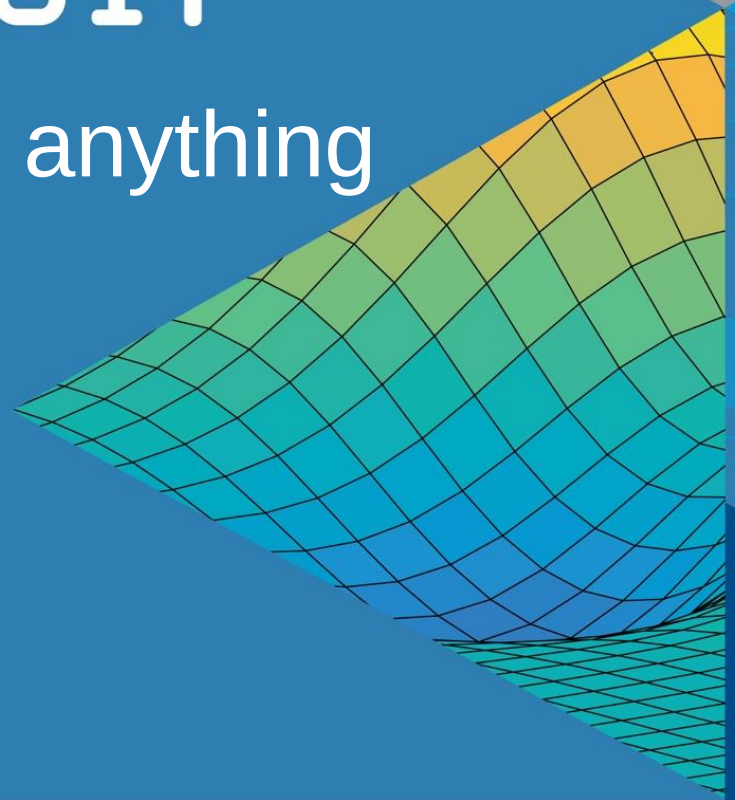
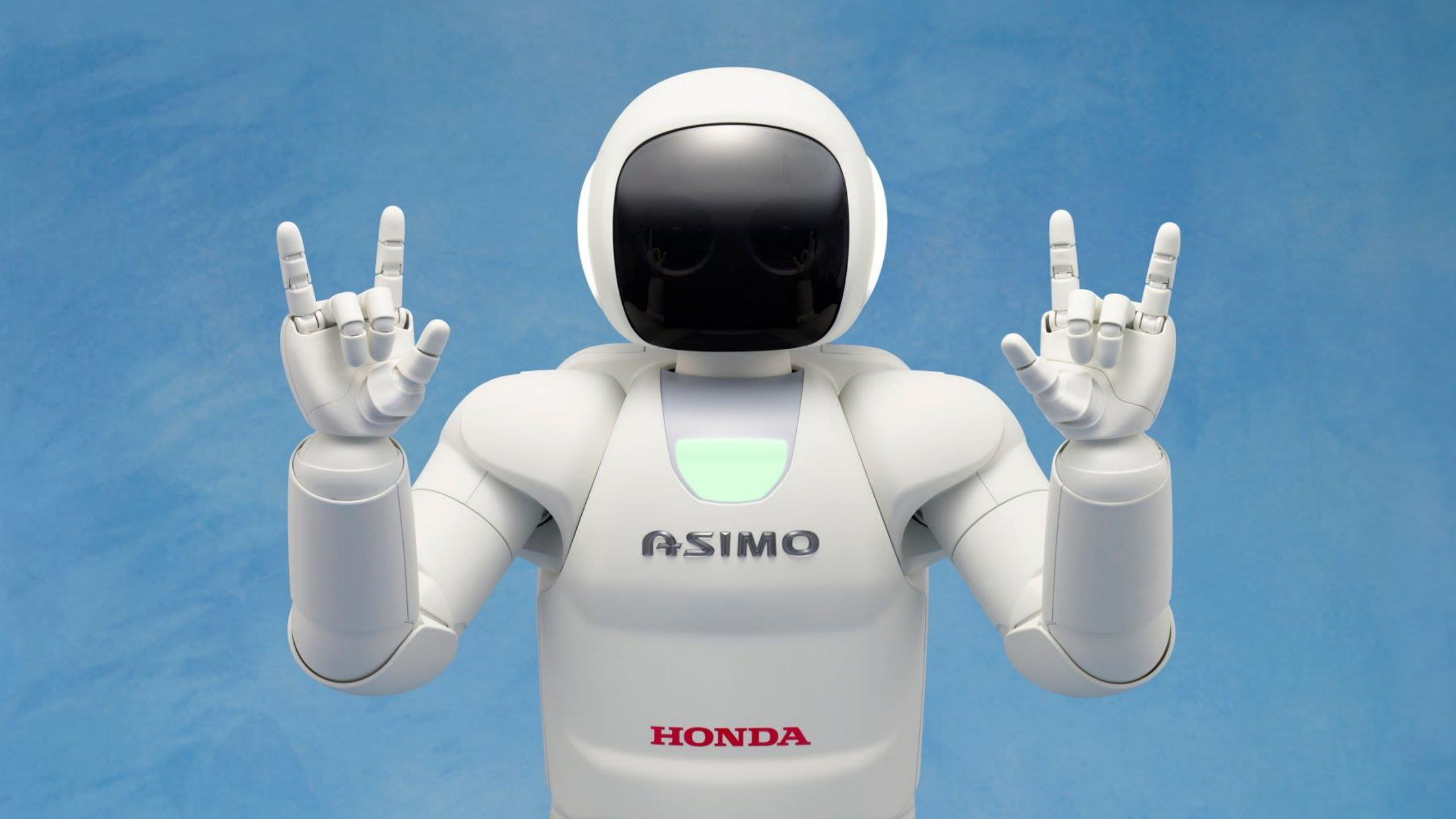
MATLAB EXPO 2017

How to build an **autonomous** anything



Jim Tung
MathWorks Fellow
MathWorks


WAYMO


ASIMO
HONDA


amazon


5" 12,000 PSI
5" 12,000 PSI
BAKER HUGHES


127 mg/dl
189 mg/dl
97 mg/dl
Well, hello Sunshine. What's for breakfast?
CGM

Autonomous Technology

Autonomous

Acting independently

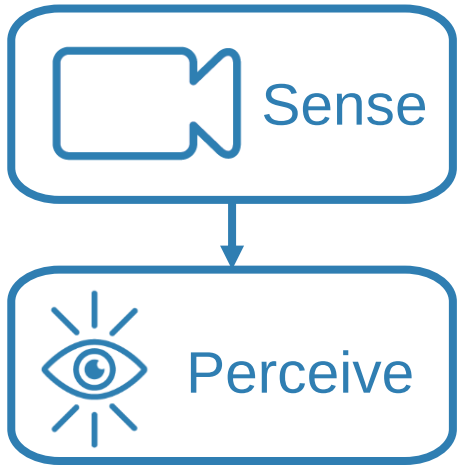
Autonomous Technology

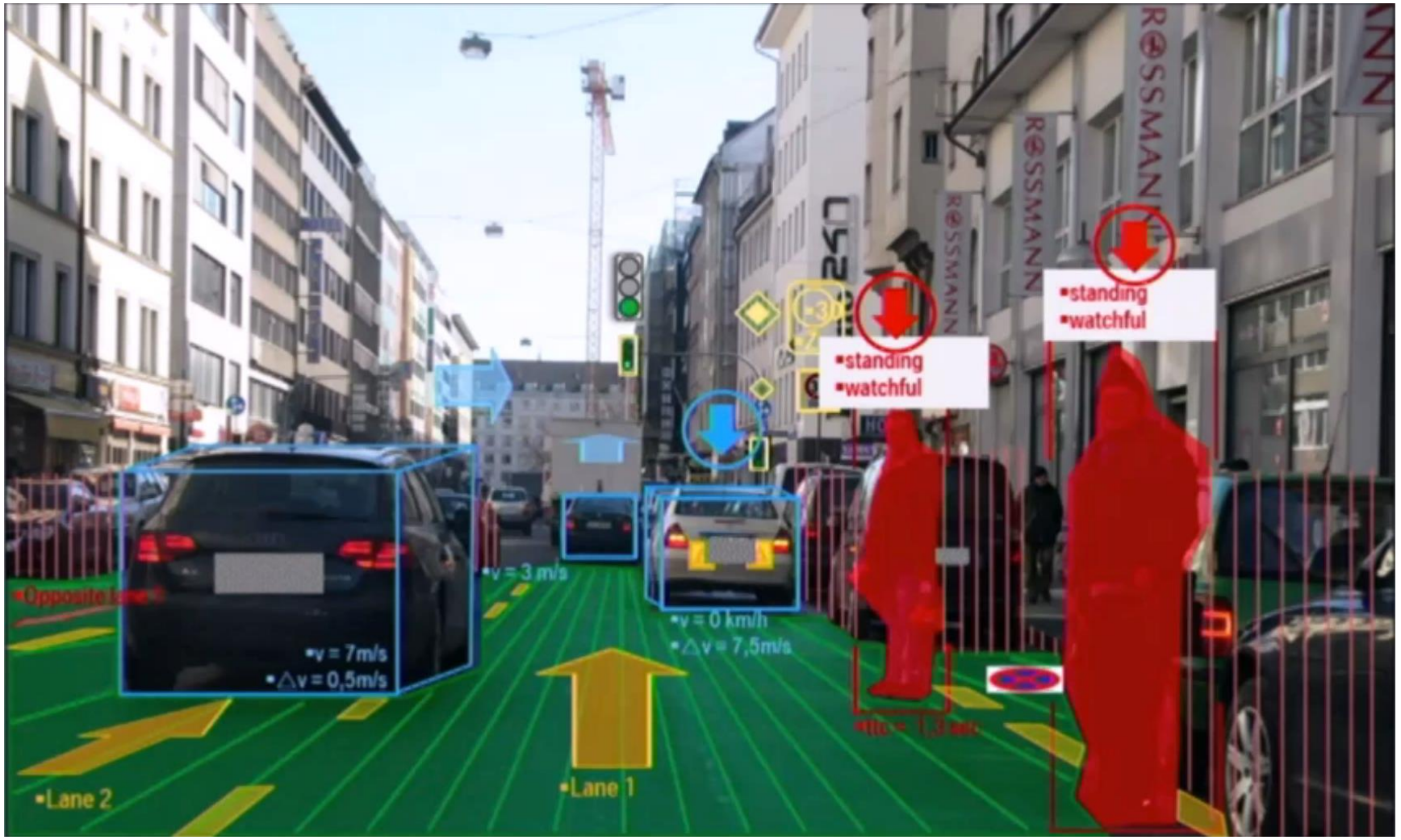
Provides the ability of a system to act independent of direct human control under unrehearsed conditions

Capabilities of an Autonomous System

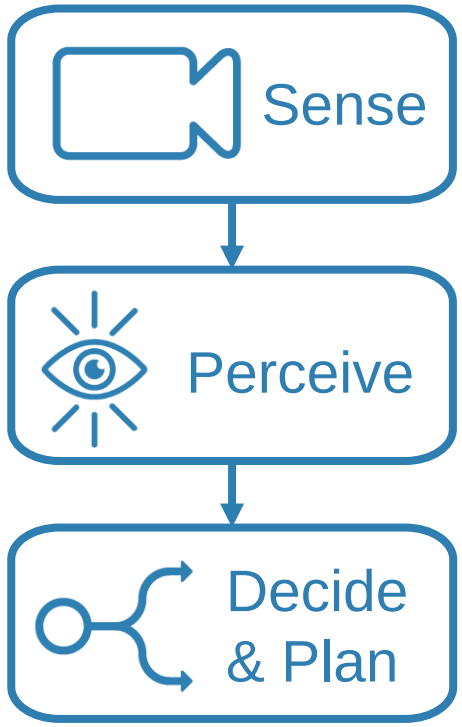
Sense

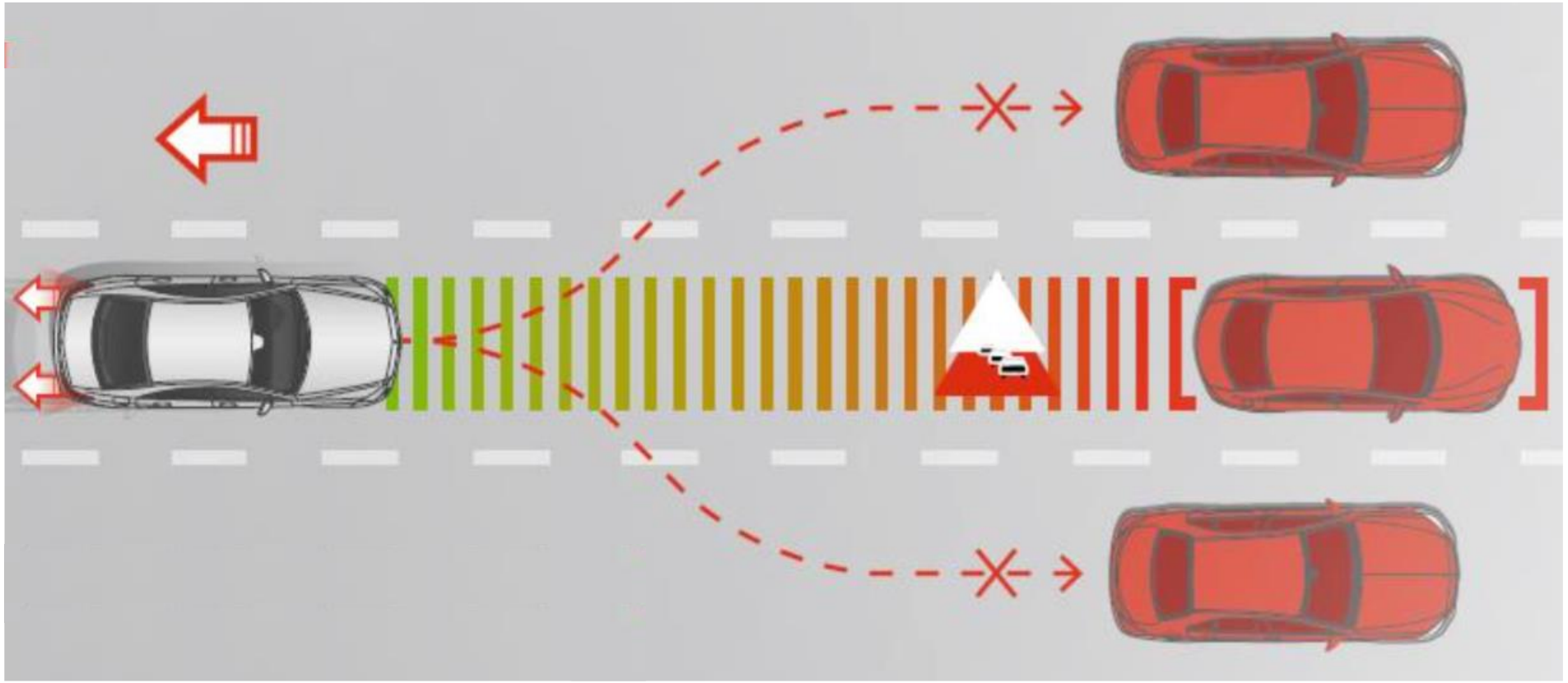
Capabilities of an Autonomous System



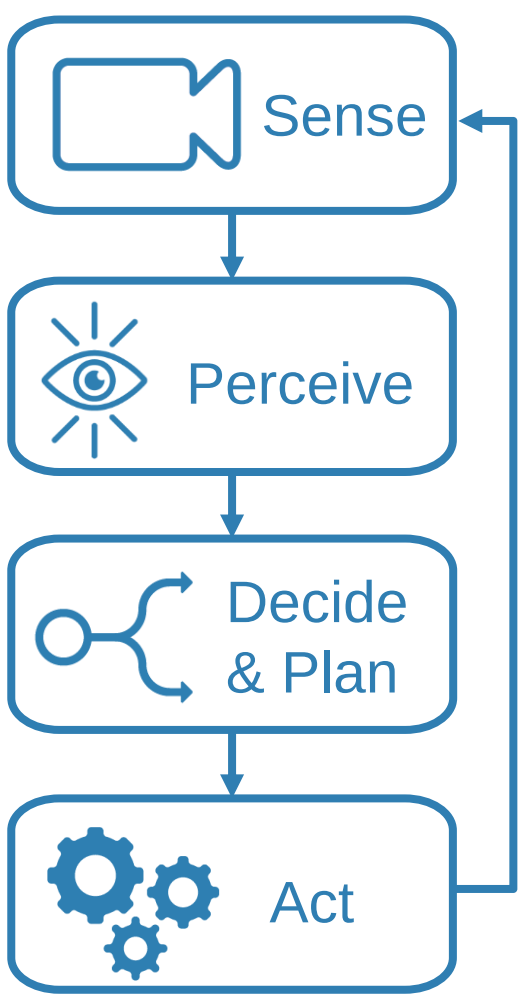


Capabilities of an Autonomous System

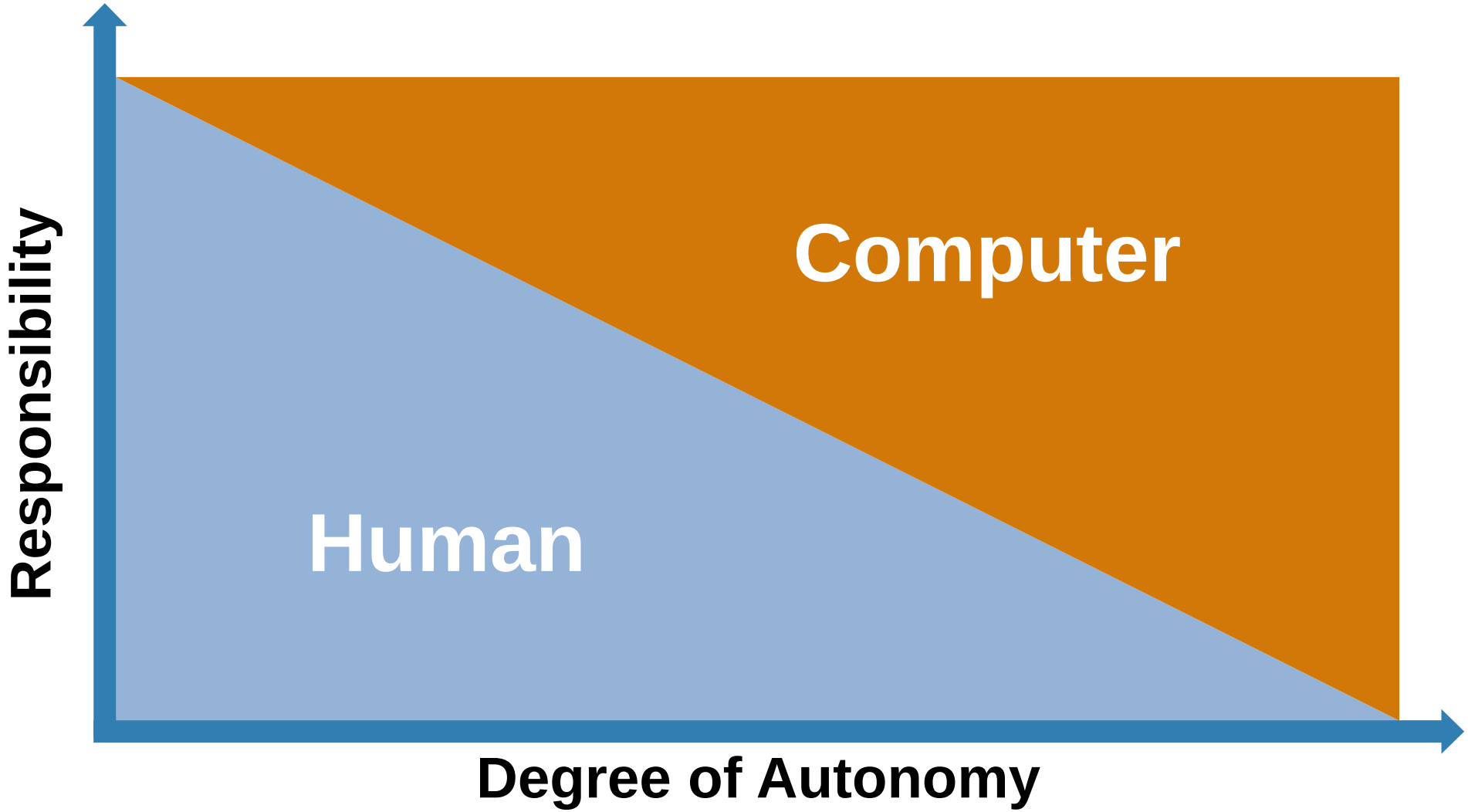




Capabilities of an Autonomous System



Autonomous Technology – Balancing Responsibility




Cost of rig: $1,000,000+
Repair cost: $100,000
Cost of valve: $200
5" 12,000 PSI
5" 12,000 PSI
BAKER HUGHES

Autonomous Service for Predictive Maintenance

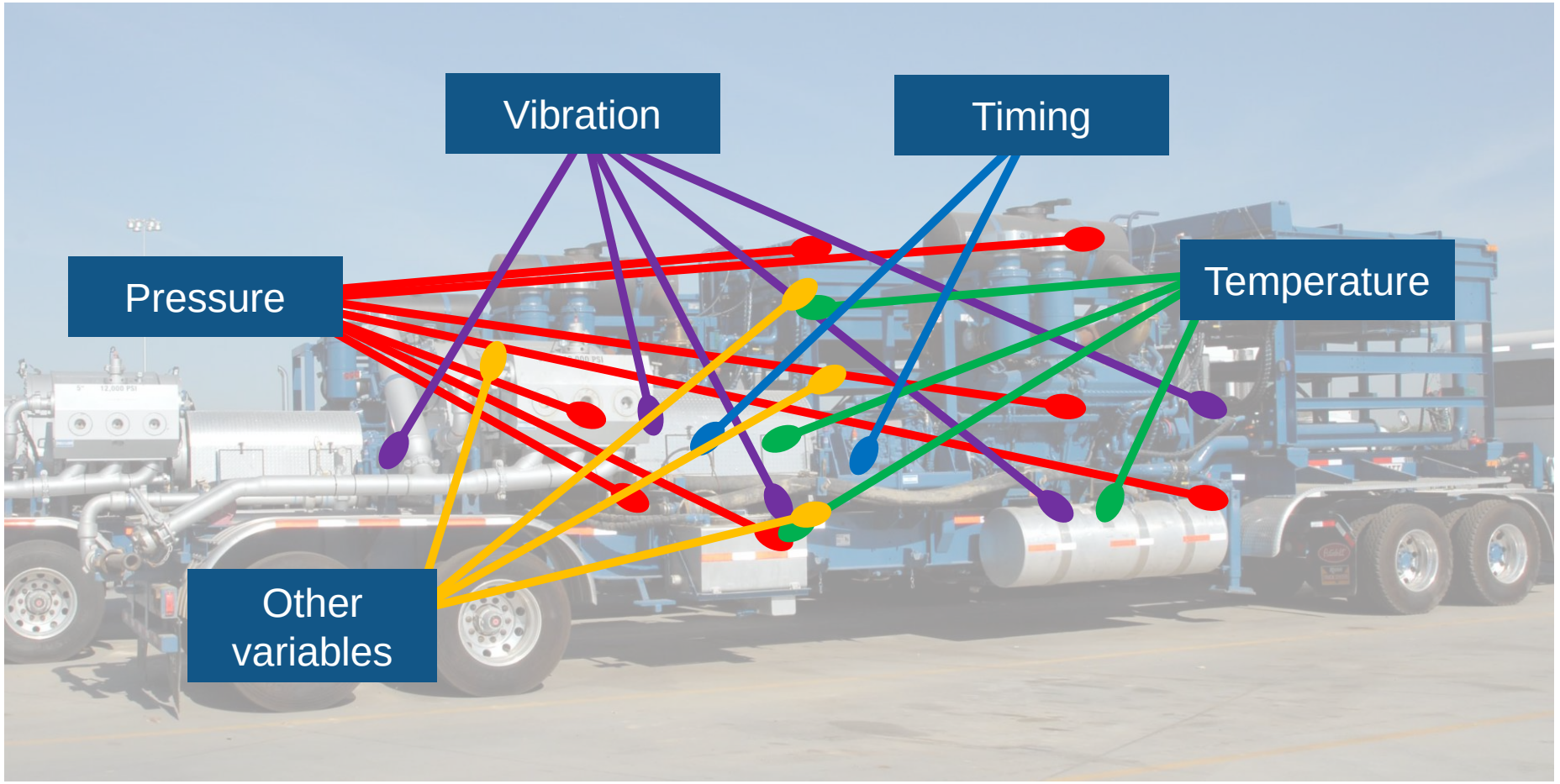
Sense

Perceive

Decide & Plan

Act

Which sensor values should they use?



Autonomous Service for Predictive Maintenance

Sense

Perceive

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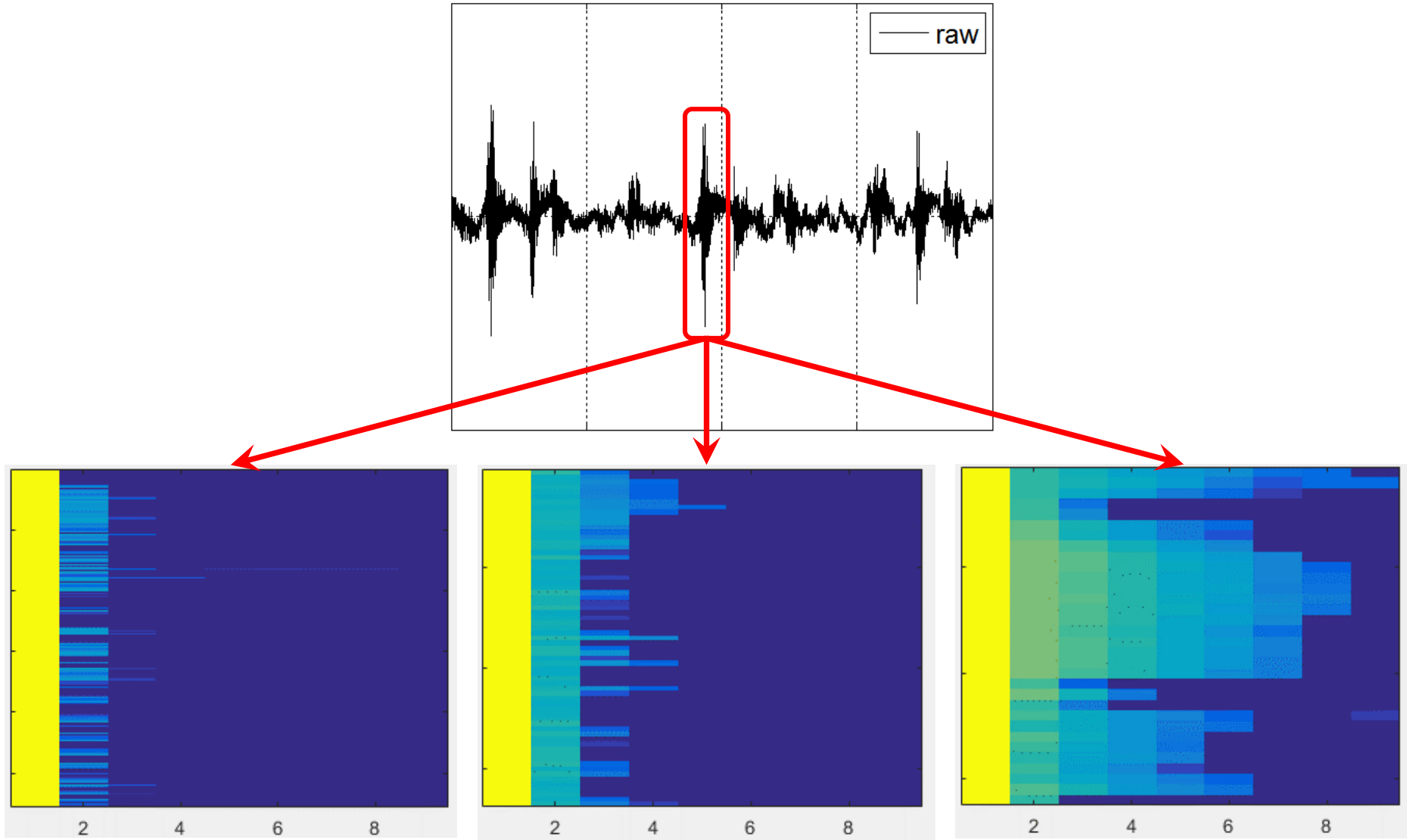
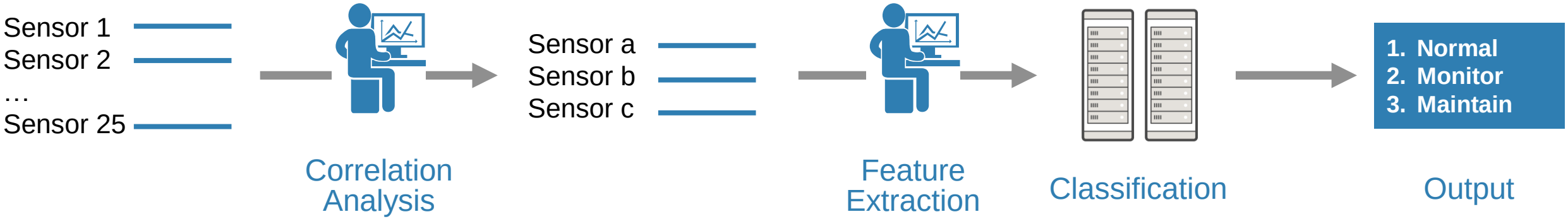


Normal Operation | Monitor Closely | Maintenance Needed

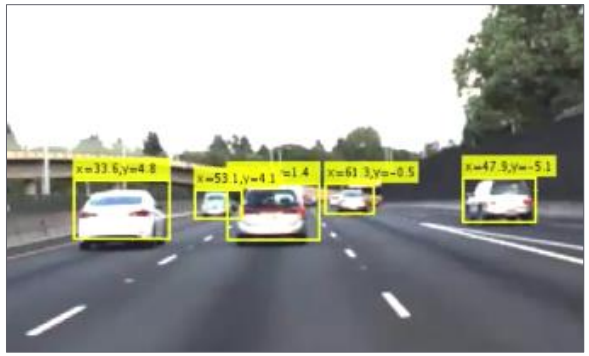
Machine Learning or Deep Learning?

Machine Learning Approach



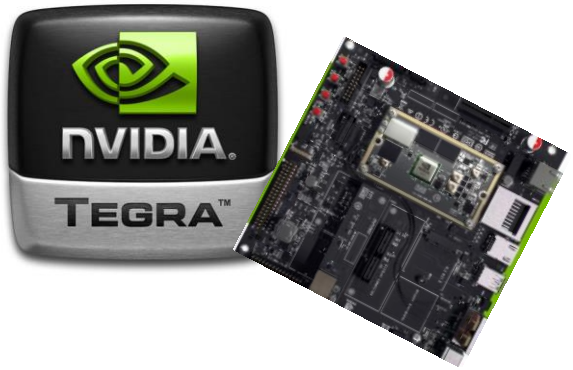
Deep Learning Approach

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

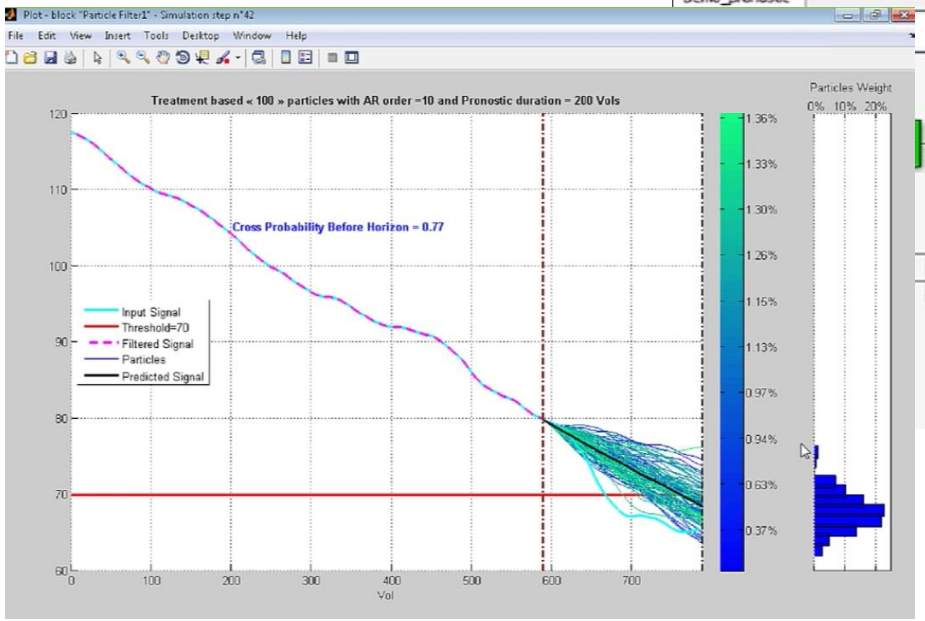
What are the best predictors?

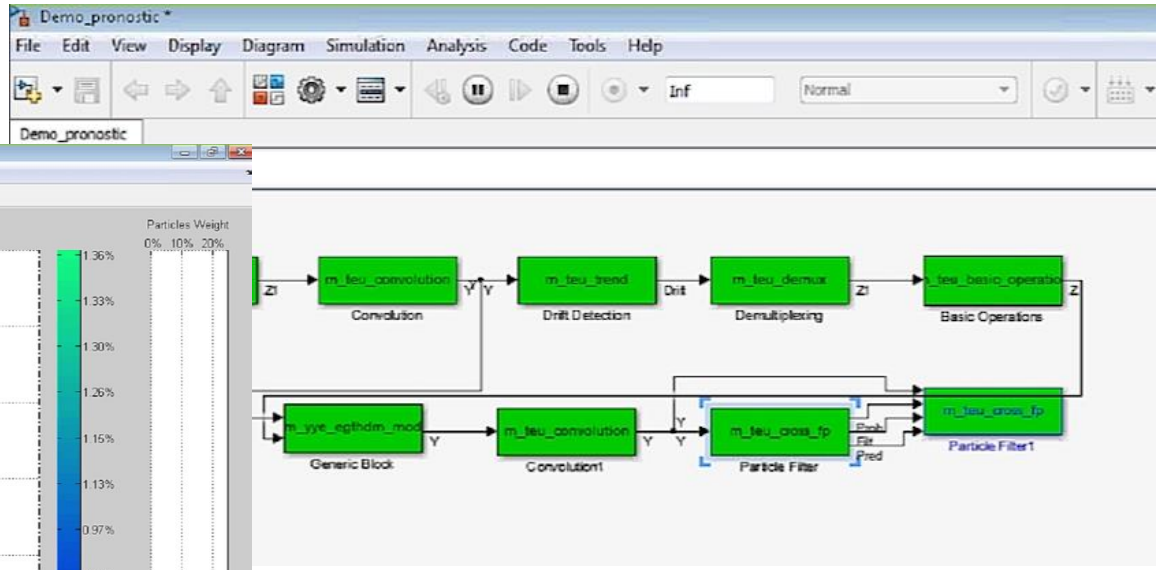
- Data-driven

What are the best predictors?

- Data-driven
- Model-driven

SAFRAN
Snecma





Jet Engine Monitoring

Autonomous Glucose Level Management

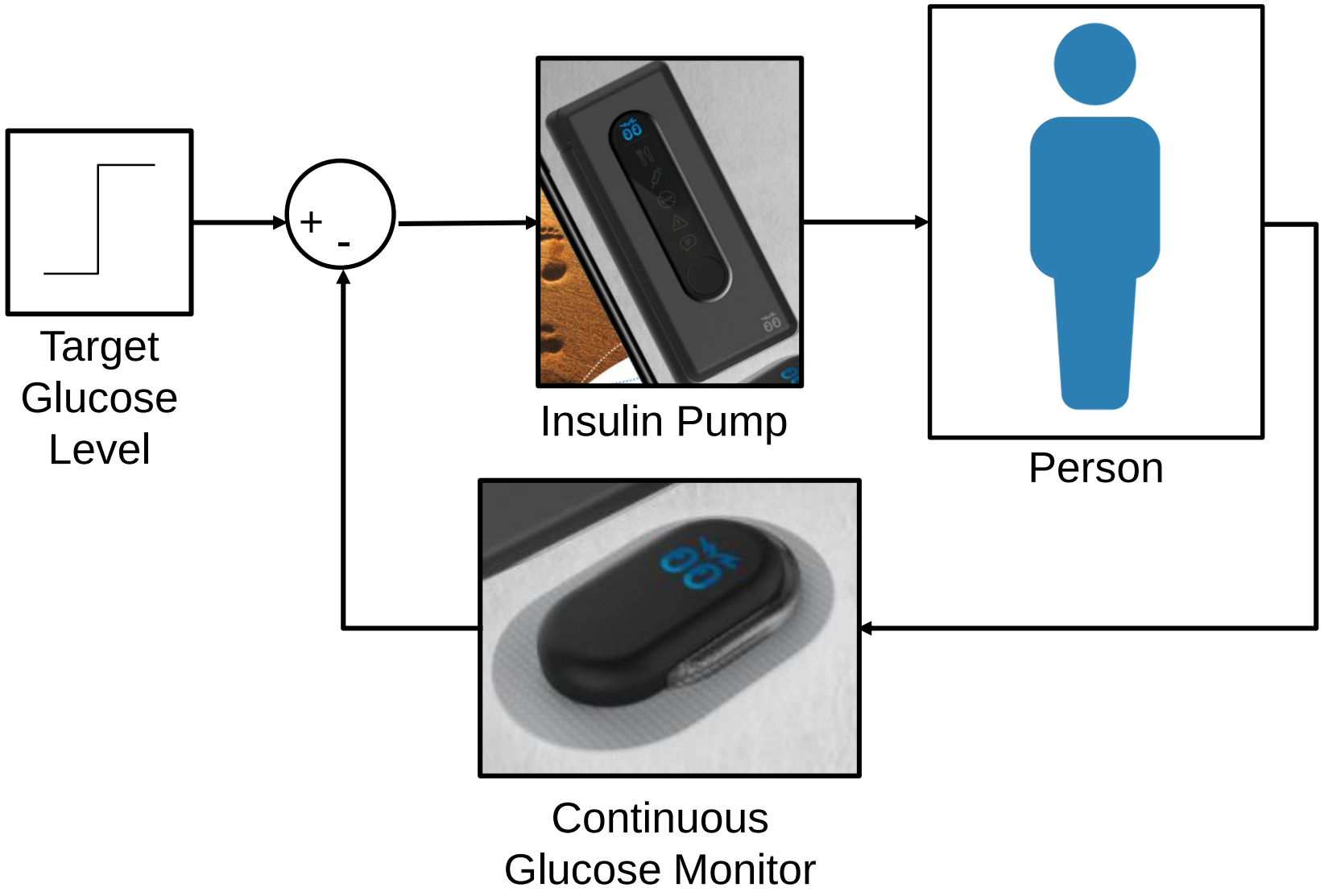
Autonomous Glucose Level Management
Bigfoot Biomedical

Sense

Perceive

Decide & Plan

Act



Autonomous Glucose Level Management
Bigfoot Biomedical

Sense

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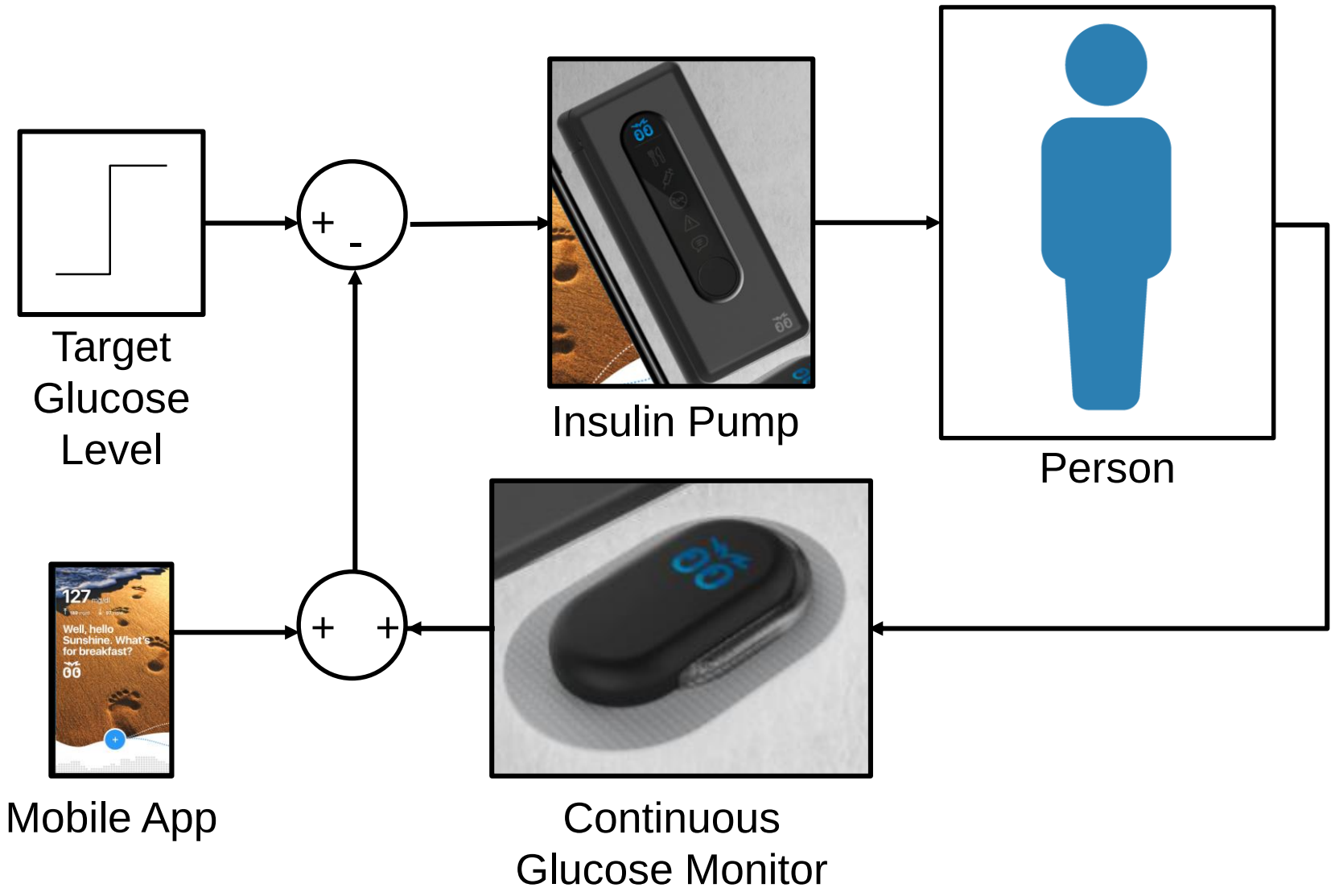

Autonomous Glucose Level Management
Bigfoot Biomedical

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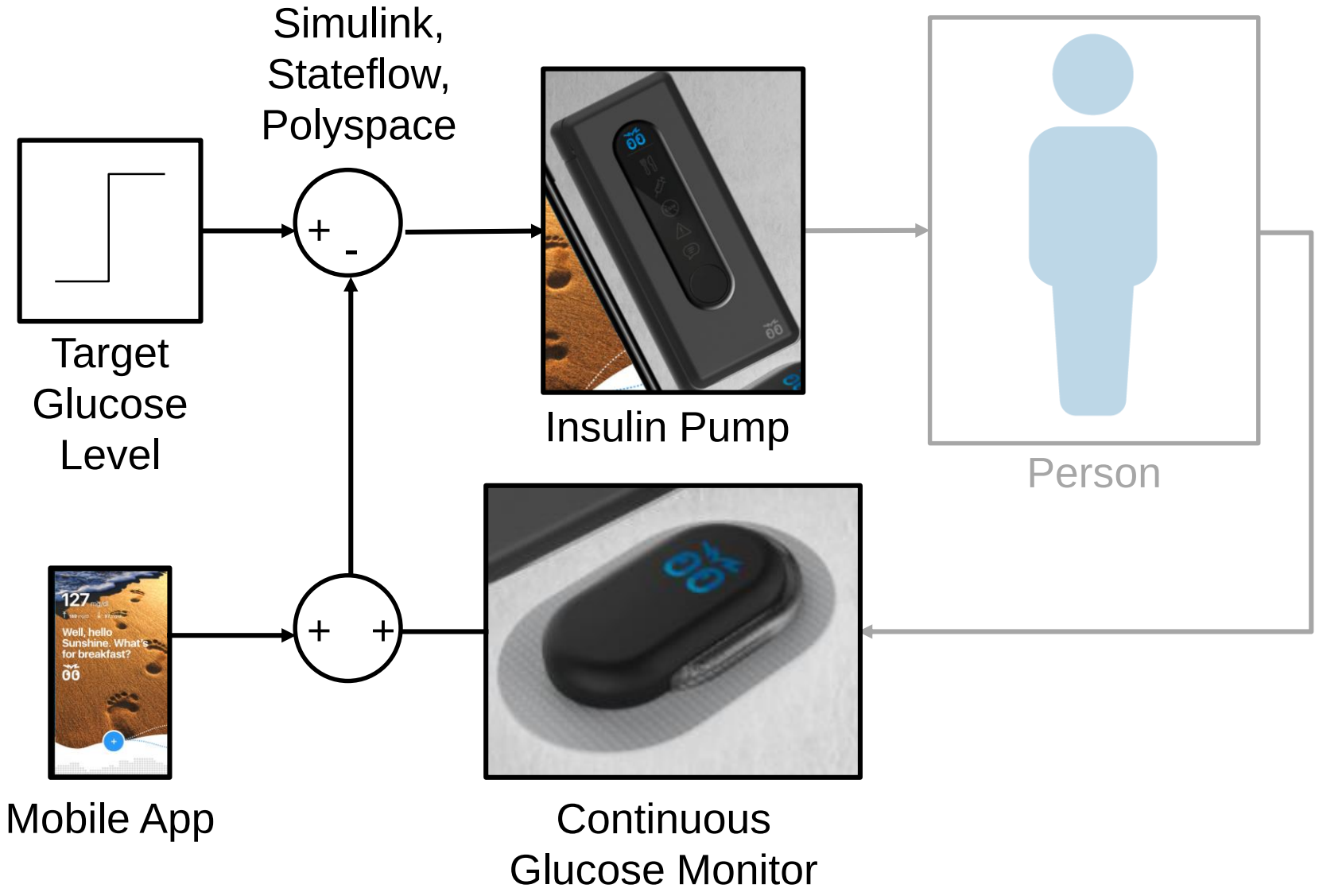

Autonomous Glucose Level Management
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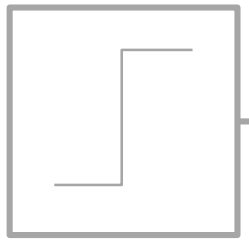
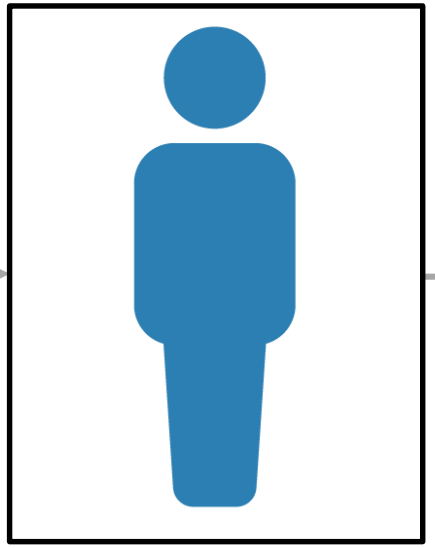
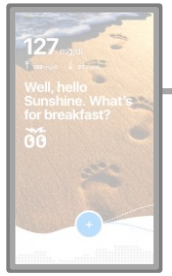


Target Glucose Level

Insulin Pump



Person



Mobile App

Continuous Glucose Monitor

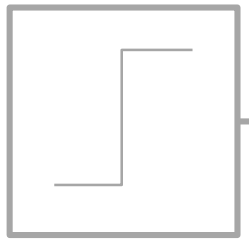
Autonomous Glucose Level Management
Bigfoot Biomedical

Sense

Perceive

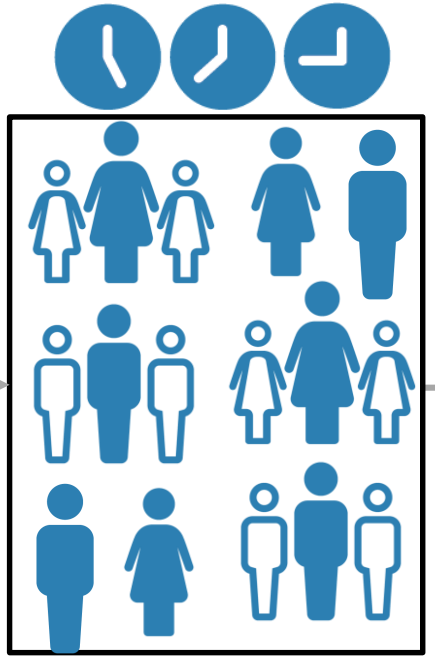
Decide & Plan

Act



Target Glucose Level

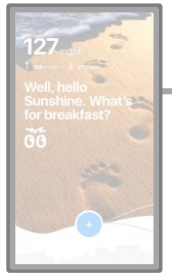
Insulin Pump



Person

2017

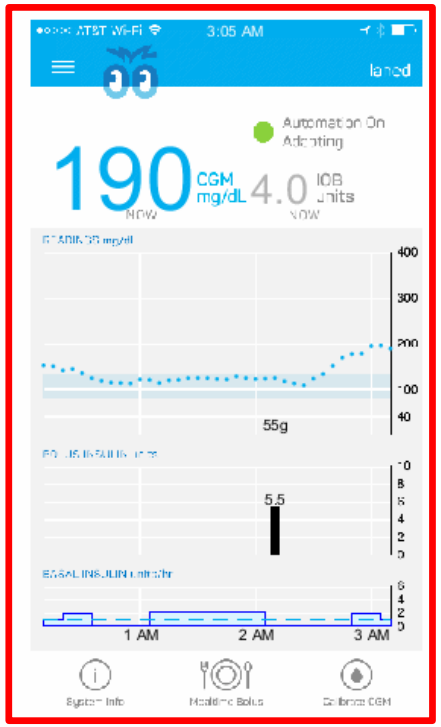
2018

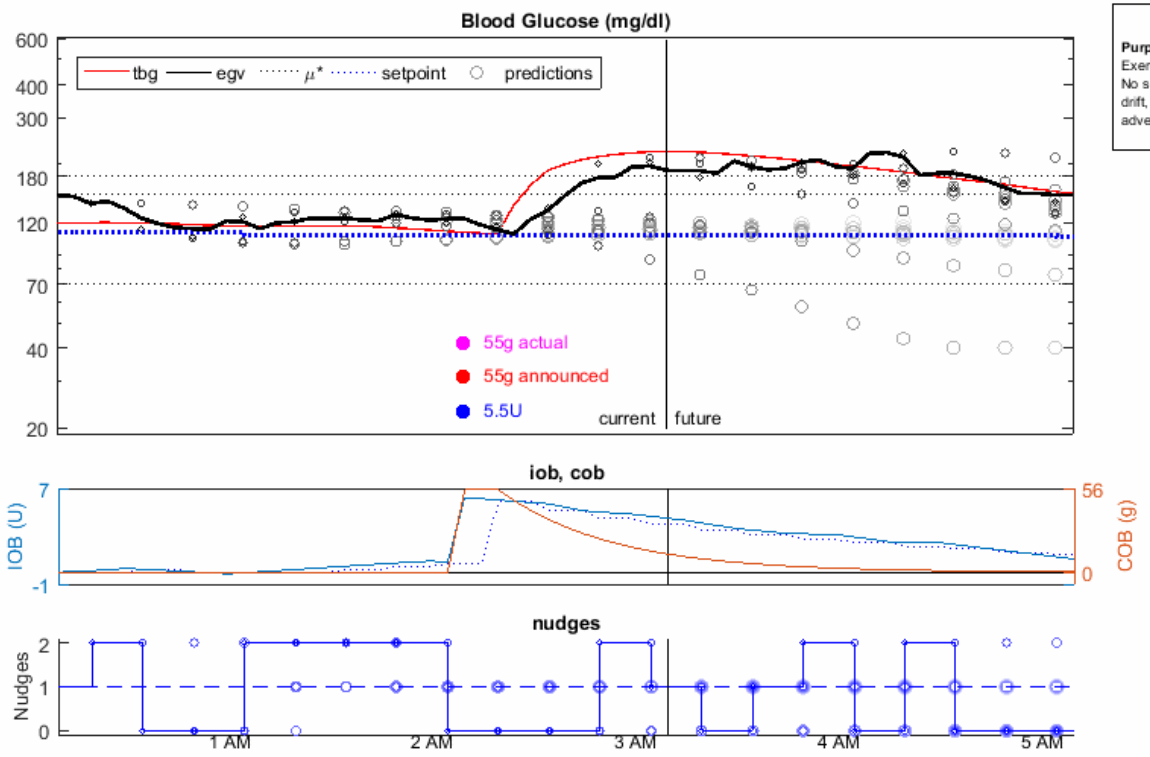


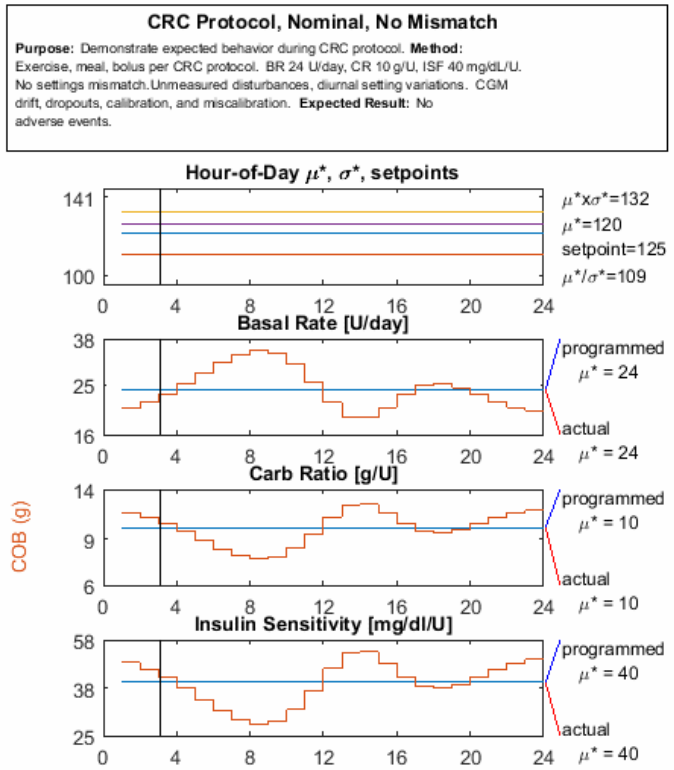
Mobile App

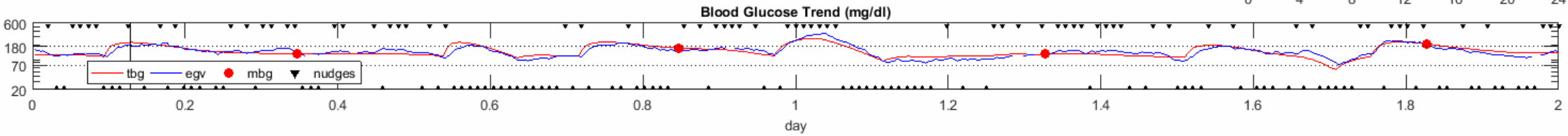
Continuous Glucose Monitor

Virtual Clinic
Generating data through simulation

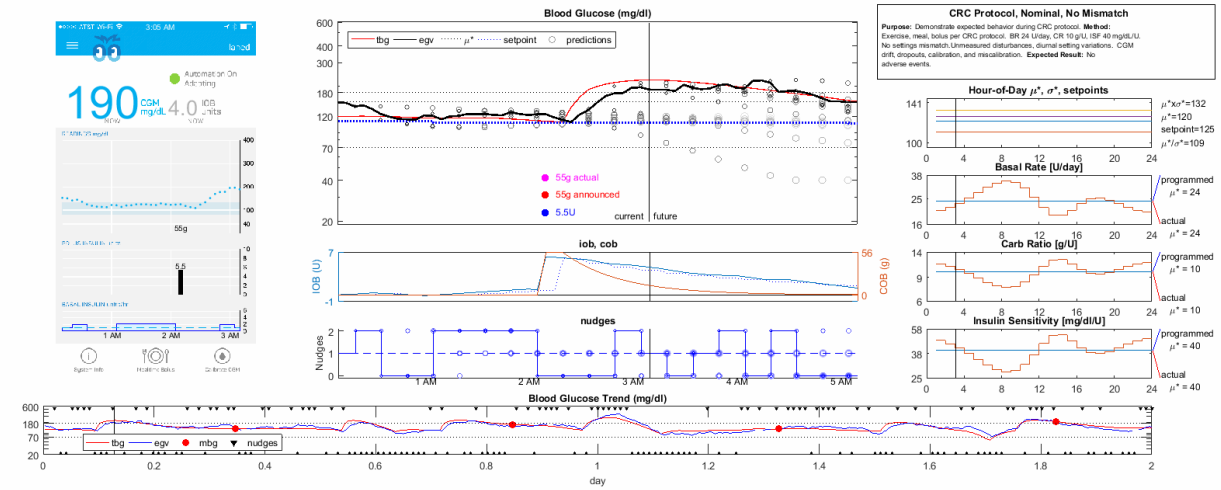






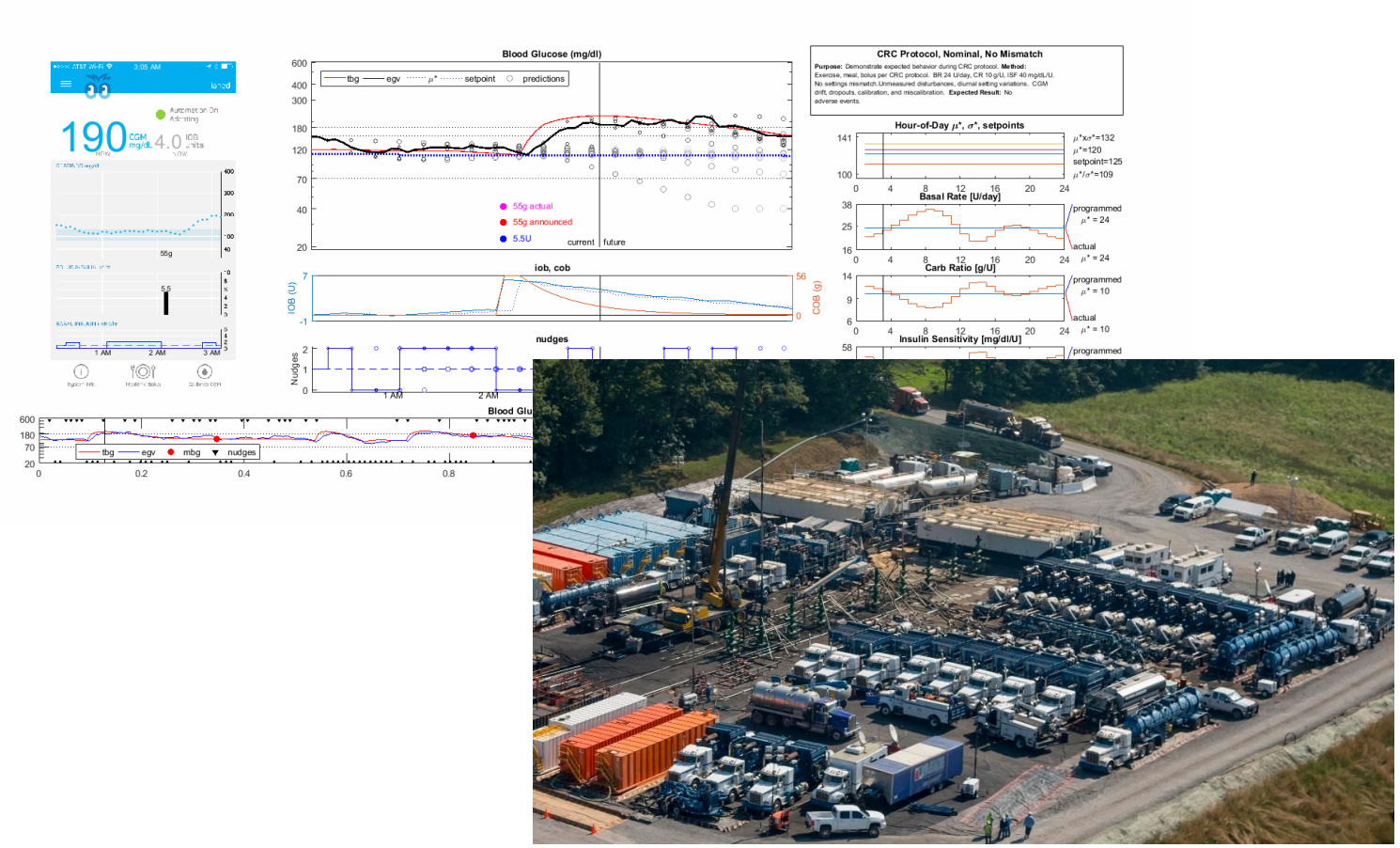


Virtual Clinic
Scaling computations to simulate 50 million patients a day



Where will you get your data?

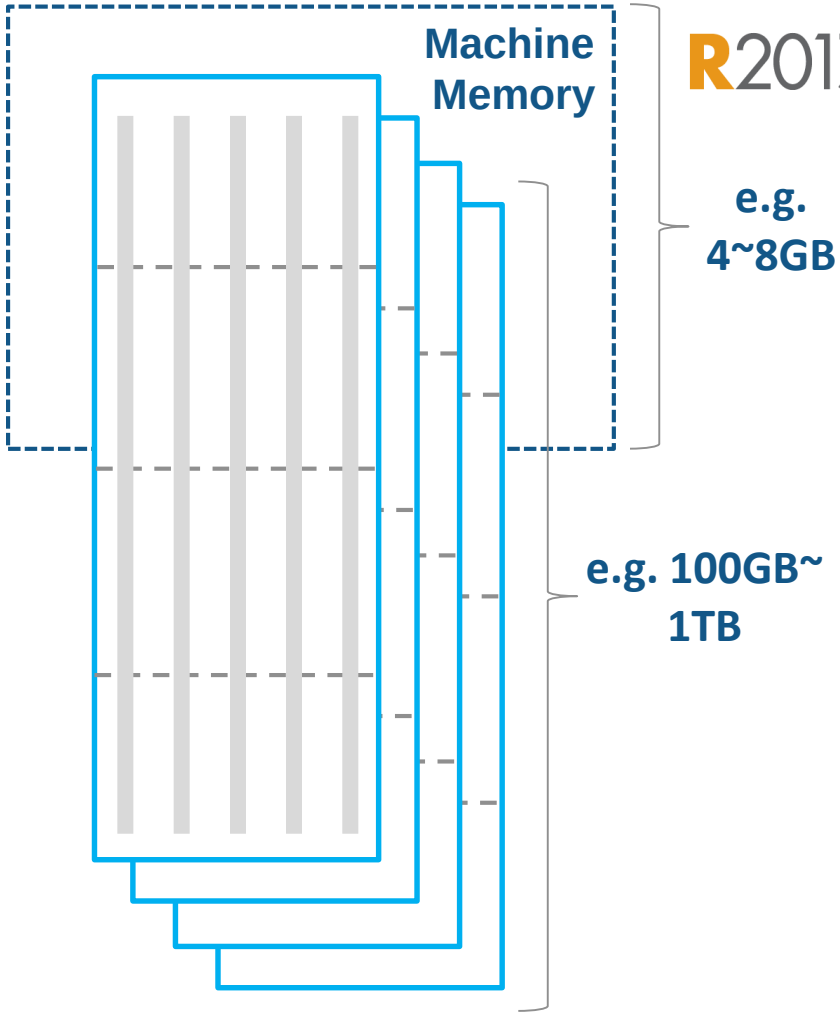
- Simulation
- Public repositories
- In the lab
- In the field
- Internet of Things (IoT)

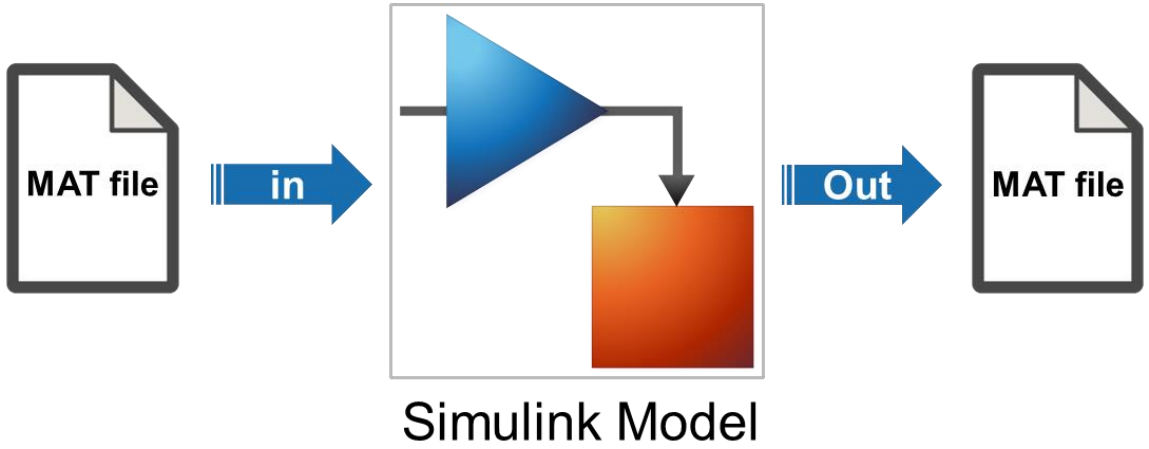


Working with Big Data Just Got Easier

Tall arrays in MATLAB

R2016b
R2017a





Stream large input signals from MAT-files

R2017a

Autonomous Trailer Filling

Sense

Perceive

Decide & Plan

Act

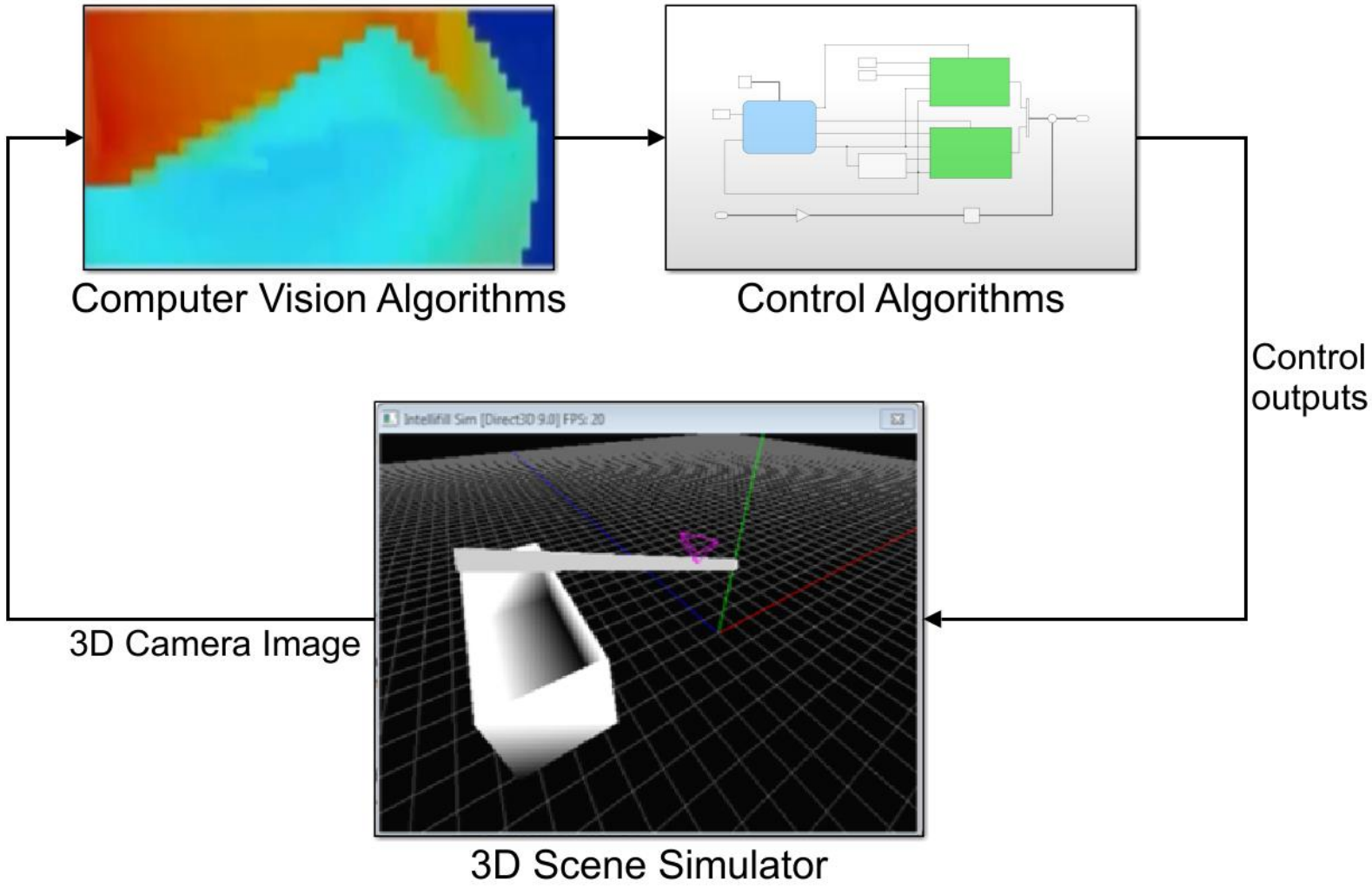
Autonomous Trailer Filling

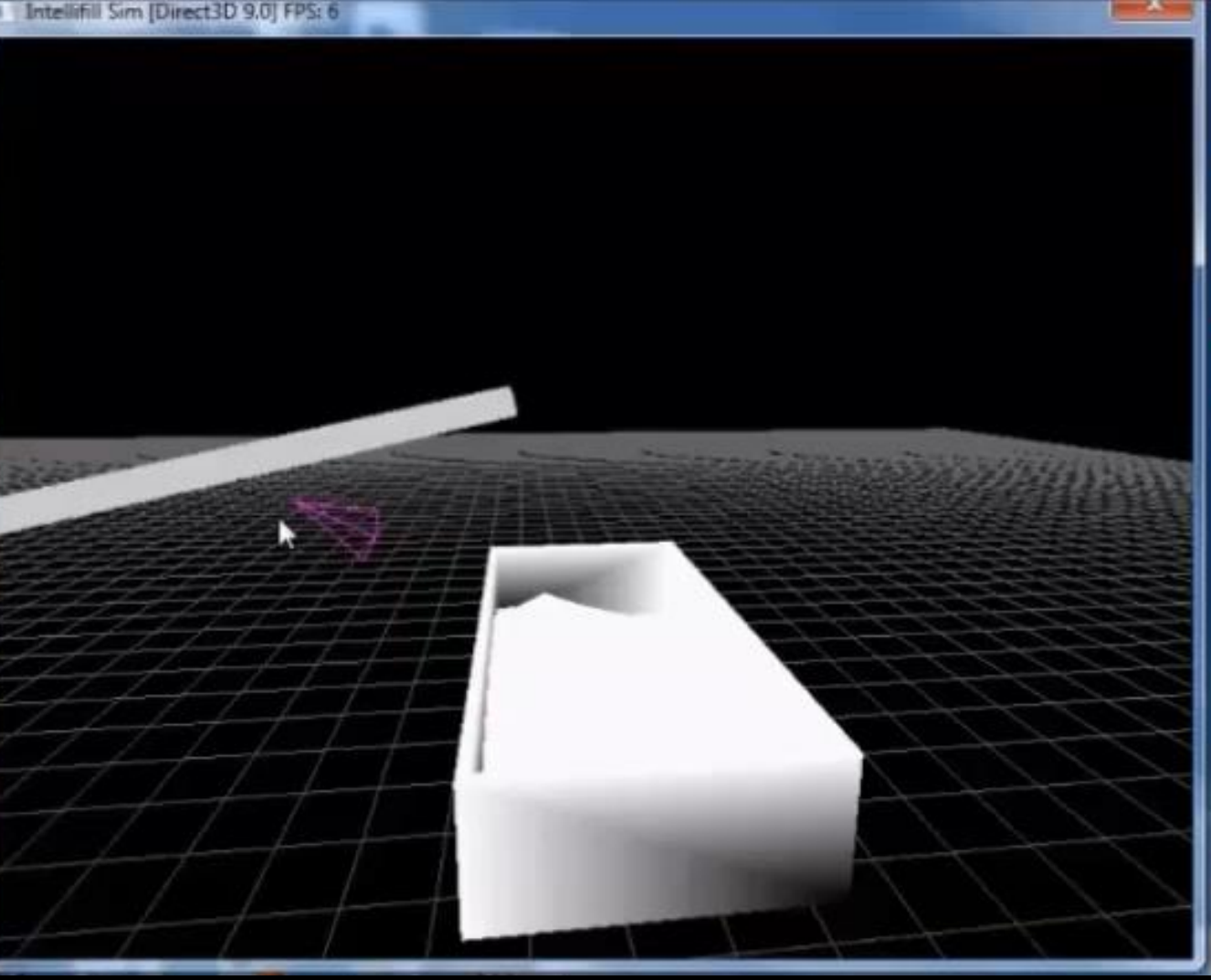
Sense

Perceive

Decide & Plan

Act

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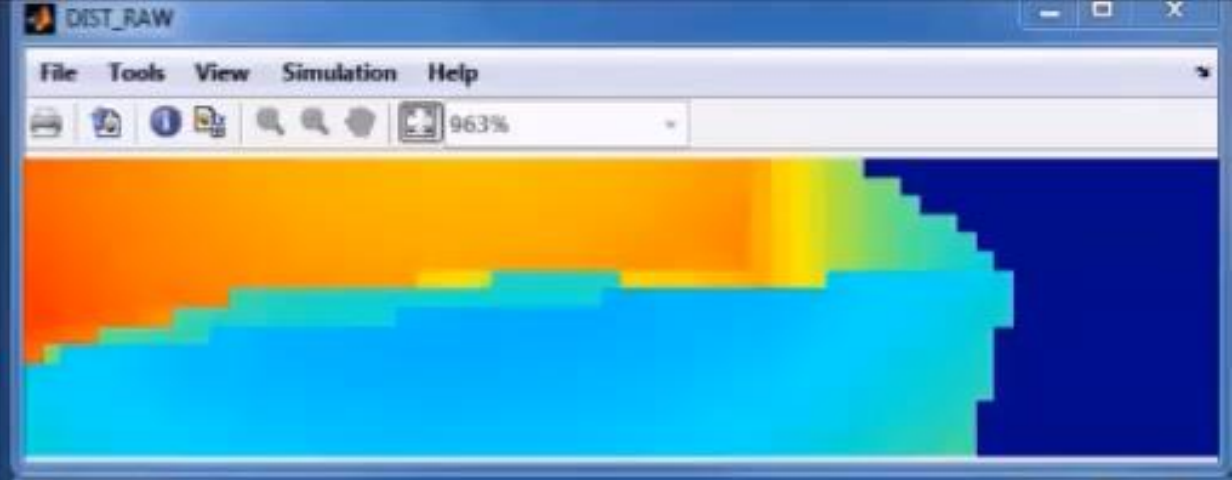
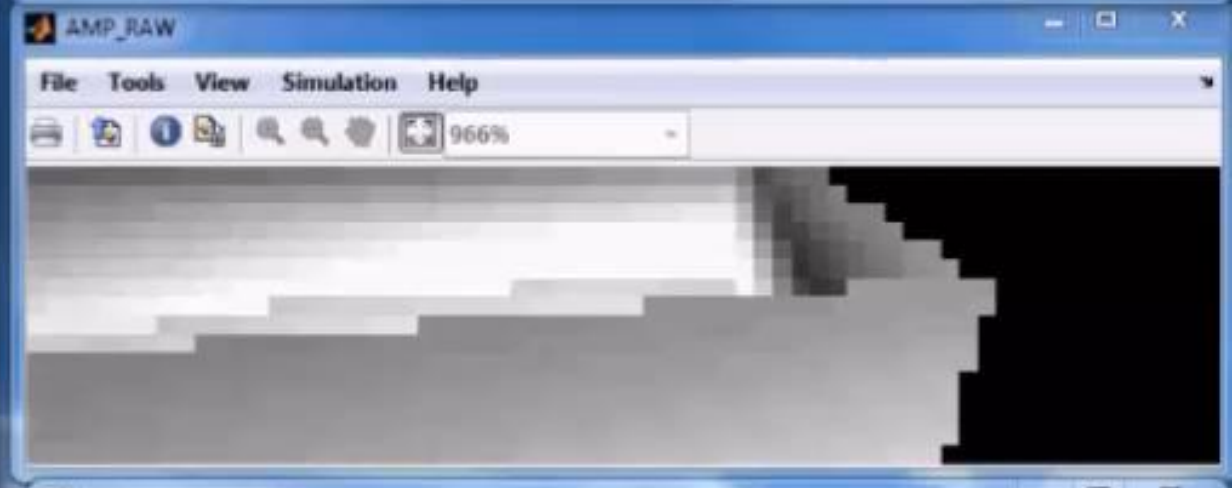

DIST_RAW
File Tools View Simulation Help
963%


AMP_RAW
File Tools View Simulation Help
966%


Overlay_Dist_image
File Tools View Simulation Help
236%
0133
LW
0150
0150
0150
0000
0142
RW
CCW
0279

Autonomous Trailer Filling

Sense

Perceive

Decide & Plan

Act

3D Cameras

Computer vision and controls algorithms

CAN

ECU

Actuators

Autonomous Trailer Filling

Sense

Perceive

Decide & Plan

Act

3D Cameras

Vehicle Display Controller

- Driver Input
- Visualization

CAN

ECU

Actuators

Computer vision and controls algorithms

Autonomous Trailer Filling

Sense

Perceive

Decide & Plan

Act

Vehicle Display Controller

- Driver Input
- Visualization
- Computer Vision
- Controls

3D Cameras

Embedded Coder

CAN

Actuators

ECU

Computer vision and controls algorithms

Autonomous Trailer Filling

Sense

Perceive

Decide & Plan

Act

Vehicle Display Controller

- Driver Input
- Visualization
- Computer Vision
- Controls

3D Cameras

CAN

Monitoring

ECU

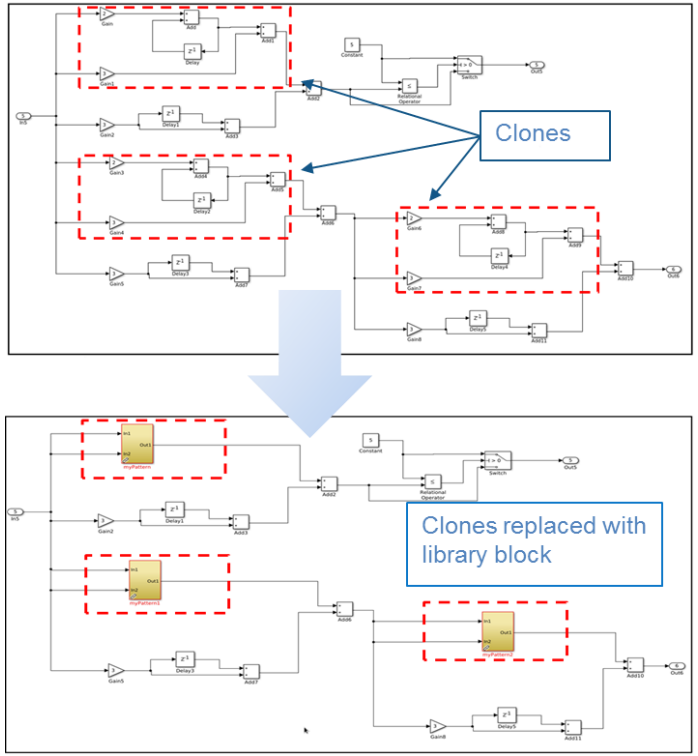
Actuators

How will you put it into production?

- Embedded Systems
- IT Systems
- Cloud
- Desktop Apps

Investments in Model-Based Design

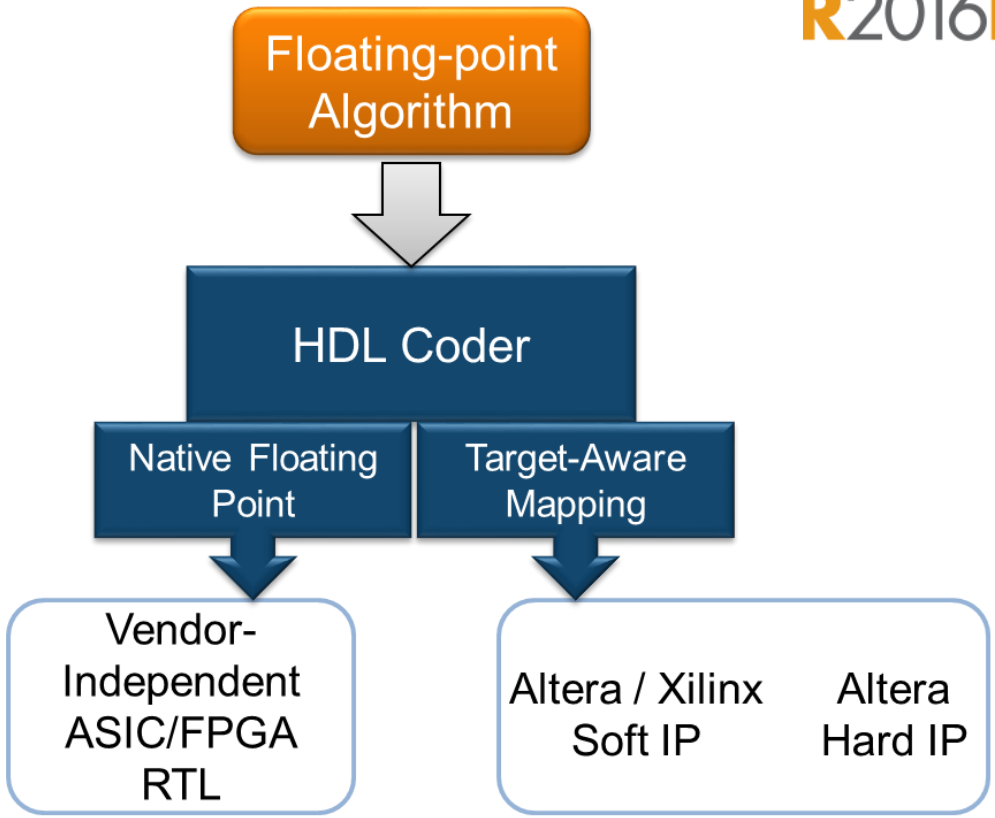
Efficient code generation



R2017a

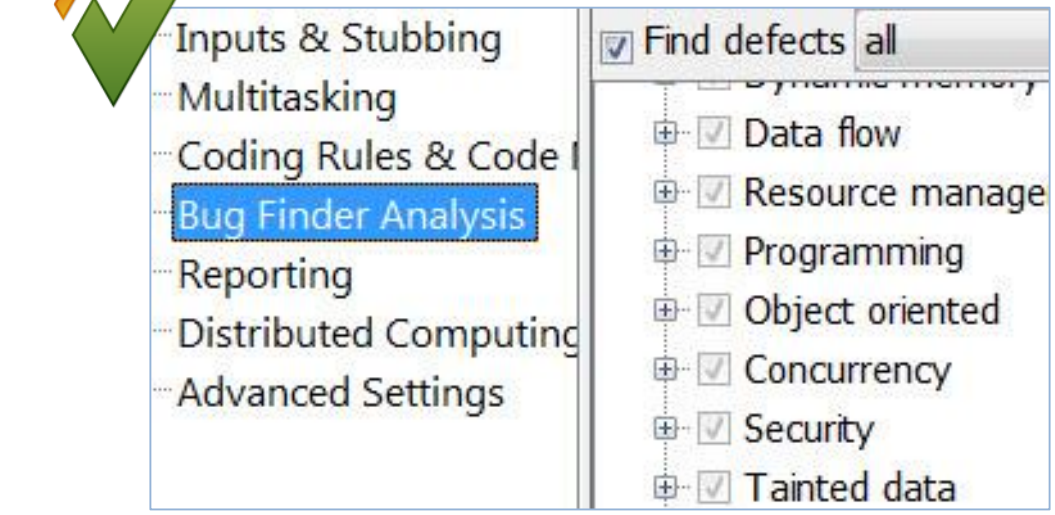
Floating-point HDL code generation

R2016b



Investments in Model-Based Design

Code verification in support of CERT C standard

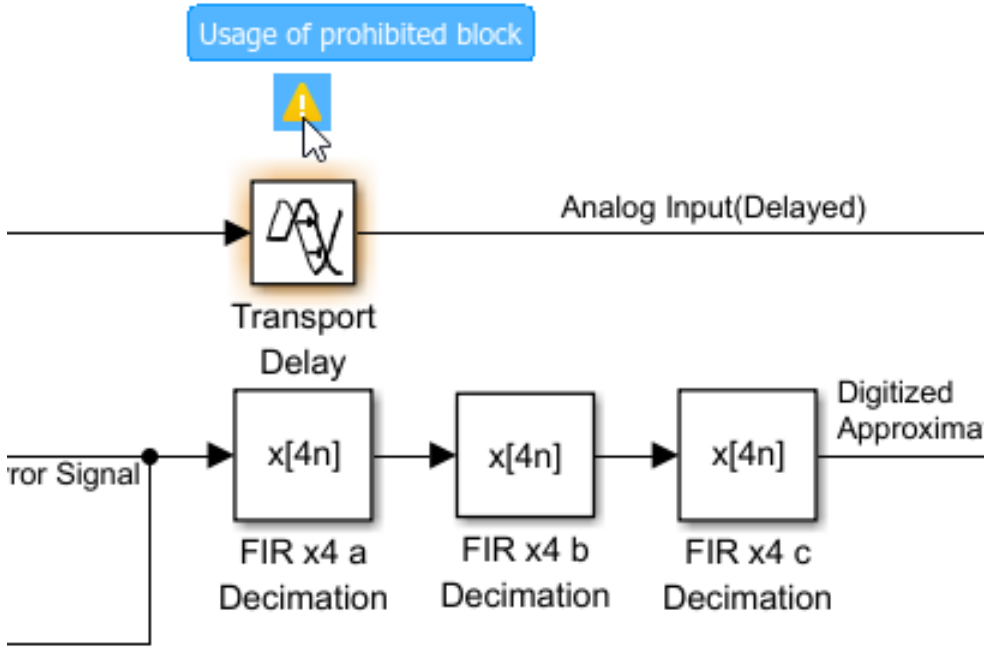



```
if (output_v7 >= 0) {
    saved_values[output_v7] = s8_ret;
    return s8_ret
}
return reset_temp
```

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

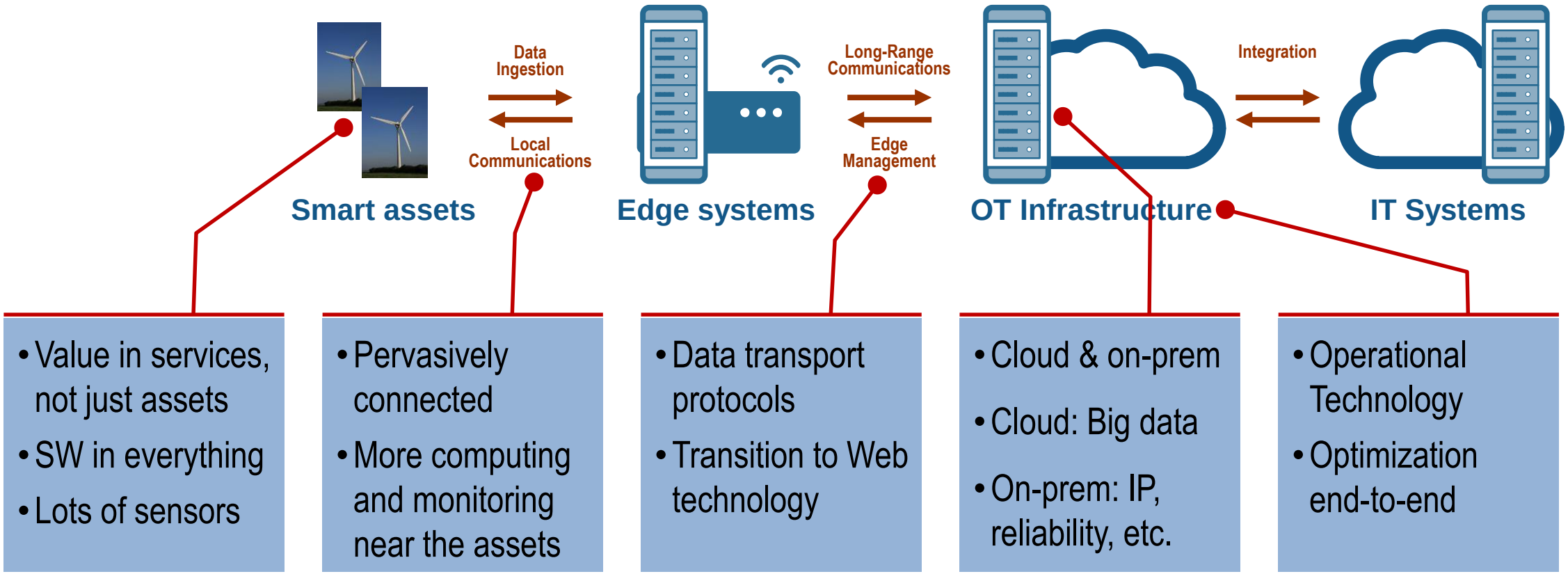
CERT C	Description	Polyspace Code Prover
ARR30-C	Do not form or use out-of-bounds pointers or array subscripts	Array access out of bounds

Detect and fix standards compliance issues at design time

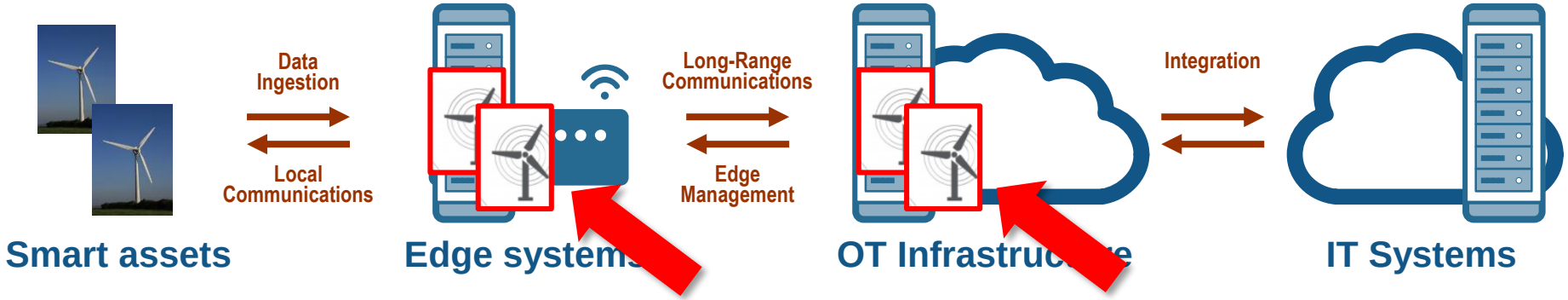


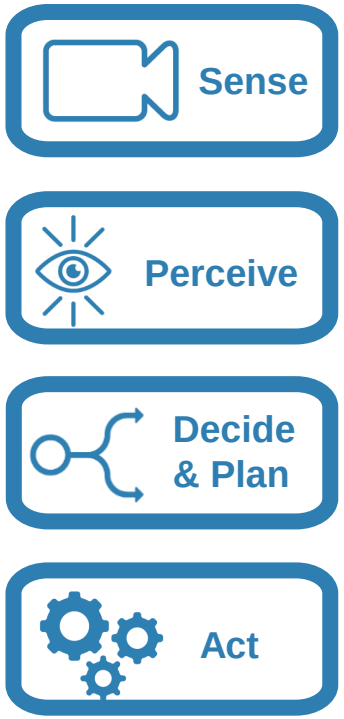
R2016b

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…

Smart assets

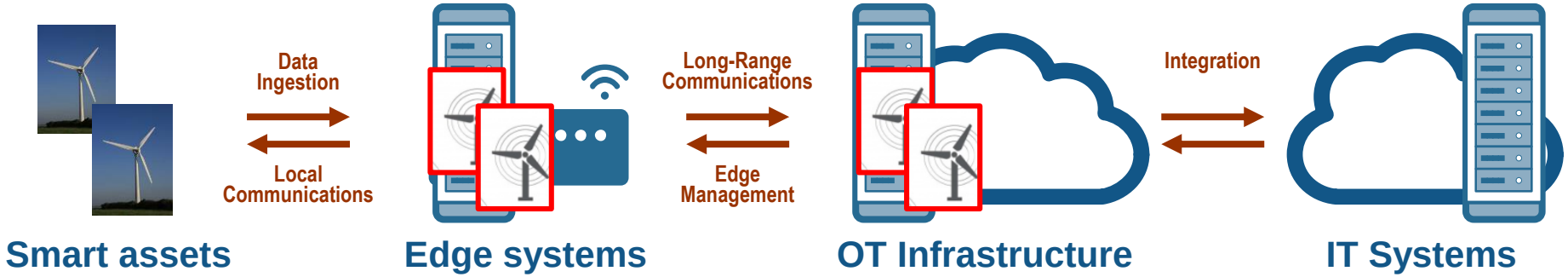
Long-Range Communications

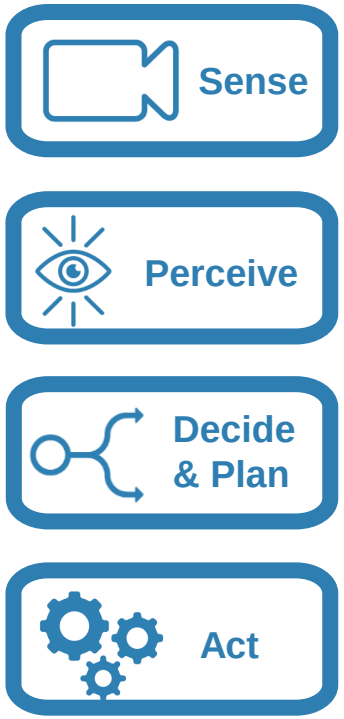
Asset Management

OT Infrastructure

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

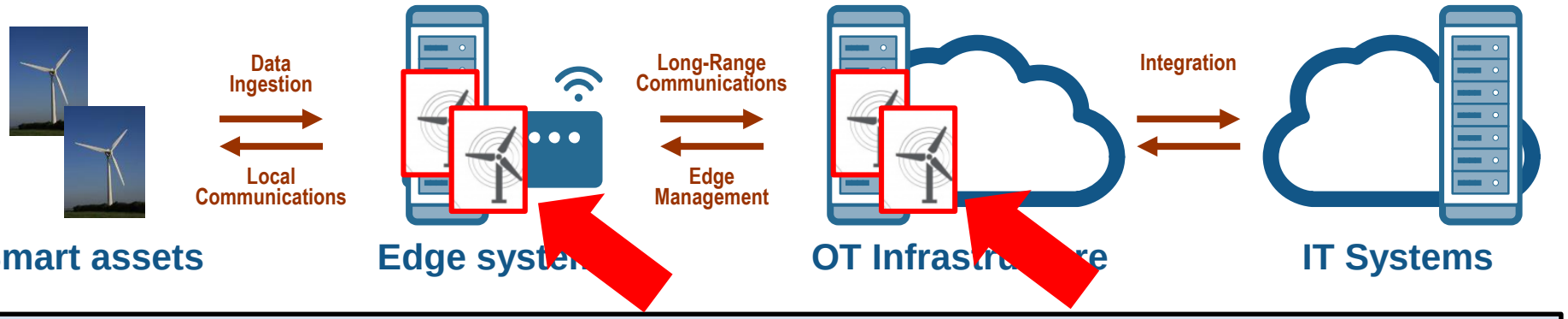


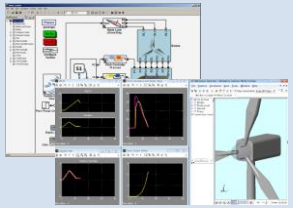


Digital Twin:

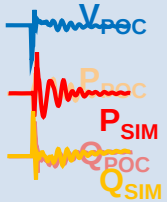
- models (dynamic, FEM, data-driven, etc.) and data
- for each asset (e.g., system, component, or system of systems)
- performance and conditions over the asset's history.
- continuously updated as the asset is operated.
- always represents a faithful representation of the current state of the asset.

MATLAB and Simulink for Digital Twins: Key Capabilities

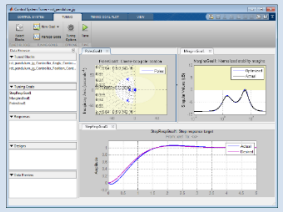




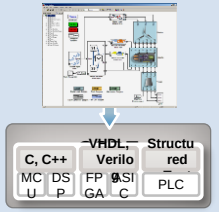
Multi-domain system modeling



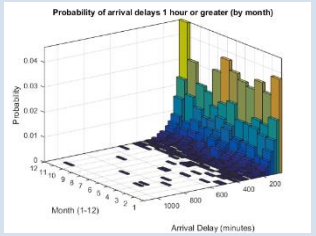
Parameter estimation



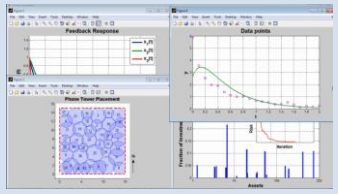
Control design and analysis



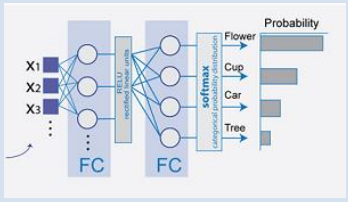
Automatic code generation



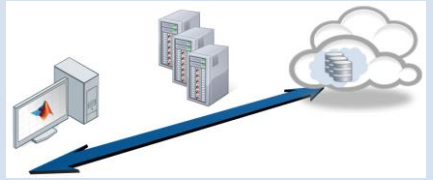
Variety and Volumes of Data



Optimization



Machine Learning and Deep Learning

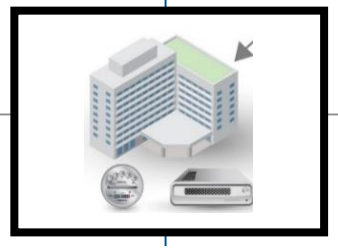


Enterprise system integration, with cluster/cloud execution

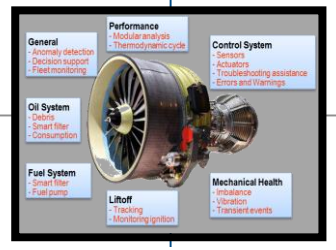
MATLAB and Simulink for Digital Twins throughout the lifecycle

Wind farm planning

Ensuring power grid reserves



Cloud-based HVAC optimization



Engine prognostics & health monitoring

Future car infrastructure

Automatic braking systems

Asteroid rendezvous

System

Process

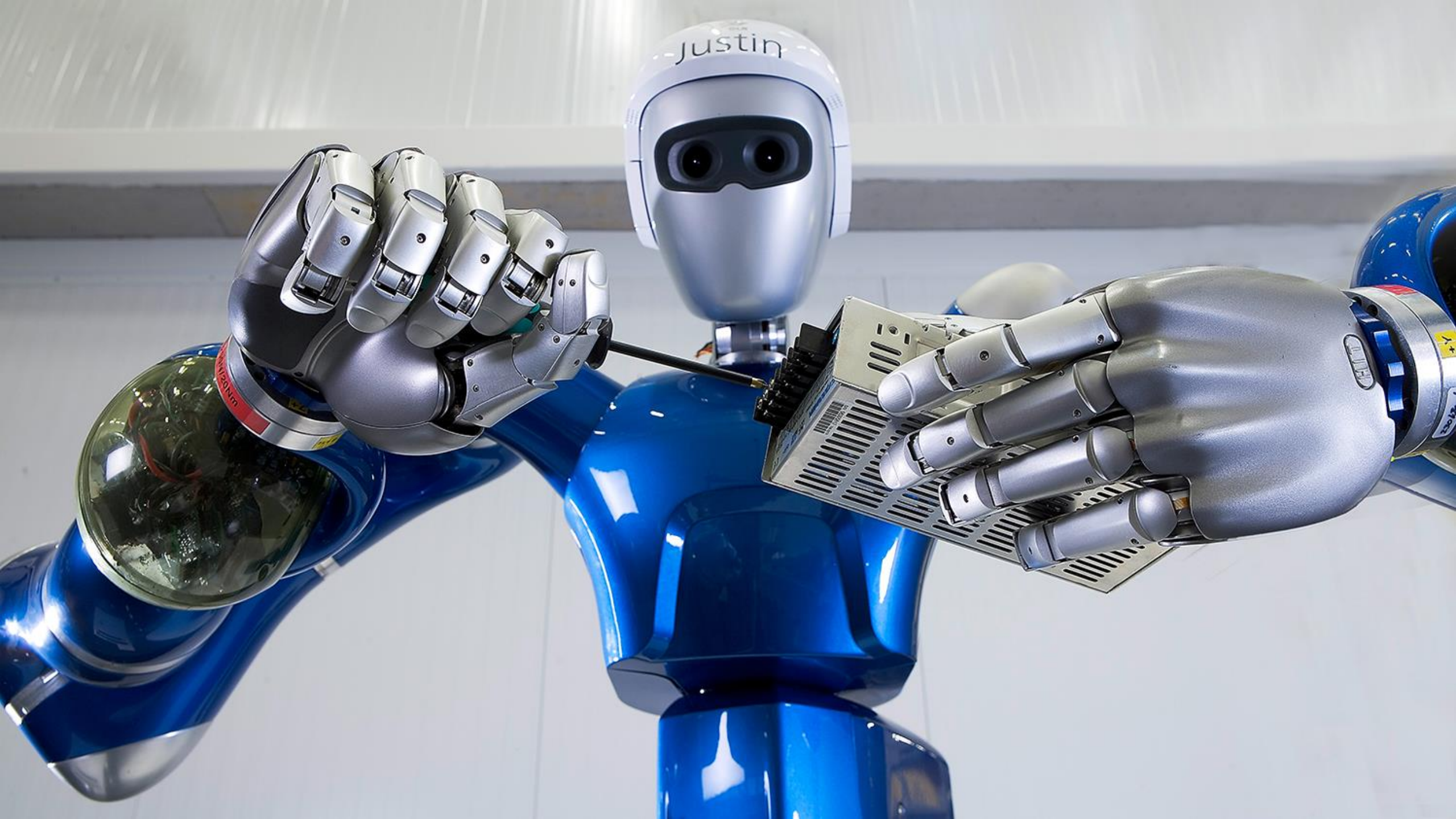
Product

Planning

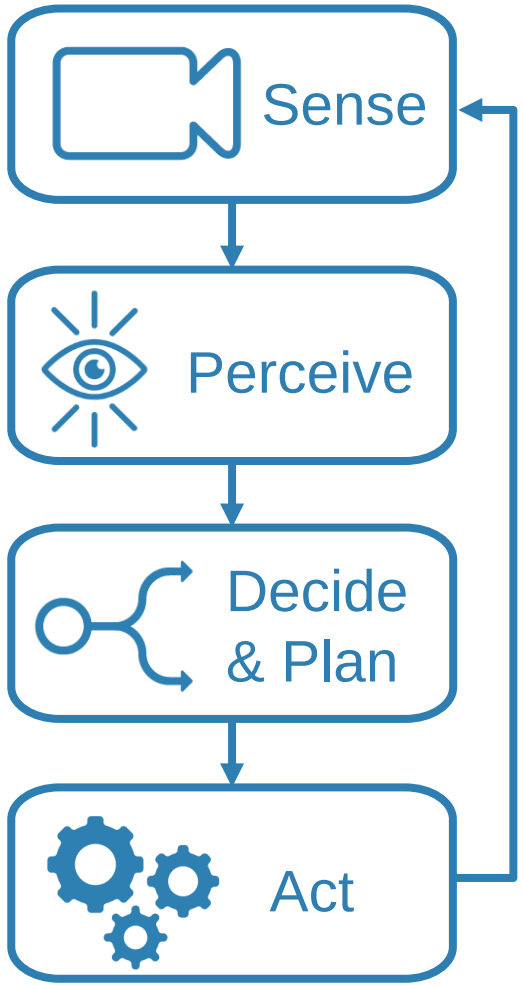
Development

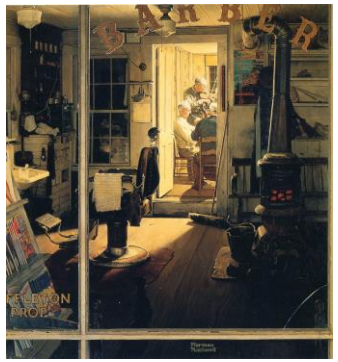
Operation

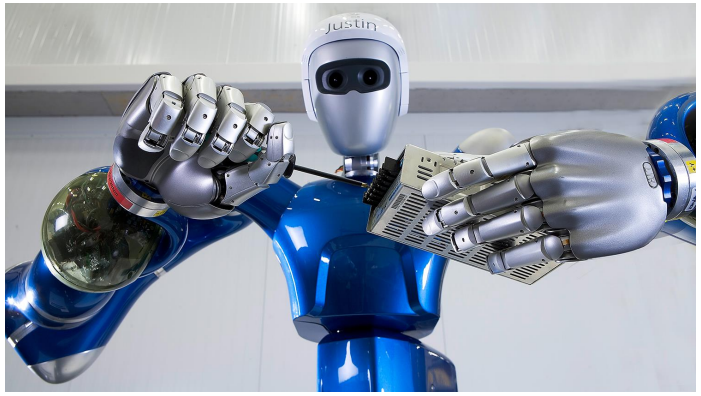
Maintenance


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?