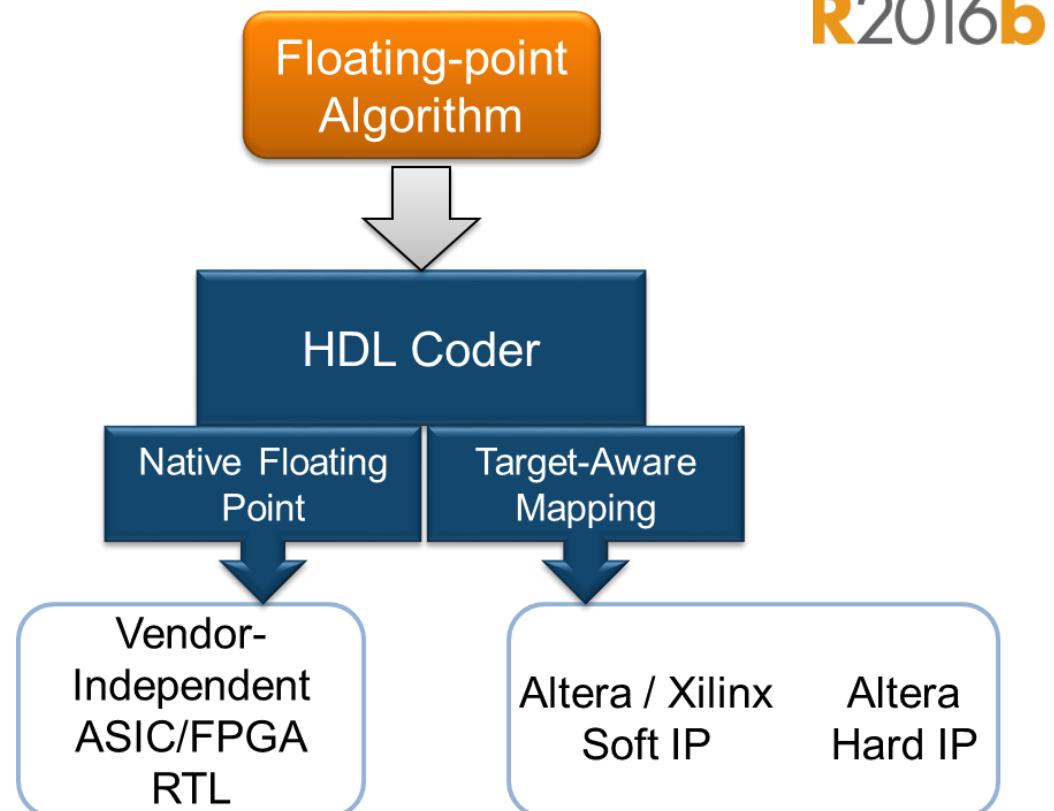
Investments in Model-Based Design

Efficient code generation



R2017a

Floating-point HDL code generation



Investments in Model-Based Design



Code verification in support of CERT C standard

Inputs & Stubbing
Multitasking
Coding Rules & Code I
Bug Finder Analysis
Reporting
Distributed Computing
Advanced Settings

Find defects all

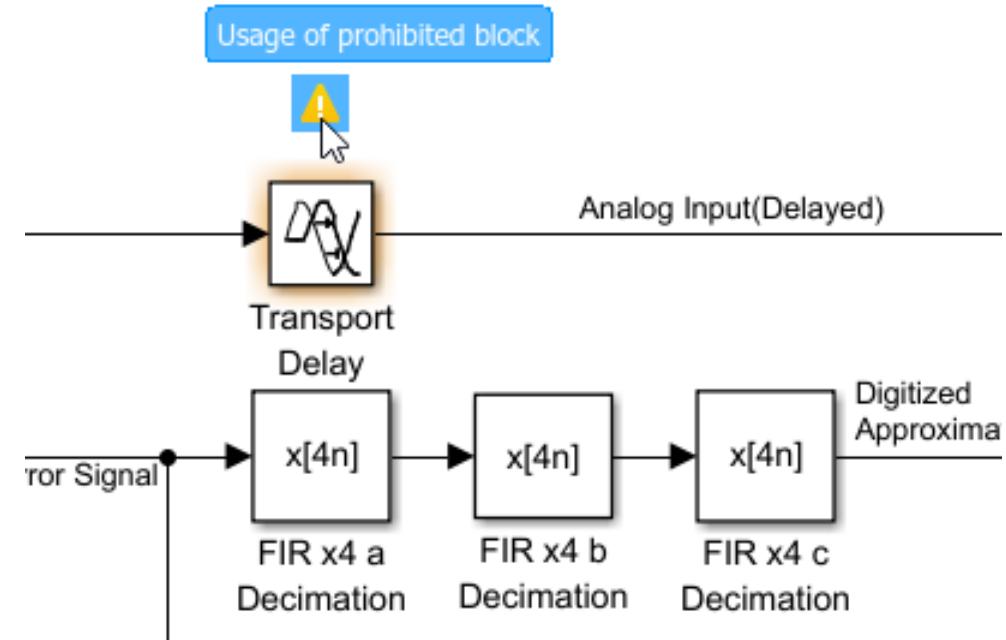
- + Data flow
- + Resource manage
- + Programming
- + Object oriented
- + Concurrency
- + Security
- + Tainted data

```
if (output_v7 >= 0) {
    saved_values[output_v7] = s8_ret;
    return s8_ret
}
return reset_temp
```

Assignment to element of static array (int 16): [-32 .. 112]
array size: 127
array index value: [0 .. 555]

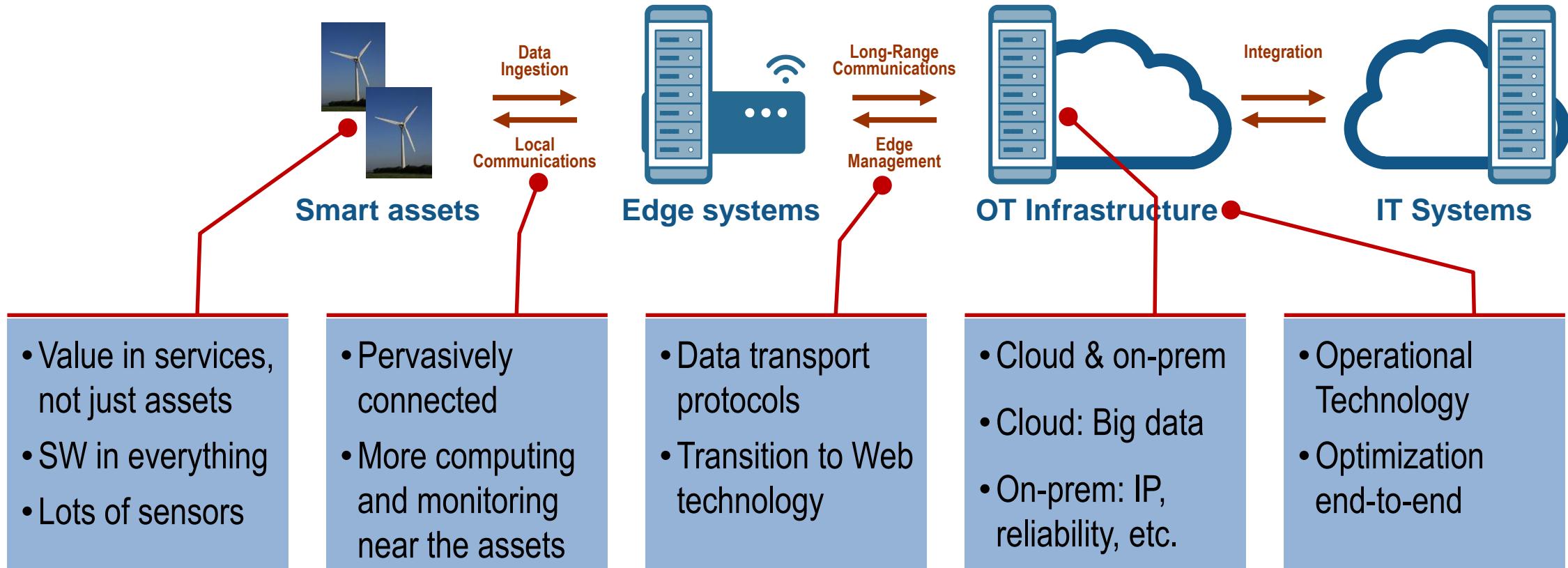
CERT C	Description	Polyspace Code Prover
ARR30-C	Do not form or use out-of-bounds pointers or array subscripts	Array access out of bounds

Detect and fix standards compliance issues at design time

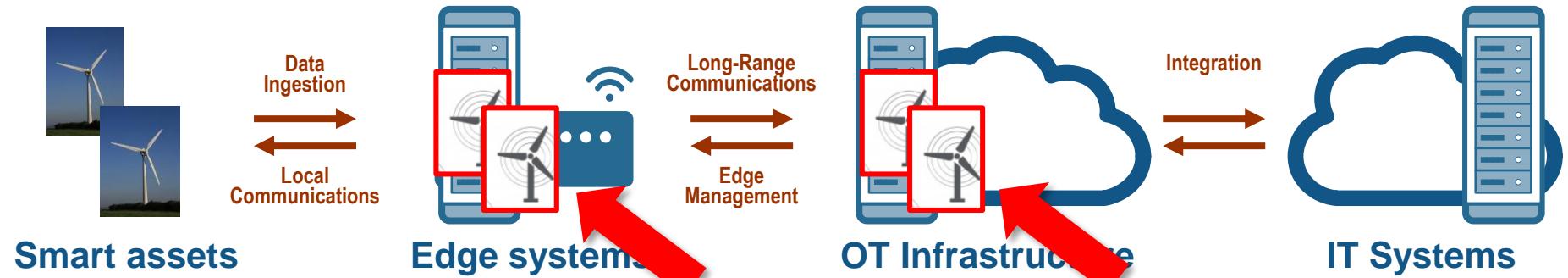


R2016b

Connected Physical Assets in Operation

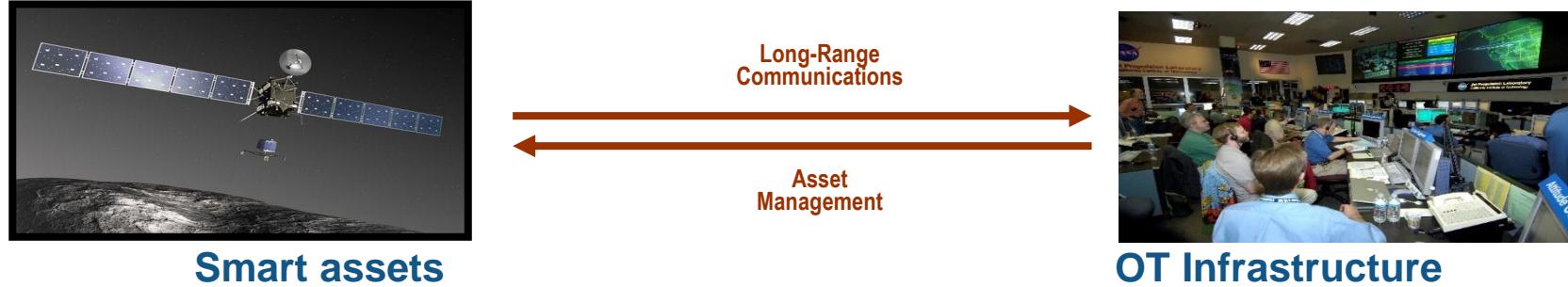


Automation through Digital Twins



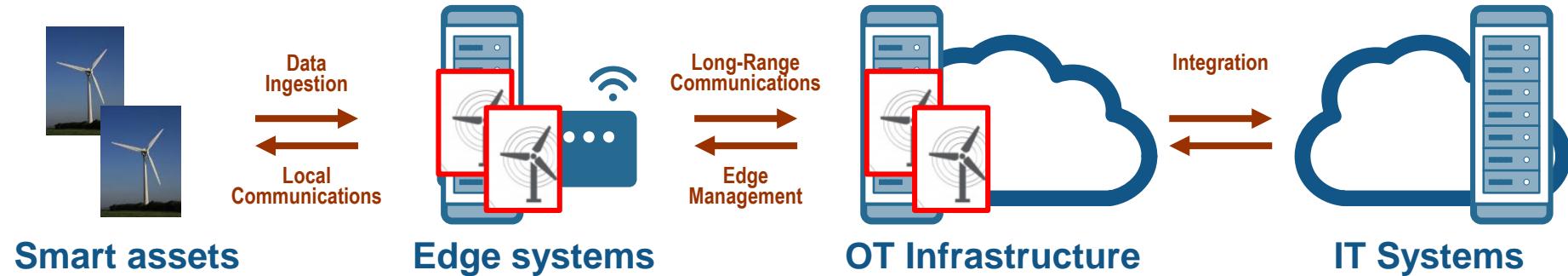
***Digital Twin: Composite of artifacts
that characterize and predict
behavior of a specific real asset.***

“Digital Twin” isn’t a new concept...



Digital Twin concept has been used for a long time, especially when there is a small number of expensive assets and when reliability is critical (e.g., spacecraft, aircraft engines). The infrastructure has been one-off.

Re-imagining the Digital Twin



Sense



Perceive



Decide
& Plan

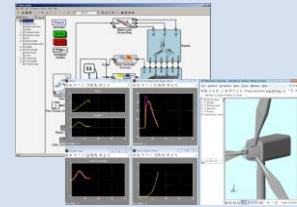
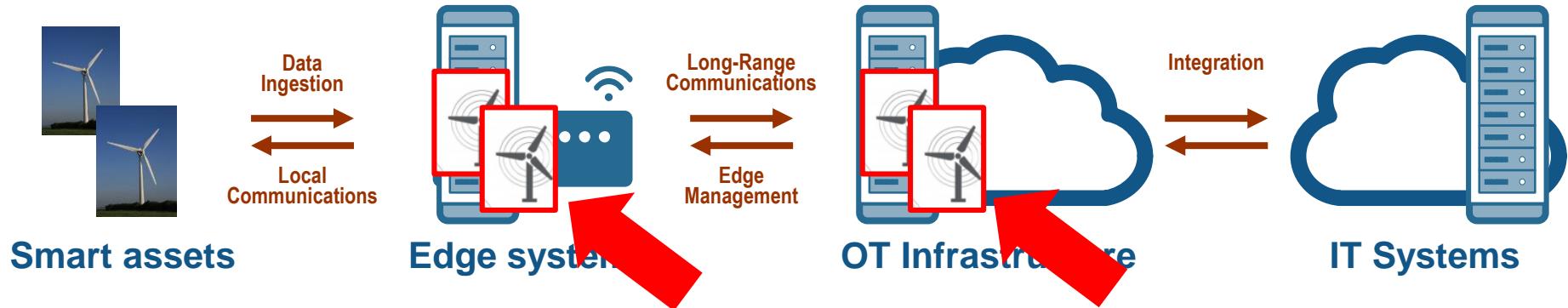


Act

Digital Twin:

- models (dynamic, FEM, data-driven, etc.) and data
- for each asset (e.g., system, component, or system of systems)
- performance and conditions over the asset's history.
- continuously updated as the asset is operated.
- always represents a faithful representation of the current state of the asset.

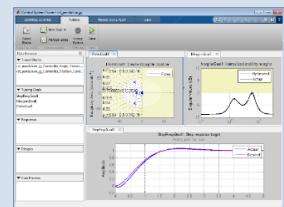
MATLAB and Simulink for Digital Twins: Key Capabilities



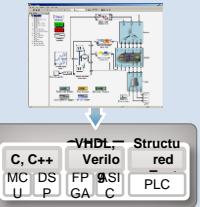
Multi-domain system modeling



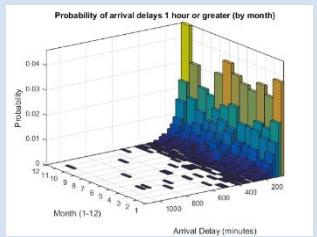
Parameter estimation



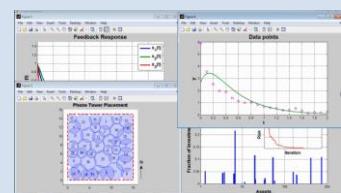
Control design and analysis



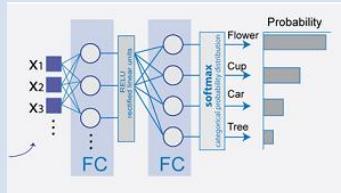
Automatic code generation



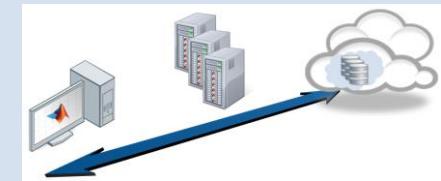
Variety and Volumes of Data



Optimization

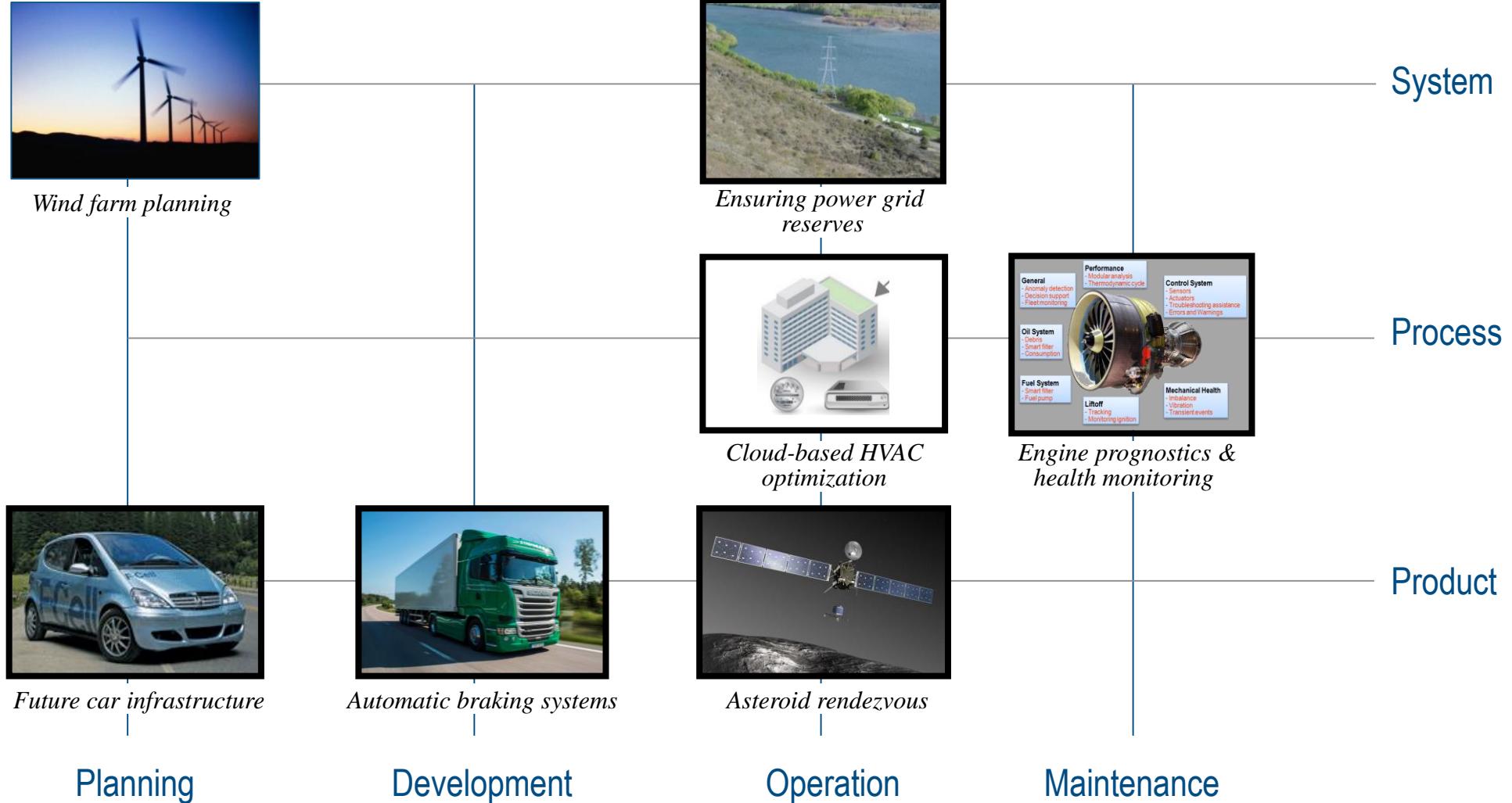


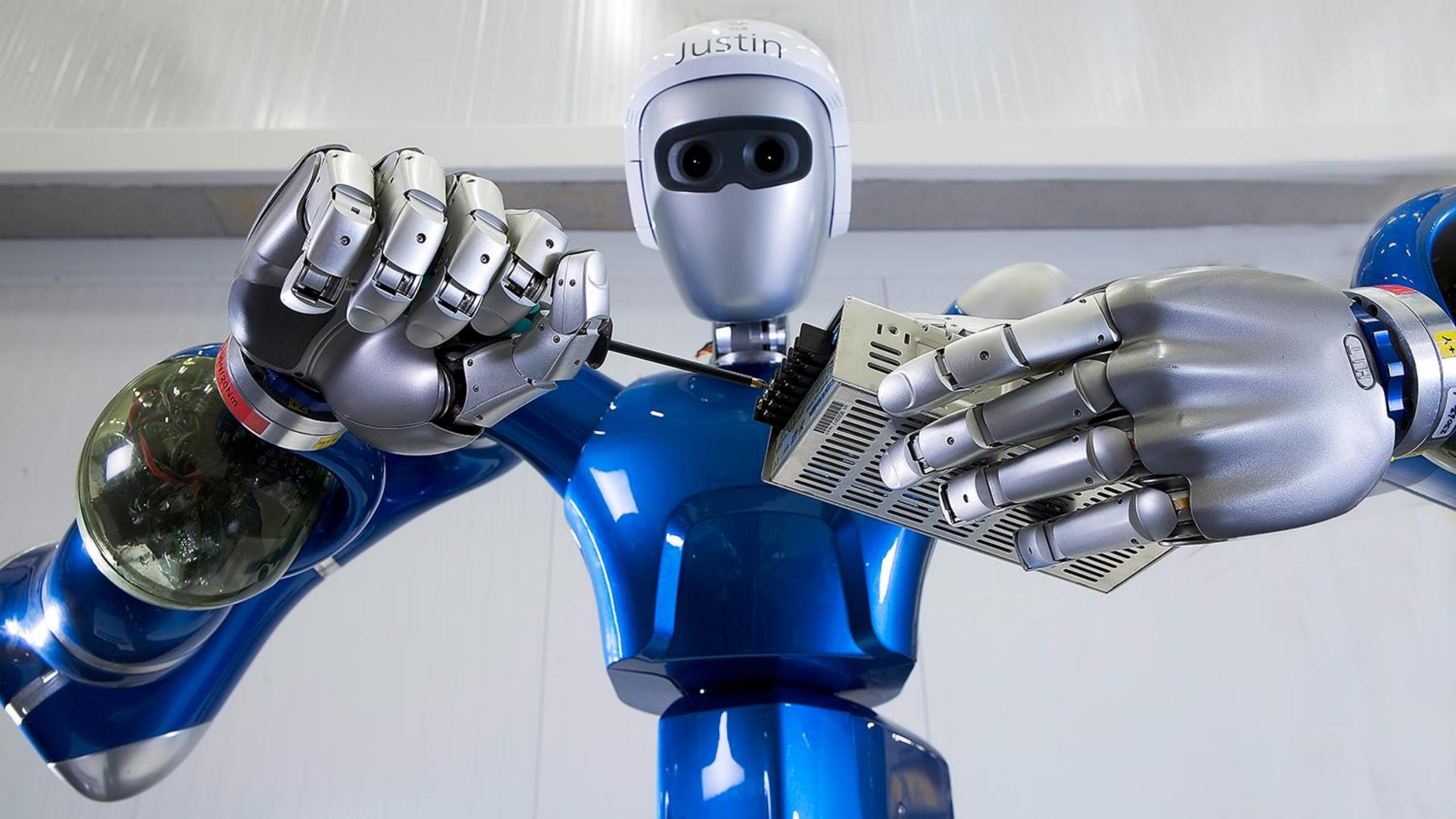
Machine Learning and Deep Learning



Enterprise system integration, with cluster/cloud execution

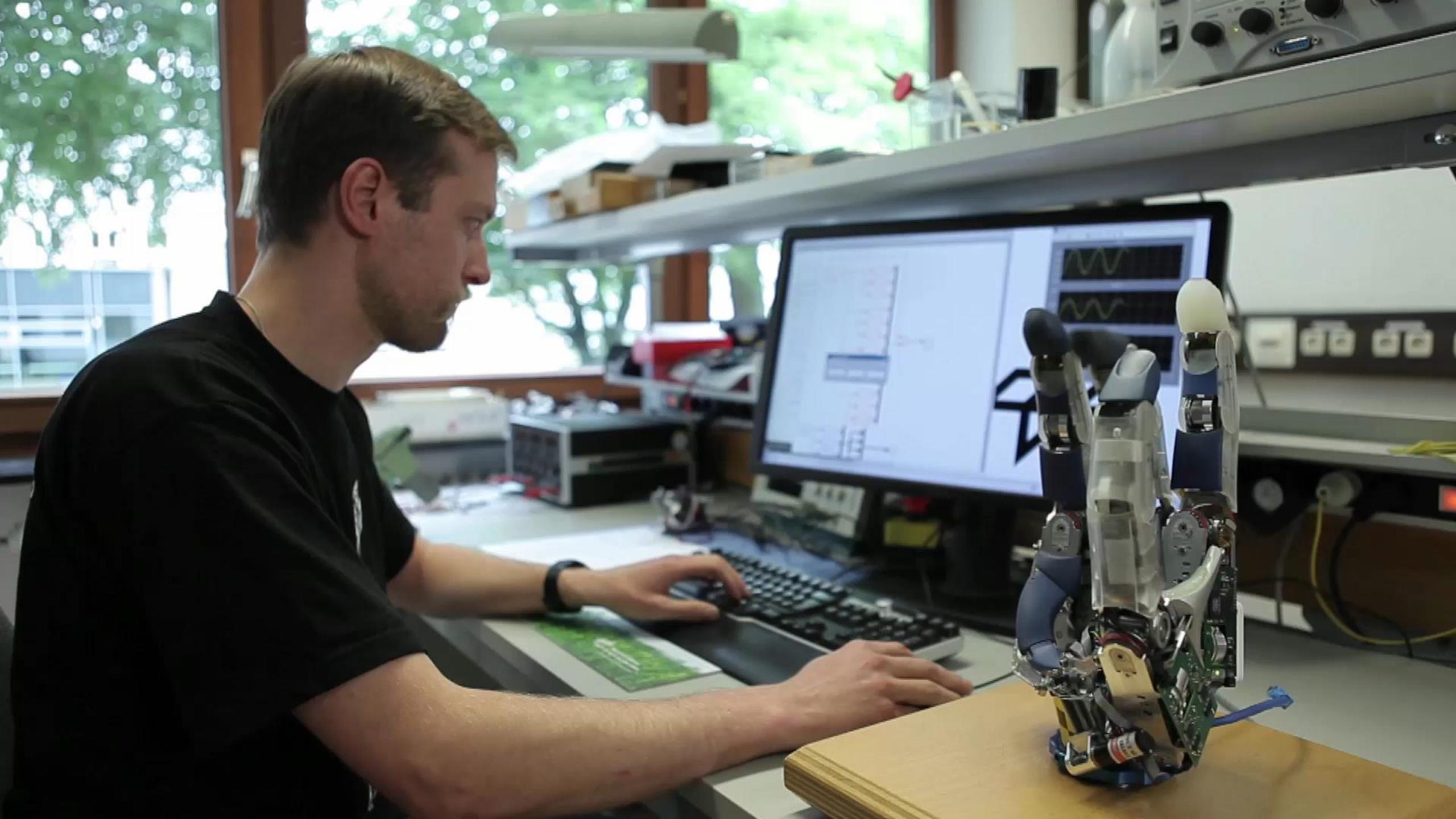
MATLAB and Simulink for Digital Twins throughout the lifecycle



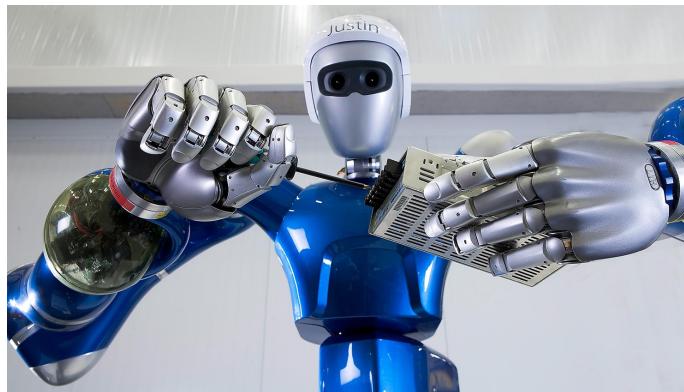
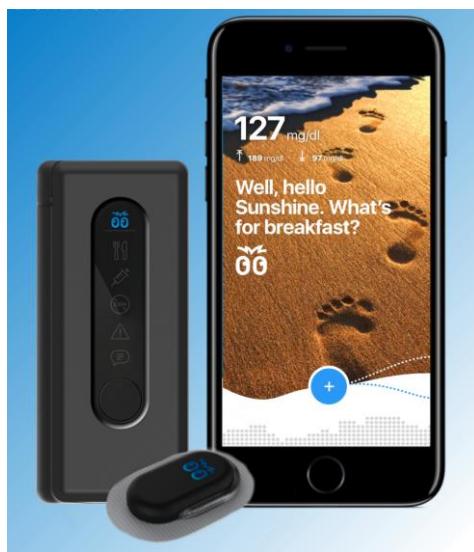
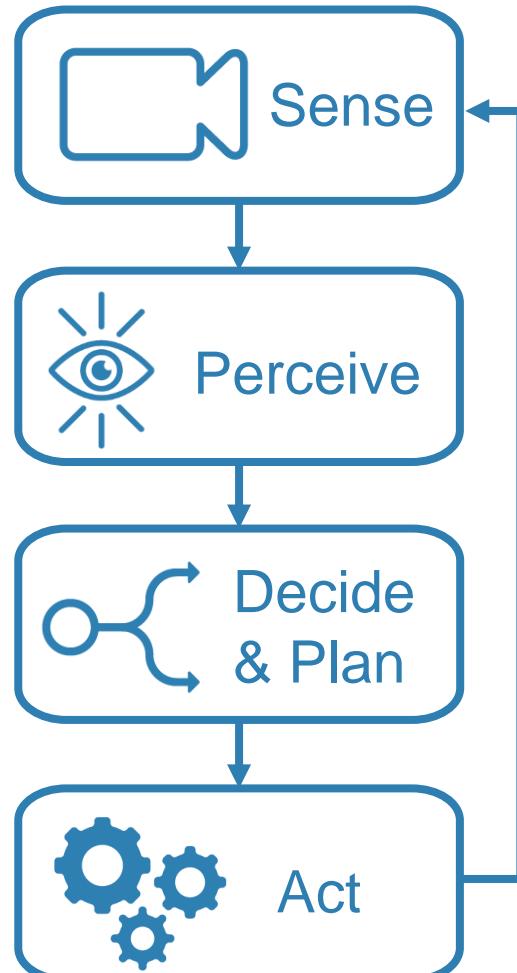


justin





Capabilities of an Autonomous System



How to build an autonomous anything

Focus on Perception

- Look for autonomy in creative places
- Do more than manually possible

Use the Best Predictors

- Data-driven
- Model-driven

Get the Right Data

Go to Production

How to build an autonomous anything

Focus on Perception

- Look for autonomy in creative places
 - Do more than manually possible
-

Use the Best Predictors

- Data-driven
 - Model-driven
-

Get the Right Data

- Reduce to actionable data
 - Take advantage of Big Data
 - Use simulation to supplement available data
-

Go to Production

- Address the architecture
- Leverage Model-Based Design for embedded
- Automate integration with enterprise IT systems

What is *your*
autonomous anything?