NATIONAL INSTRUMENTS™

The Internet of Things and Factory of Future

Andy Chang
Sr. Manager,
Academic Research &
Industrial Internet of Things

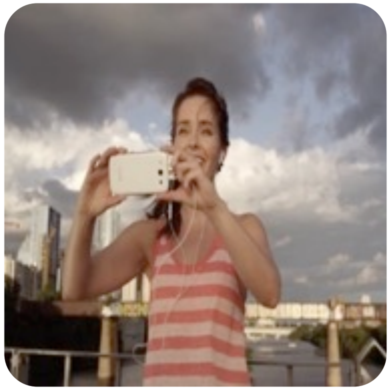
Our Mission

We equip engineers and scientists with systems that accelerate productivity, innovation, and discovery.

Our Customers


Advanced Manufacturing


Industry Research

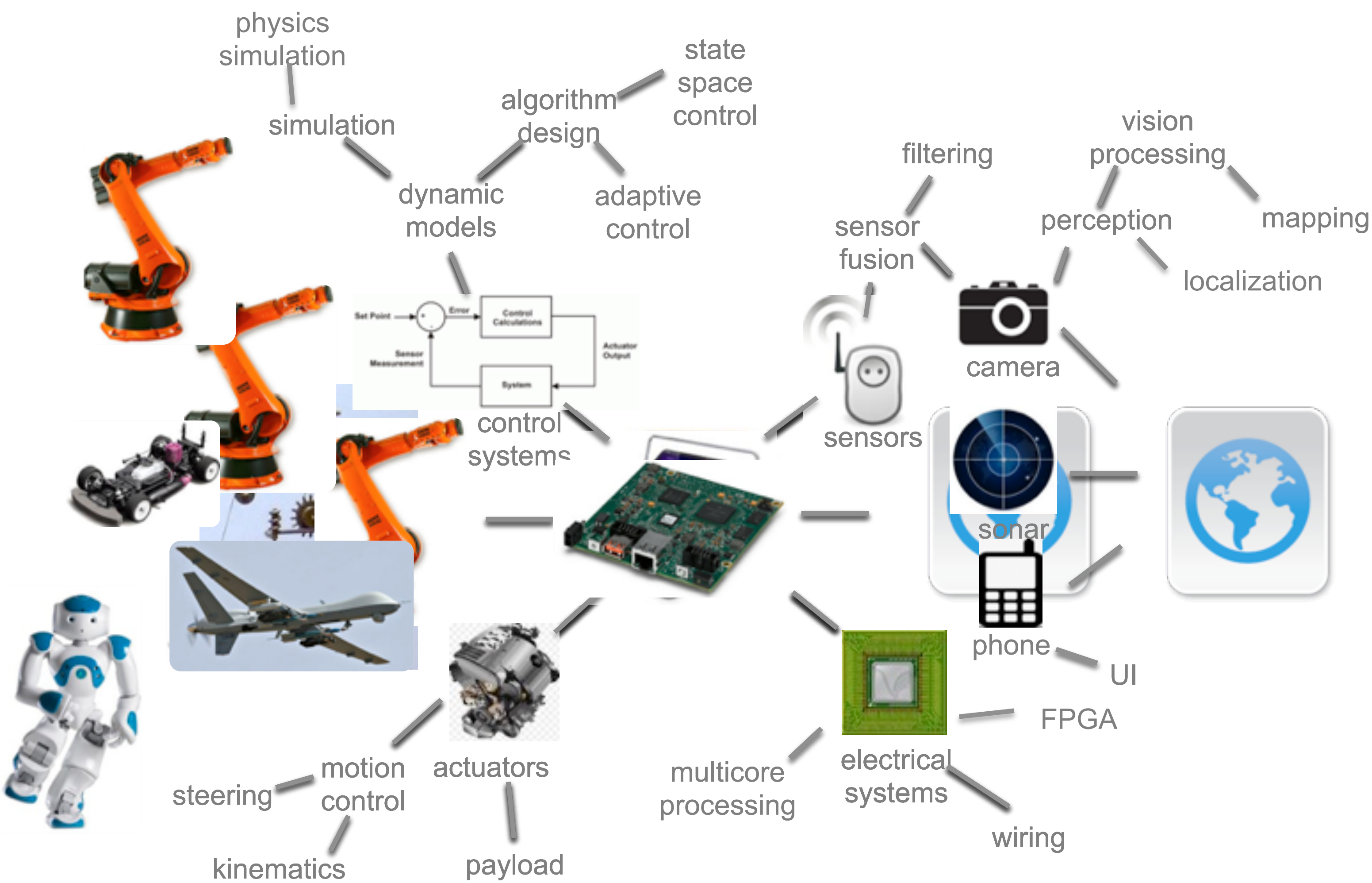

Consumer Electronics

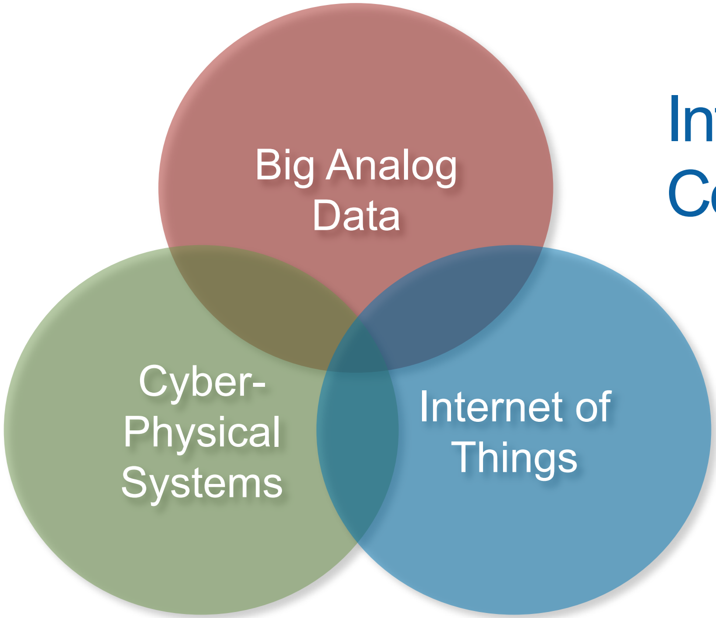

Wireless


Energy


Transportation

The Escalating Complexity of Systems . . .





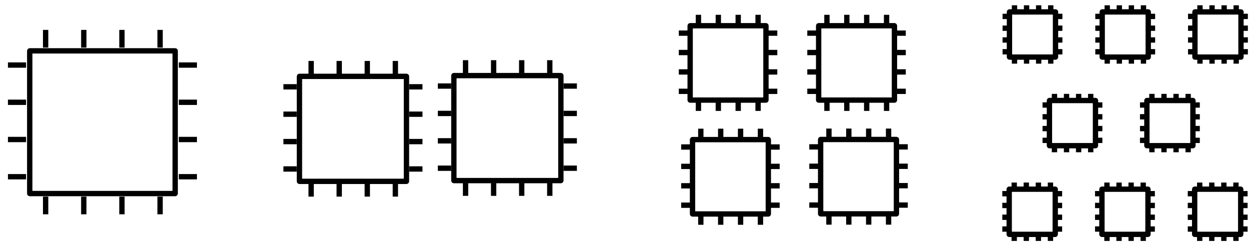
Integration of Computation, Communication, and Control

- Big Analog Data: High-Volume Data
- Cyber-Physical Systems: Control Systems
- Internet of Things: Network Connectedness

Enabling Laws for Internet of Things

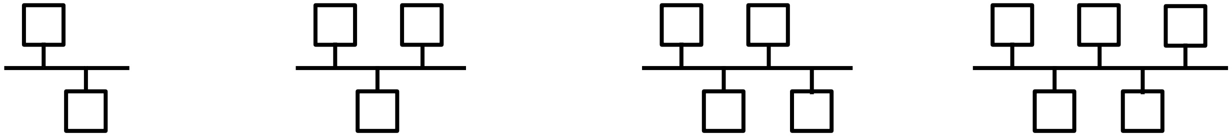
Moore's Law

$$P_n = P_o \times 2^n$$



Metcalfe's Law

$$C_m = \frac{m(m-1)}{2}$$



Perspective

Pope Election 2005

Perspective

IOT WILL IMPACT

75% ENGINEERS

IN 3 YEARS

- VDC

50 BILLION

DEVICES CONNECTED BY 2020

30X

INCREASE IN "THINGS"

- GARTNER, 2014

1.9 BILLION

SMART PHONES

17.5%

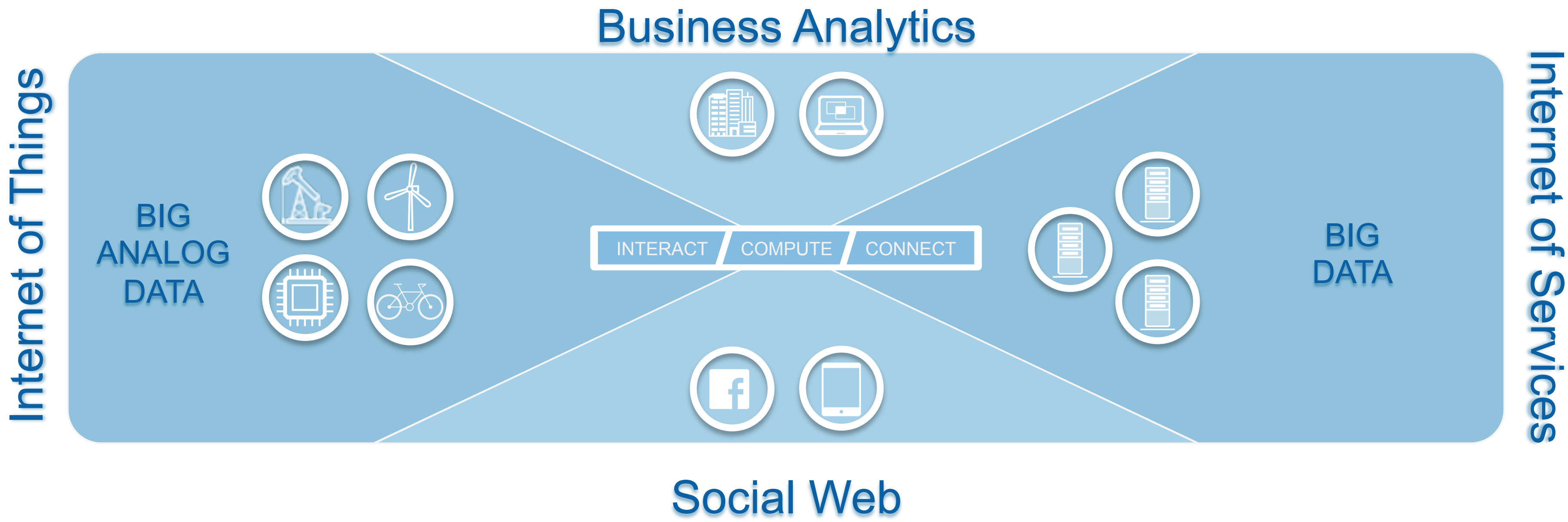
CAGR

- IDC, 2014

$19 TRILLION

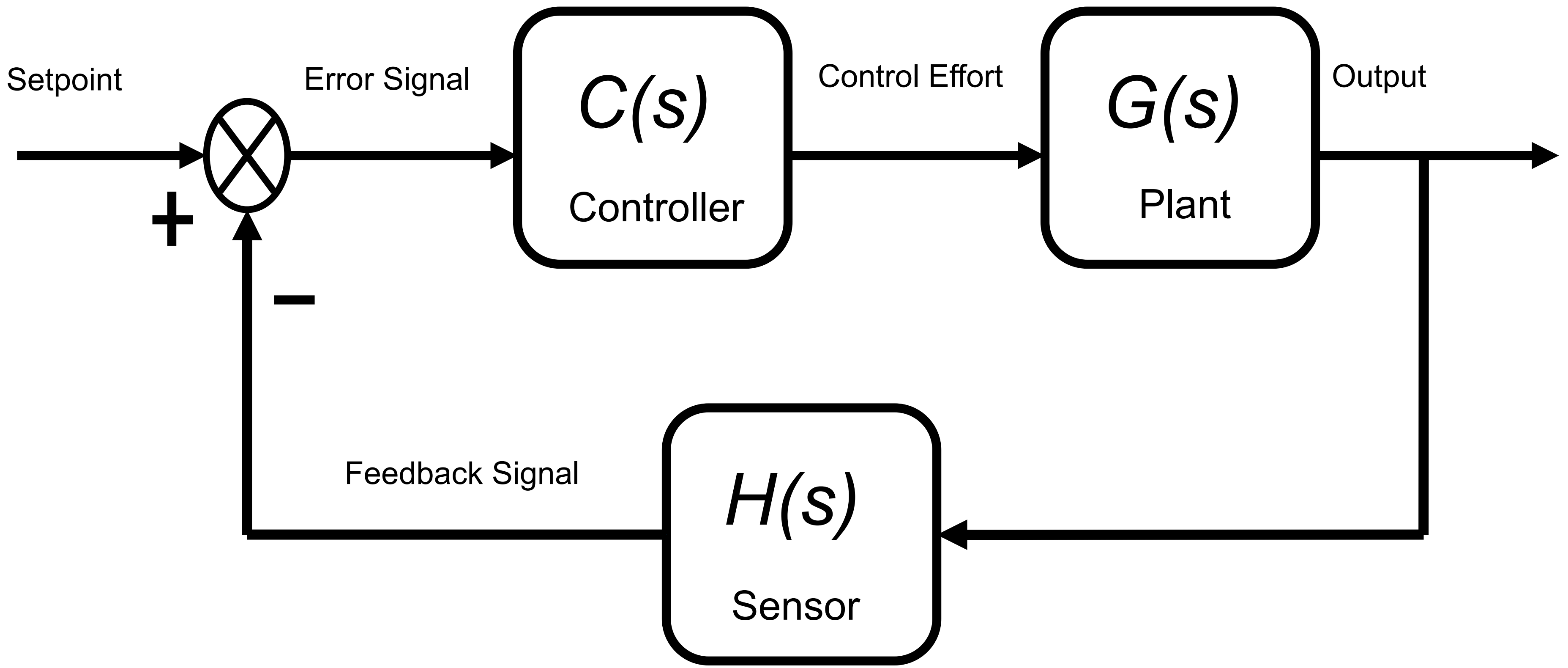
OPPORTUNITY

Landscape of Internet of Things

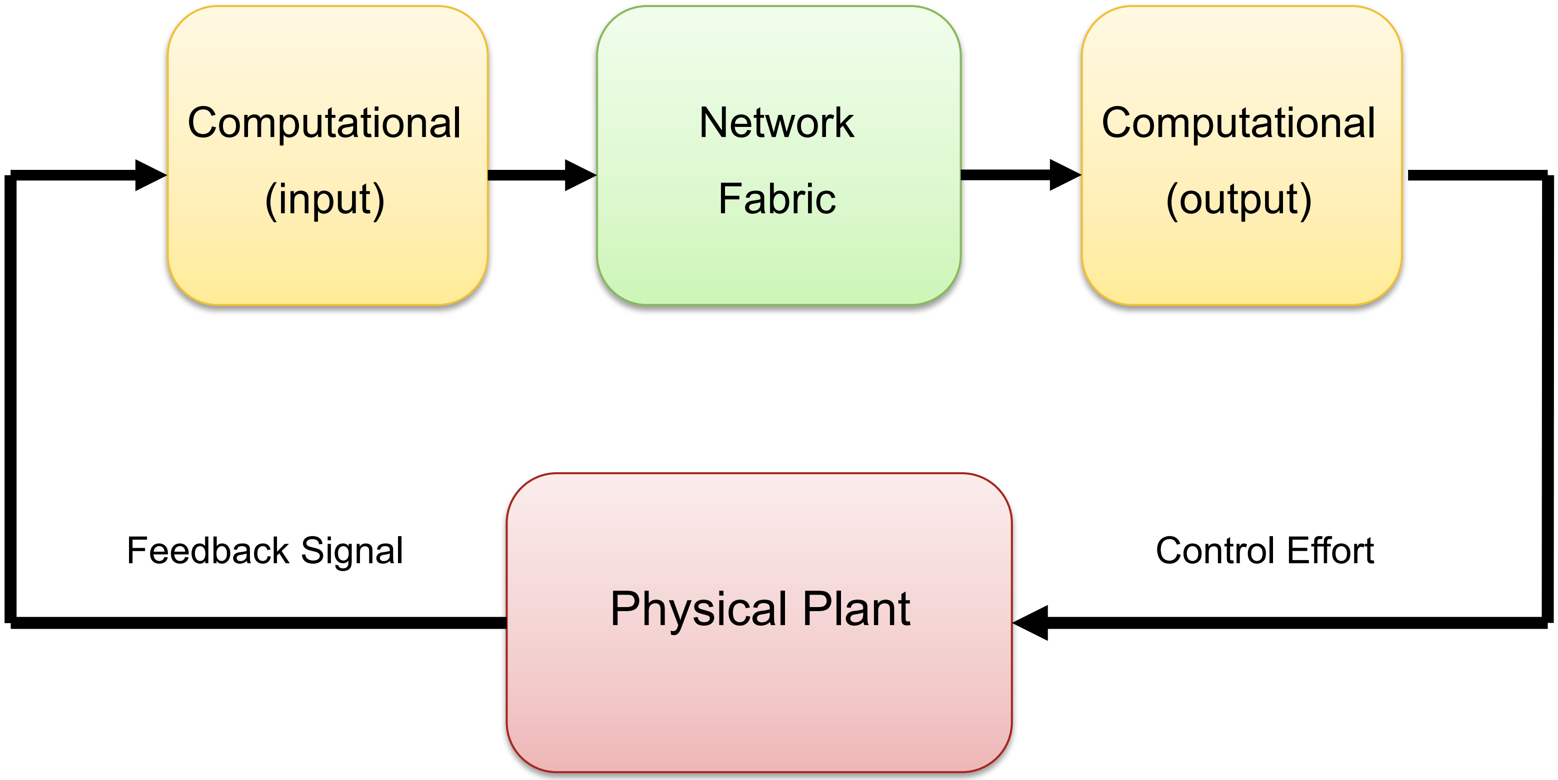


Simple Schematic

Digital Control Systems, ca, 1960

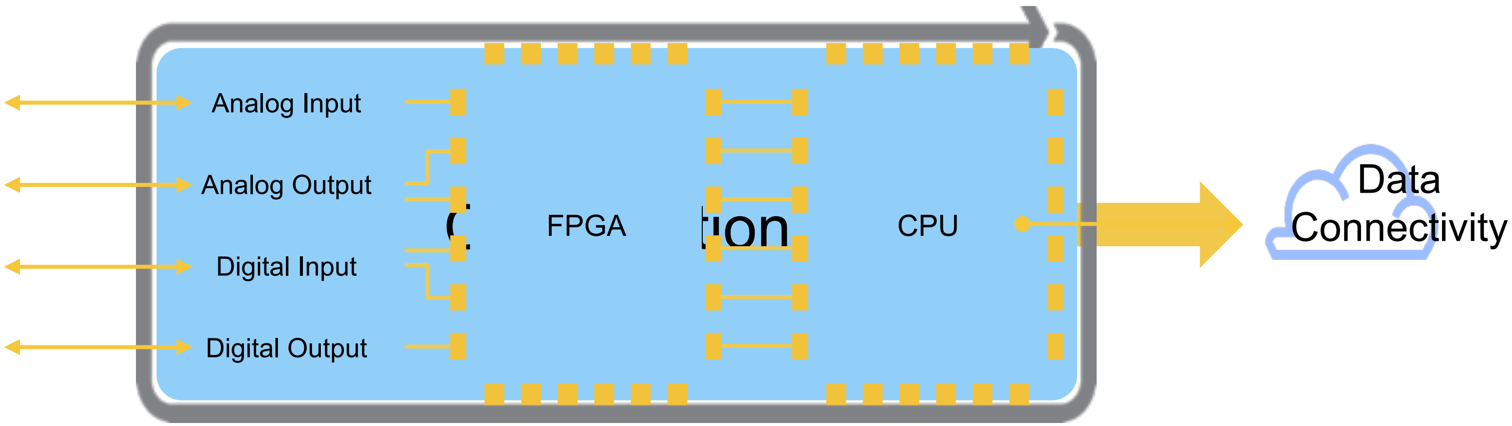


Simple Schematic



Smart Edge Node Architecture

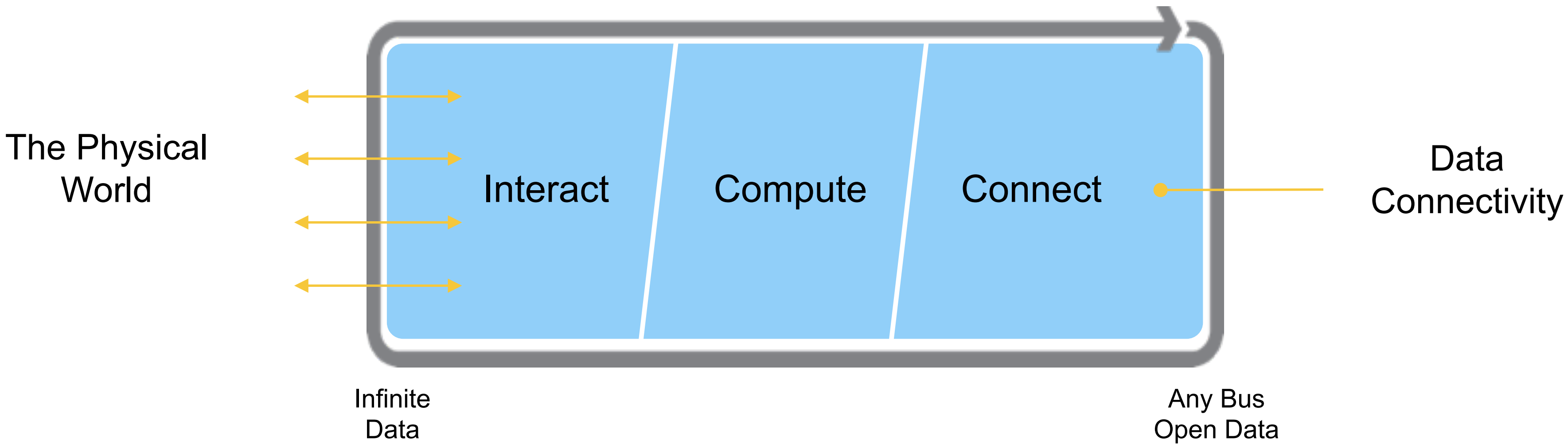
The Physical World



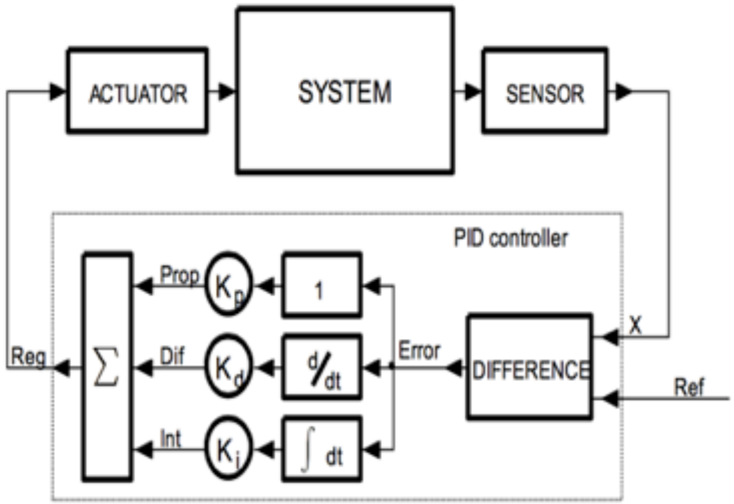
Infinite Data

Any Bus
Open Data

Smart Edge Node Architecture



Control Methodology



Bare Iron Level

```
//------------------- Calculates the PID drive value  --------------------
      Actual = analogRead(Position);
      Error = SetPt - Actual;

      if (abs(Error) < IntThresh){          // prevent integral 'windup'
         Integral = Integral + Error;       // accumulate the error integral
      }
      else {
         Integral=0;                          // zero it if out of bounds
      }
      P = Error*kP;                         // calc proportional term
      I = Integral*kI;                      // integral term
      D = (Last-Actual)*kD;                 // derivative term
      Drive = P + I + D;                    // Total drive = P+I+D
      Drive = Drive*ScaleFactor;            // scale Drive to be in the range 0-255
      if (Drive < 0){                       // Check which direction to go.
         digitalWrite (Direction,LOW);      // change direction as needed
      }
      else {                                //   depending on the sign of Error
         digitalWrite (Direction,HIGH);
      }
      if (abs(Drive)>255) {
         Drive=255;
      }
      analogWrite (Motor,Drive);            // send PWM command to motor board
      Last = Actual;                        // save current value for next time
}
```

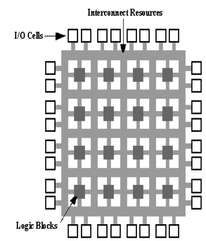
Control Implementation

Tools

- Math (.m file script)
- Simulation (Hybrid)
- User Interface (HTML)
- FPGA (VHDL, Verilog)

- Host Control (C, C++, .NET)
- DSP (Fxd pt C, Assembly)
- H/W Driver (C, Assembly)
- System Debug

Targets

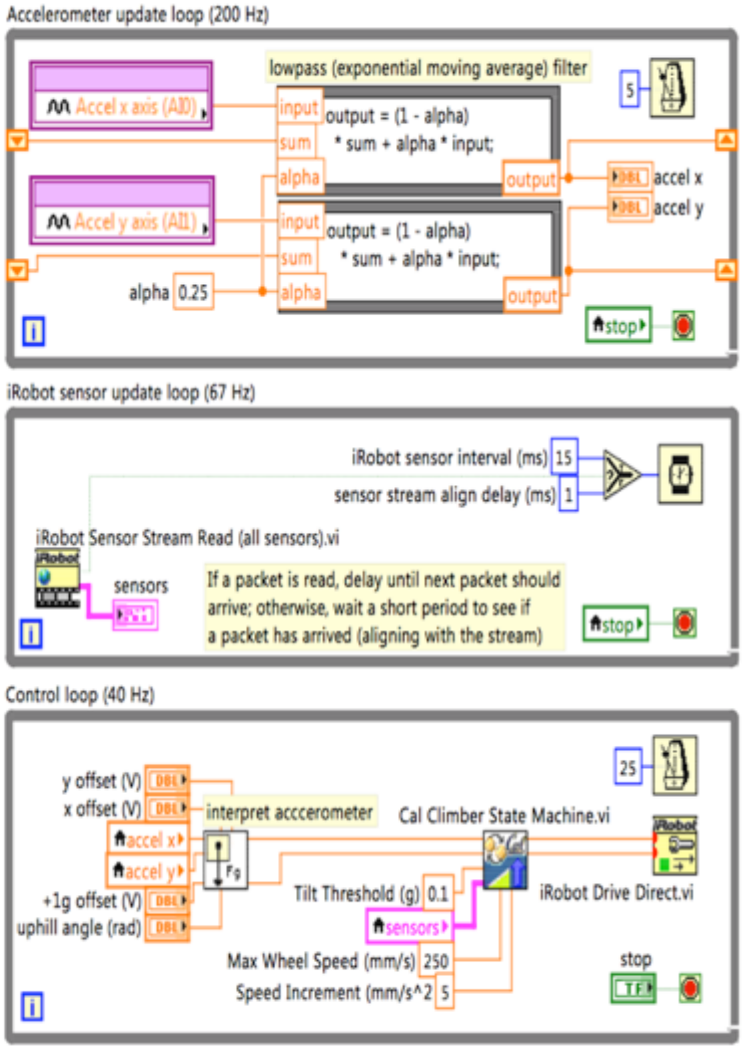


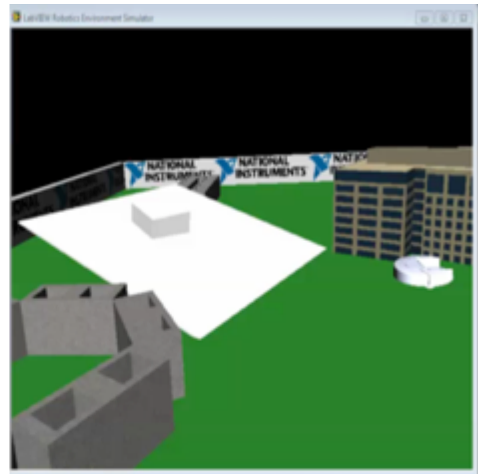
FPGAs

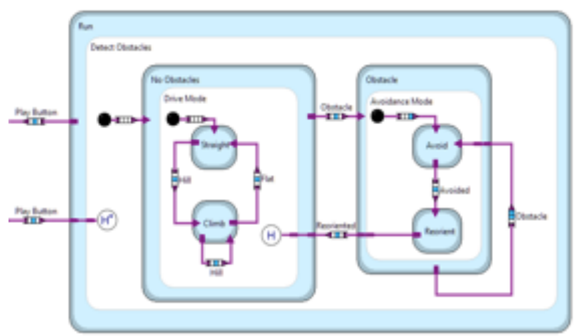
Multicore Processors (Desktop & RTOS)

- Levels of abstraction for concurrent algorithms
- Parallel processing, multi-tasking increases system complexity
- Model of computation

Algorithm Engineering for Control Systems

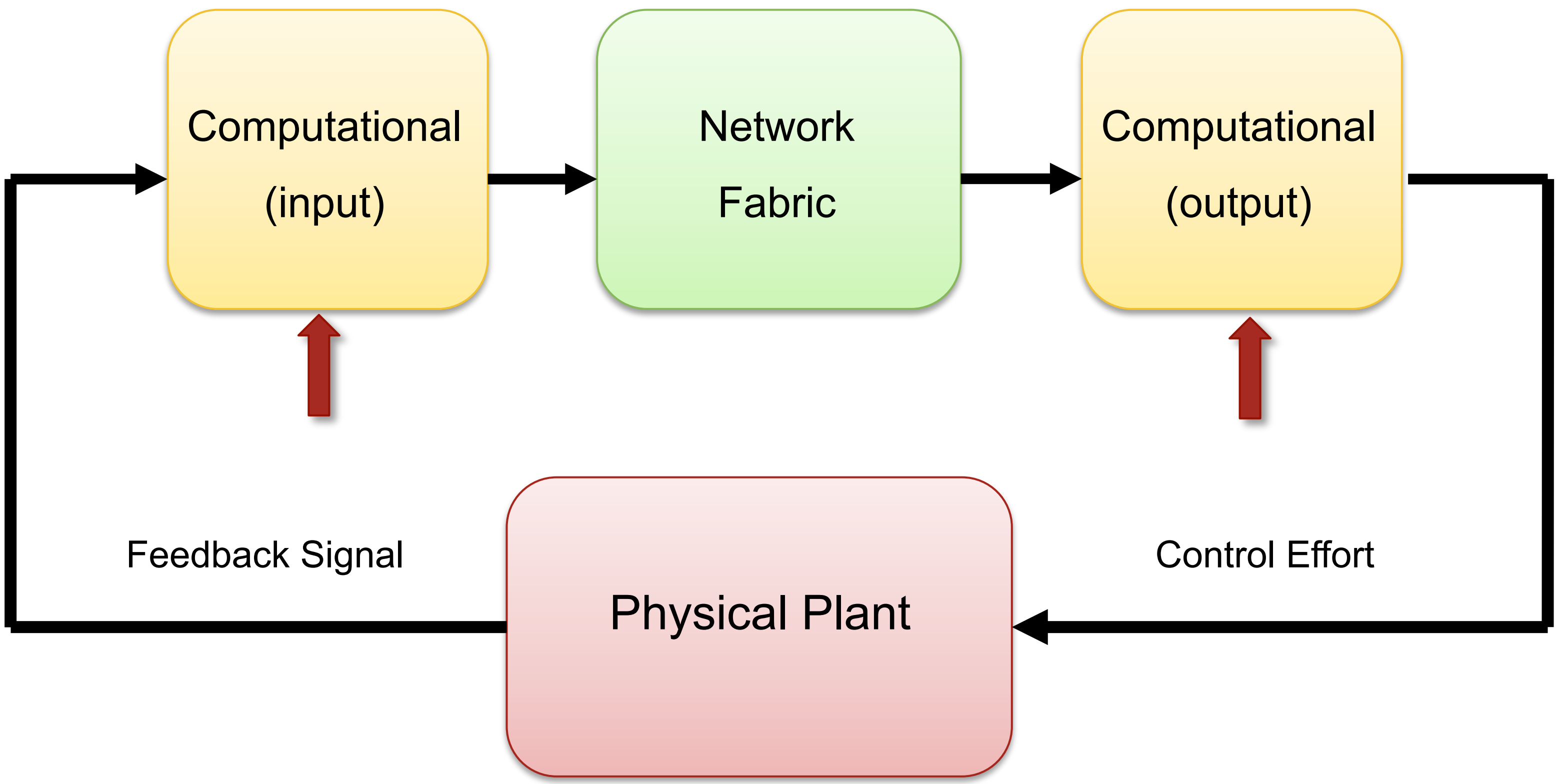






Towards Lab-Based MOOCs, Seshia, UC Berkeley, 2014

System Design on Timing

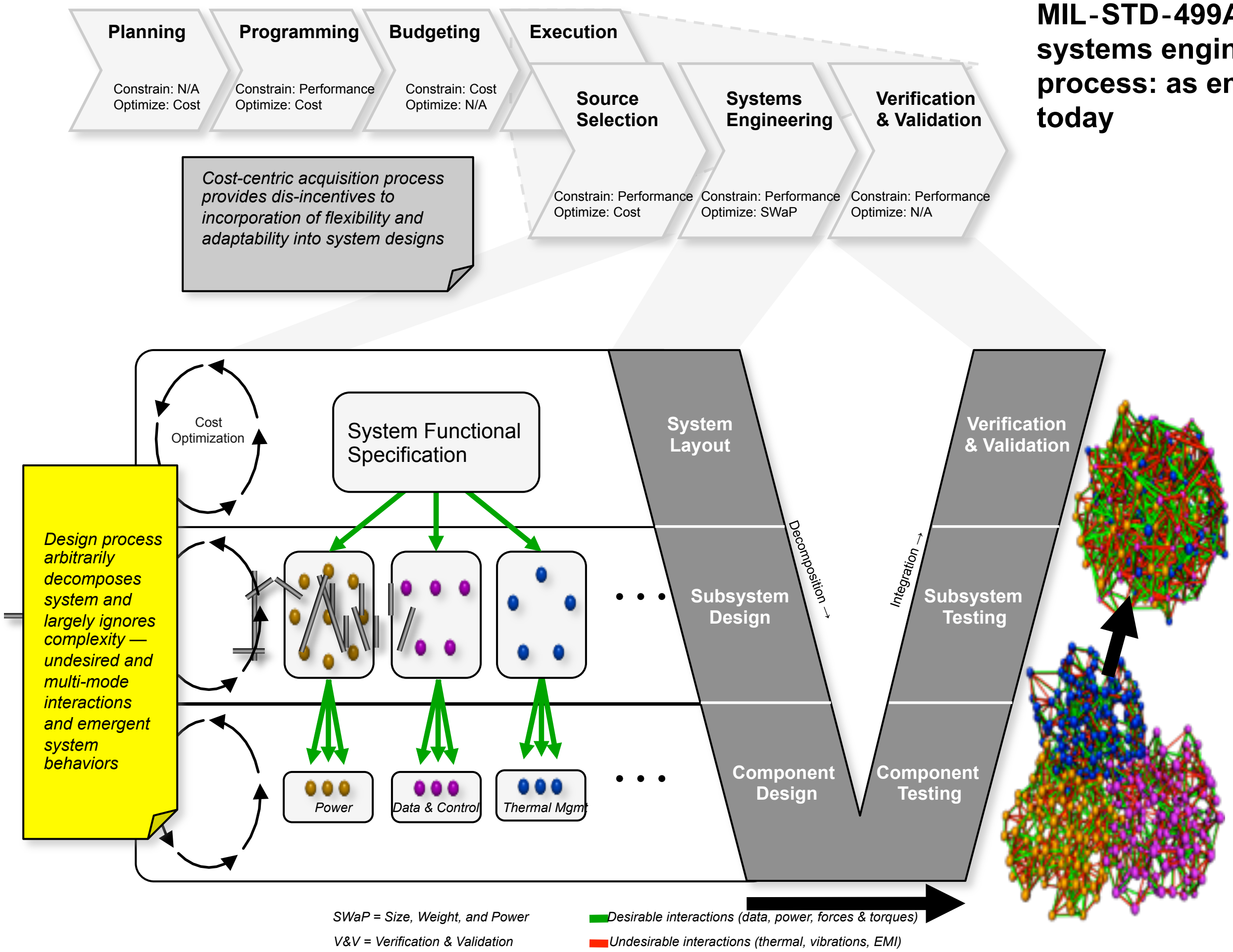


Need Time-Sensitive Network!!

$$\dot{\theta}(t) = \dot{\theta}(0) + \frac{1}{I}\int_0^t \mathbf{T}(\tau)\,d\tau$$

Status Quo in System Design (V Model):

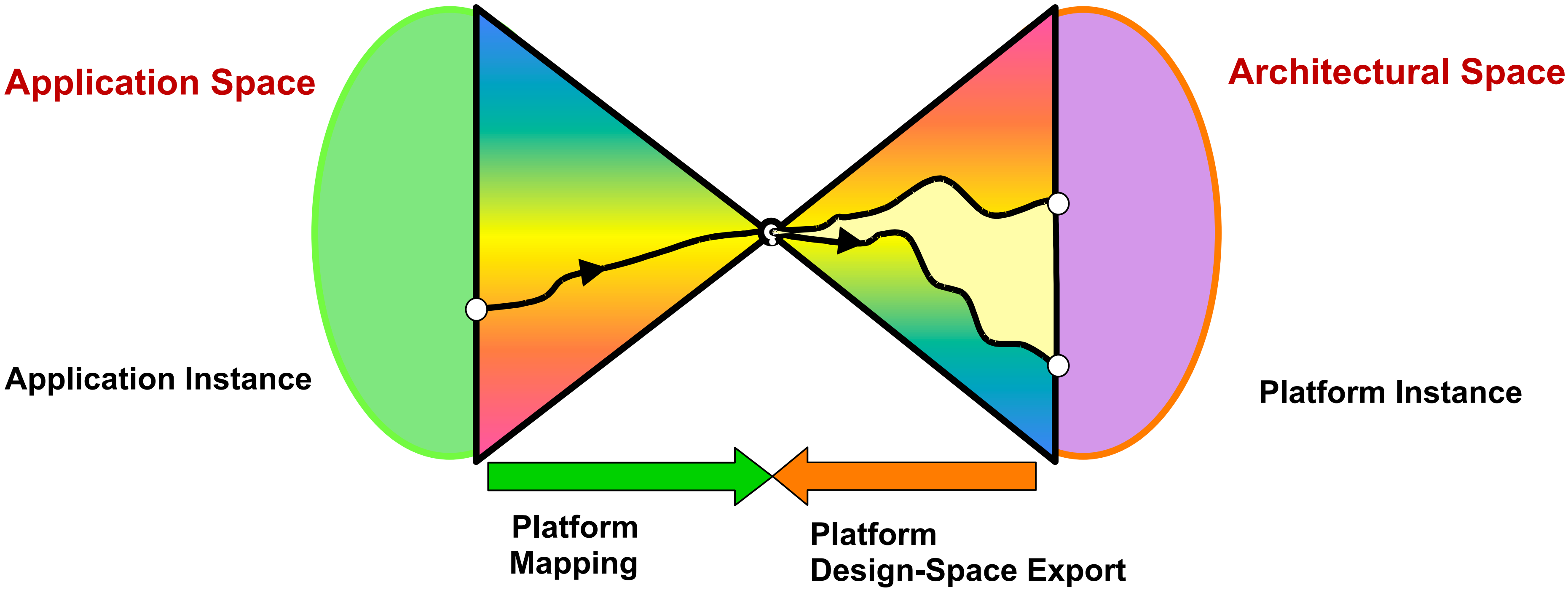
There are several areas where change is necessary



MIL-STD-499A (1969) systems engineering process: as employed today

Conventional V&V techniques do not scale to highly complex or adaptable systems (i.e., those with large or infinite numbers of possible states/ configurations)

Platform-Based Design for Internet of Things

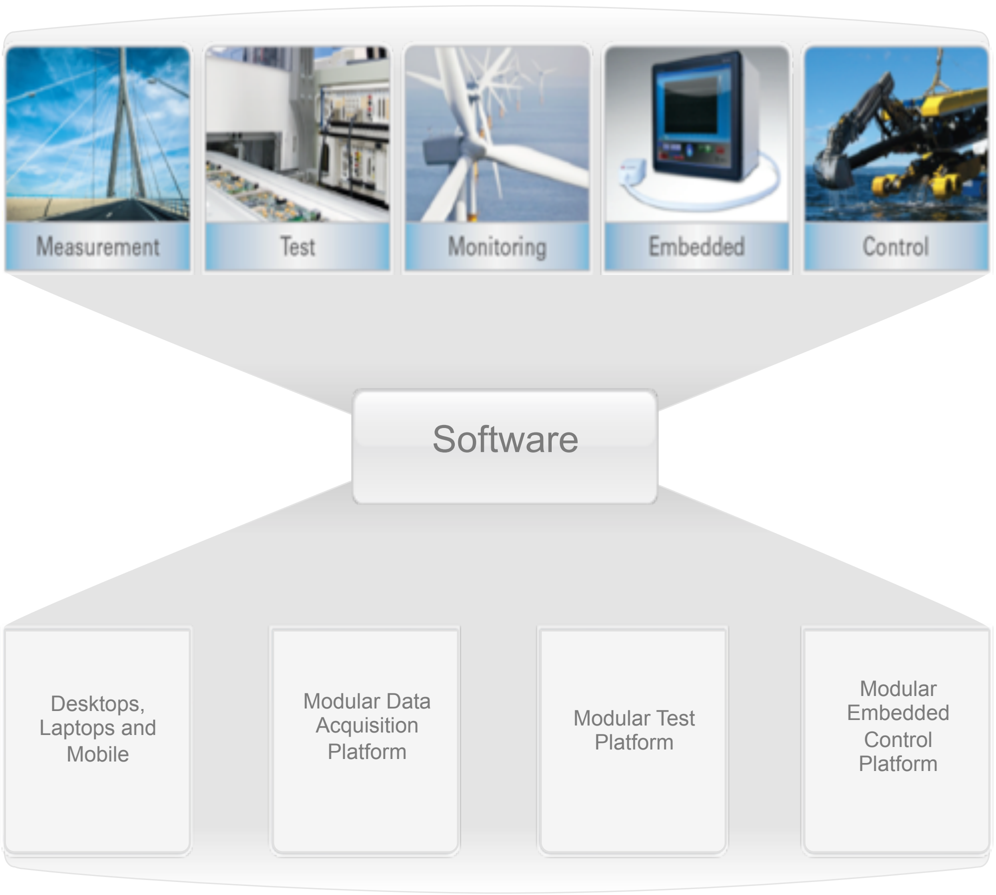


Platform: library of resources defining an abstraction layer with interfaces that allow legal connections

- Resources do contain virtual components i.e., placeholders that will be customized in the implementation phase to meet constraints
- Very important resources are interconnections and communication protocols

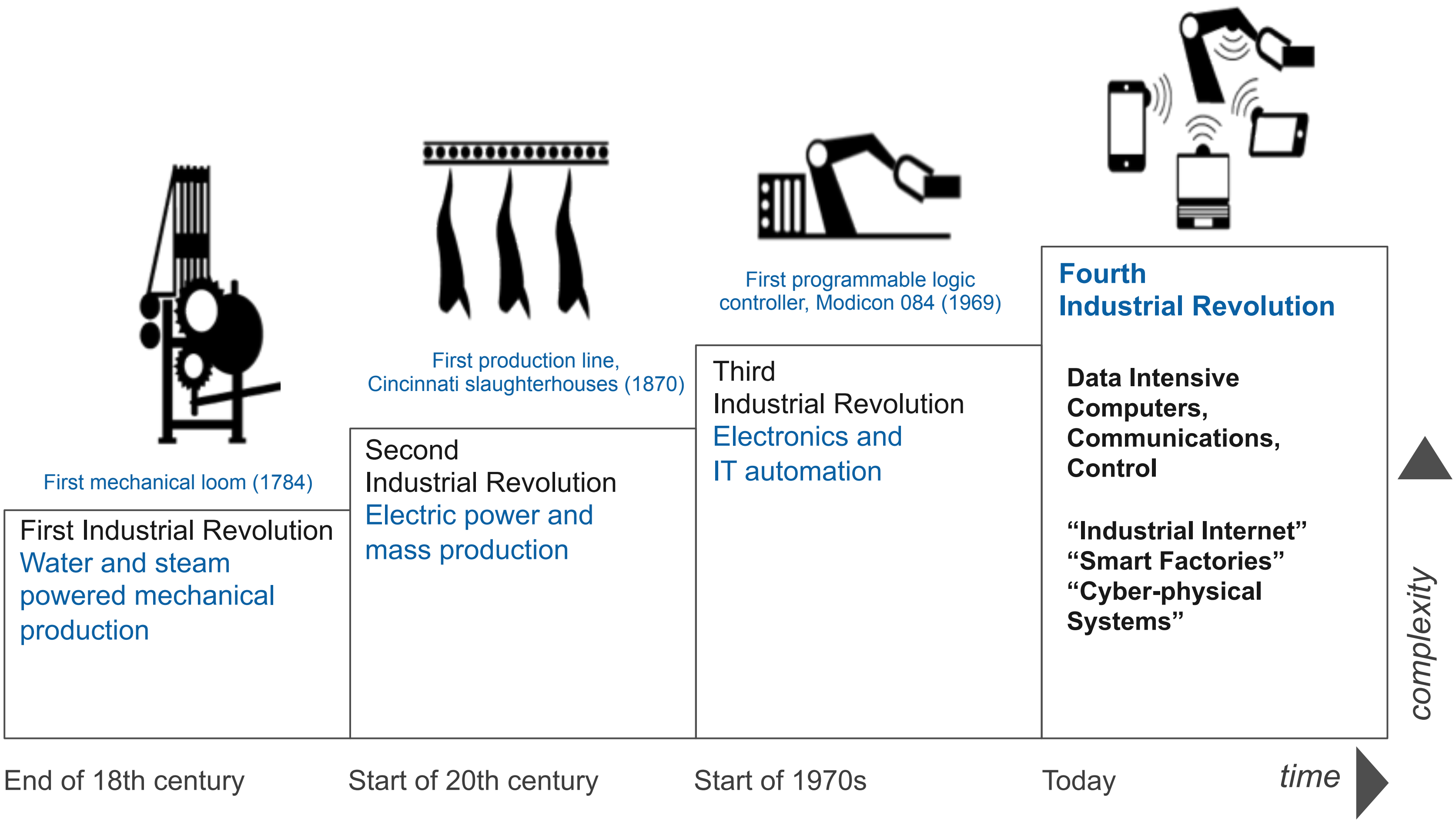
A. Sangiovanni-Vincentelli, UC Berkeley. Defining Platform Based Design. EEDesign, Feb 2002

Platform-Based Design



Platform-Based Design

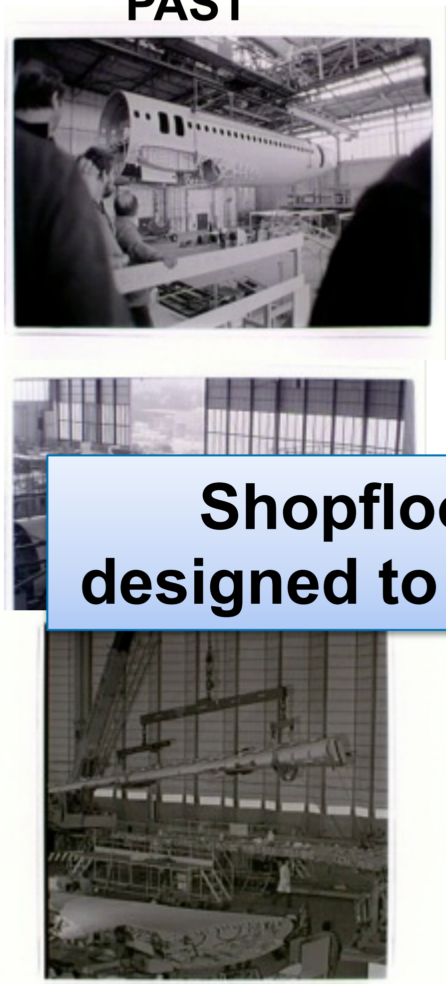
Industrie 4.0



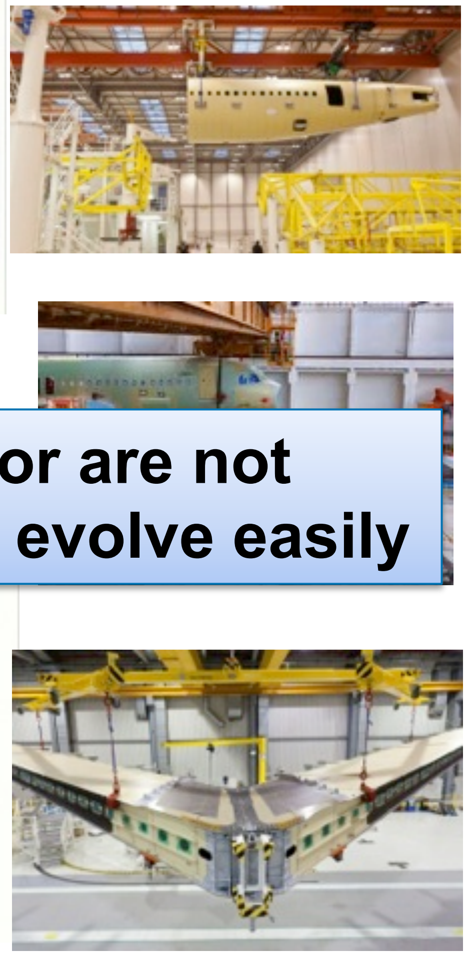
Source DKFI 2011

Status Quo for Manufacturing

PAST

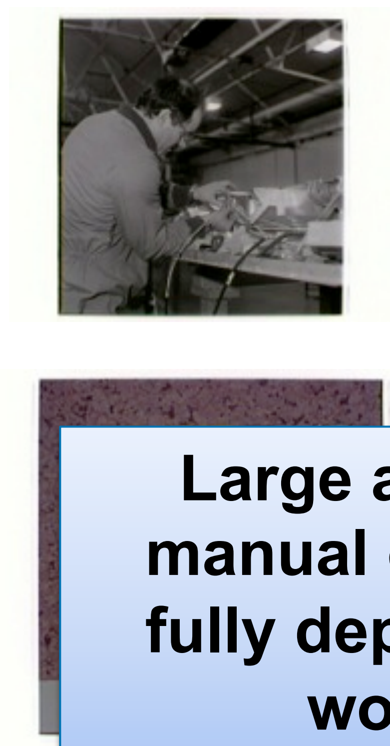


AS IS

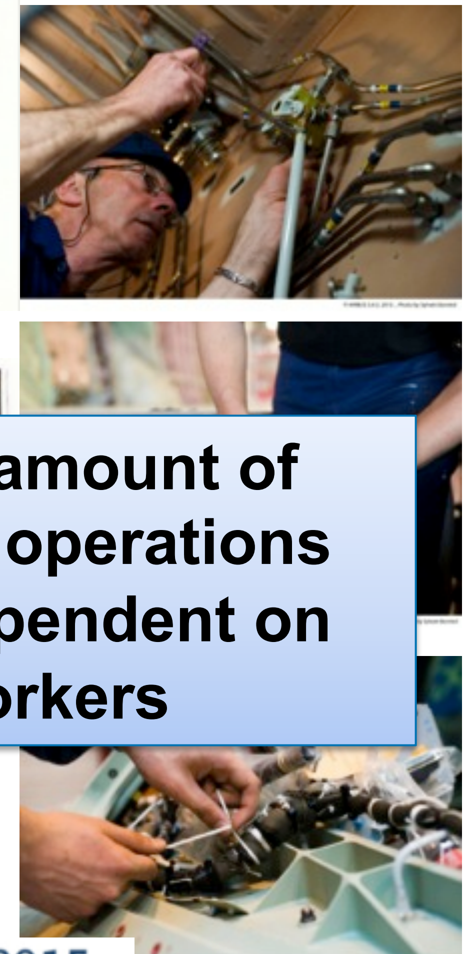


Shopfloor are not designed to evolve easily

PAST



AS IS



Large amount of manual operations fully dependent on workers

400,000+ Hole Locations
1,000+ Tightening Tools
Increase Quality Assurance


Tack and Trace-Main.vi on Track and Trace Demo.lvproj/NI-sbRIO-9651-0304f9ce
File Edit View Project Operate Tools Window Help
System Status: Idle (Press Start)
Red Less 30
Run Time: 8.08
FPS: 31.4
Stop

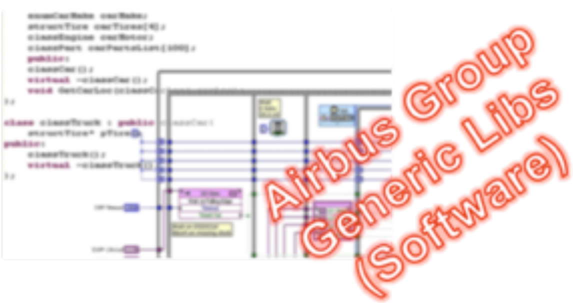
Intelligent Devices

HD camera embedded on operator glasses

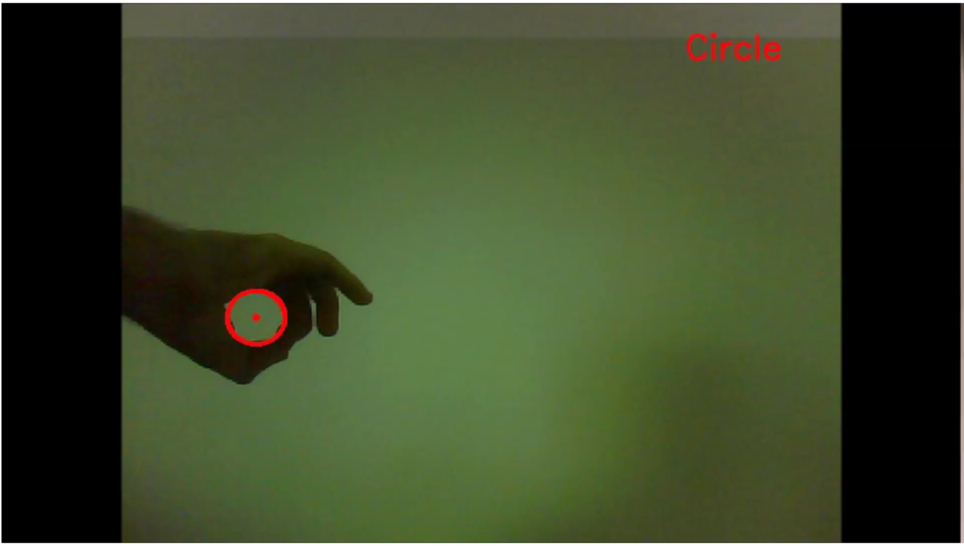
+

Processor embedded in operator suit

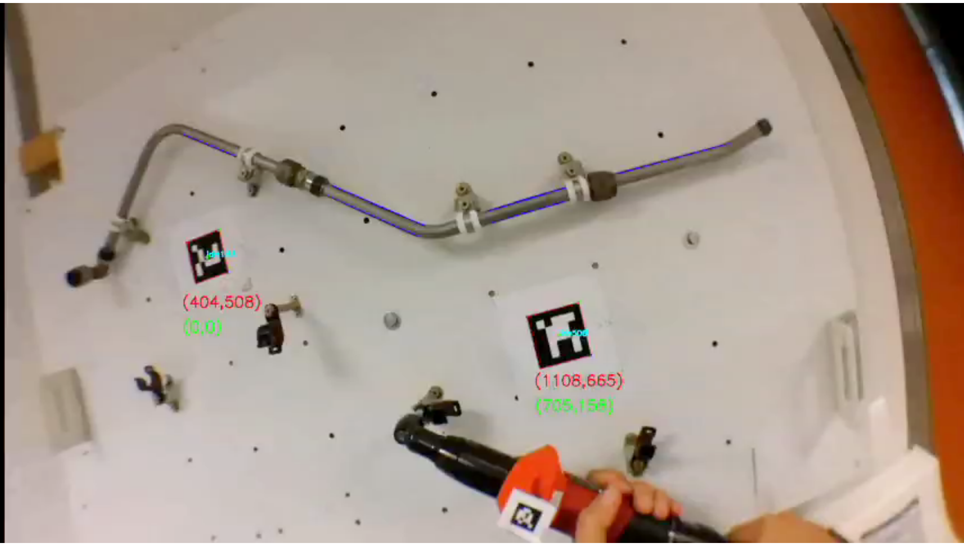
+



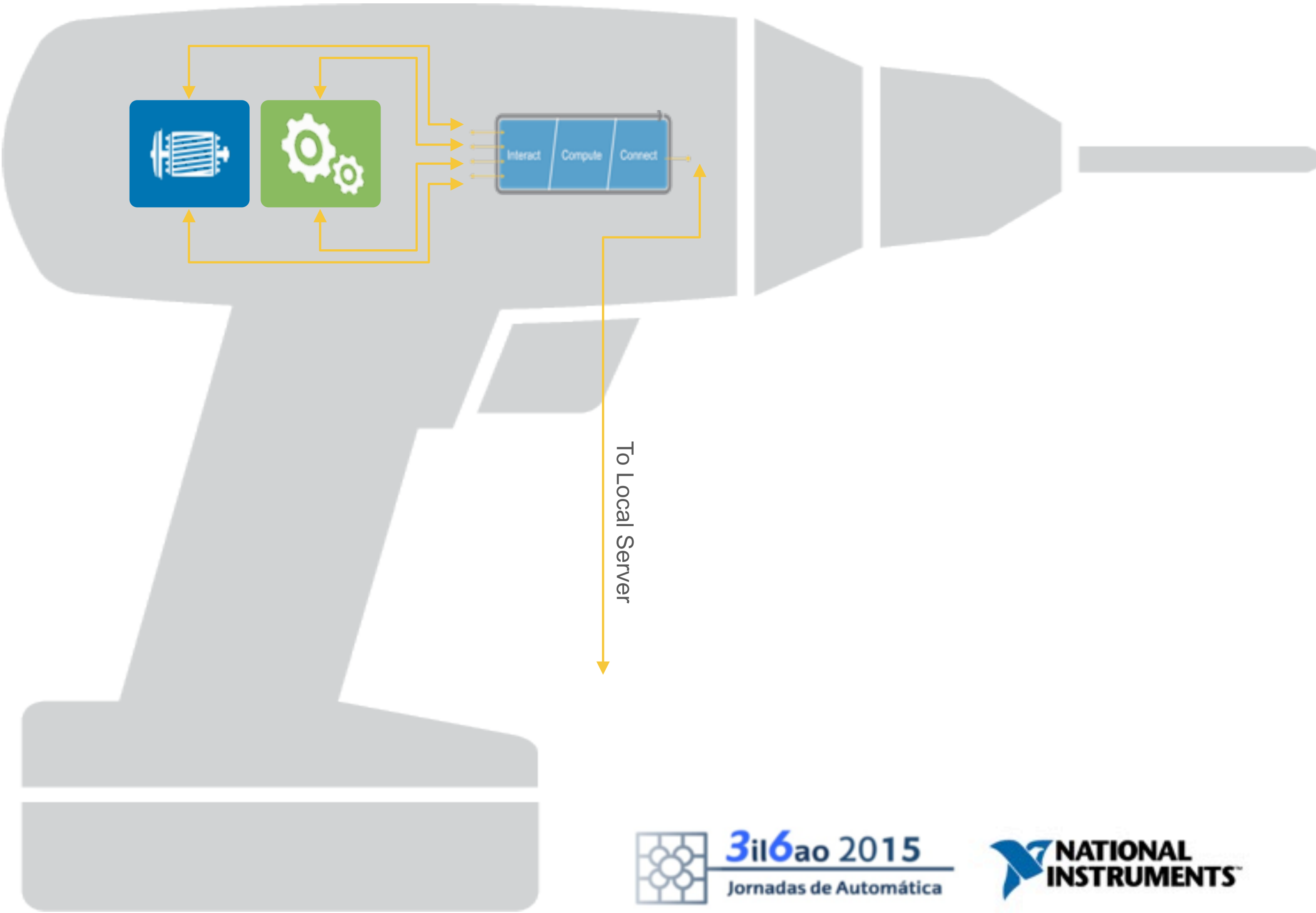
Embedded Image Processing Software

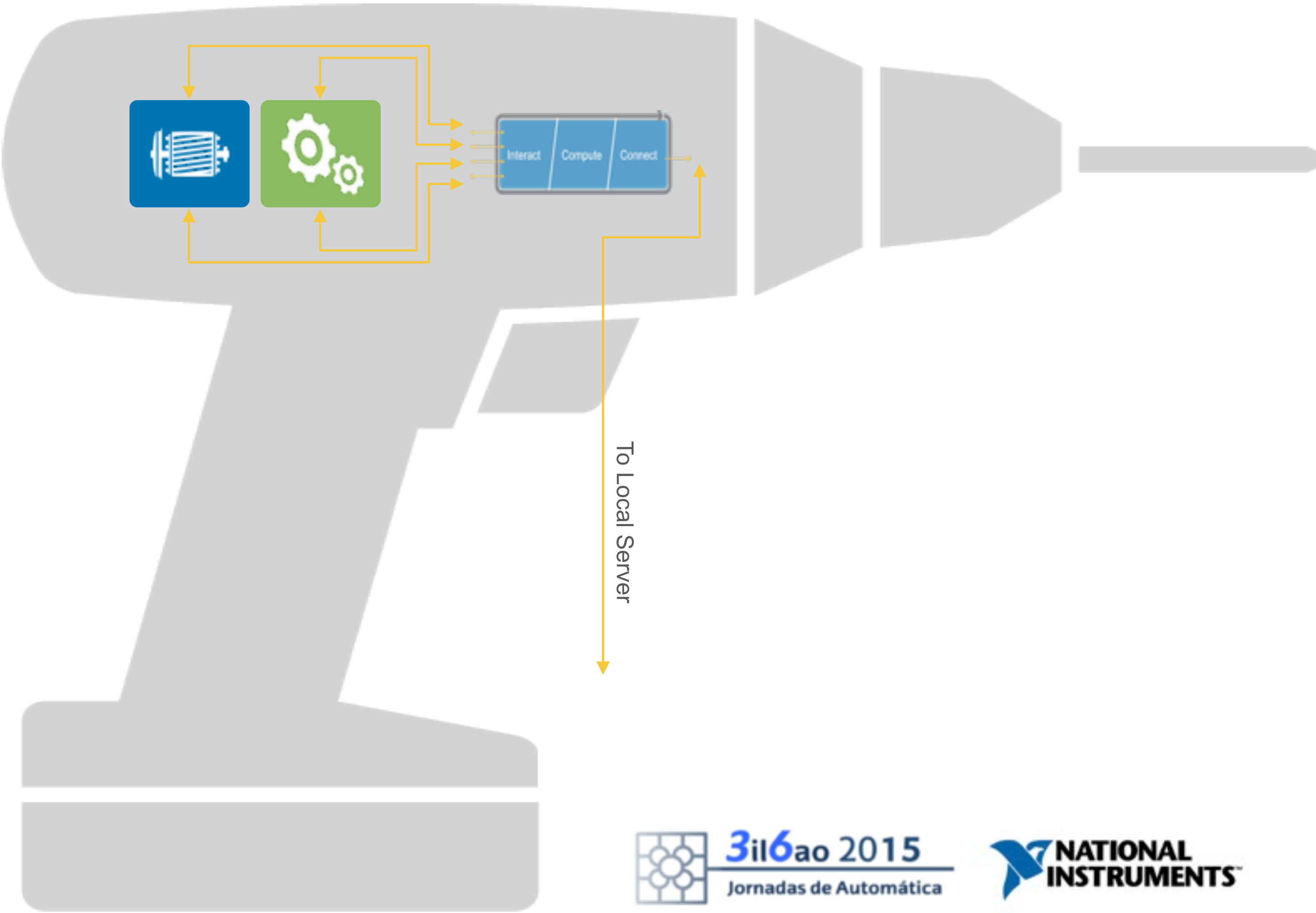


Pattern Recognition



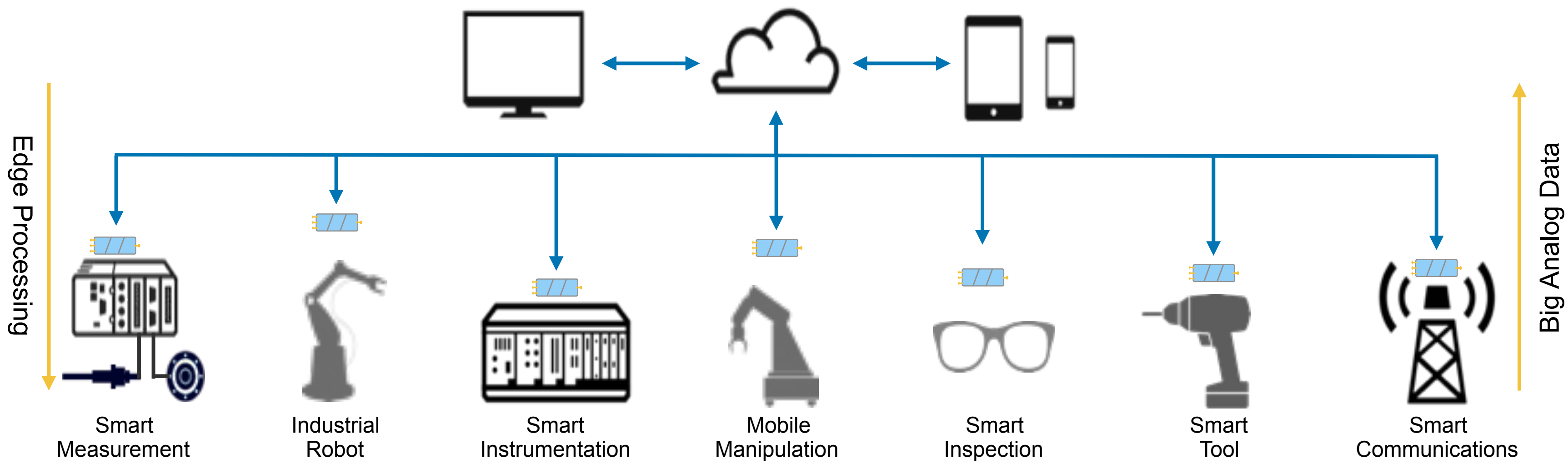
Tool Tracking


Interact
Compute
Connect
To Local Server



Interact
Compute
Connect
To Local Server

Factory of the Future

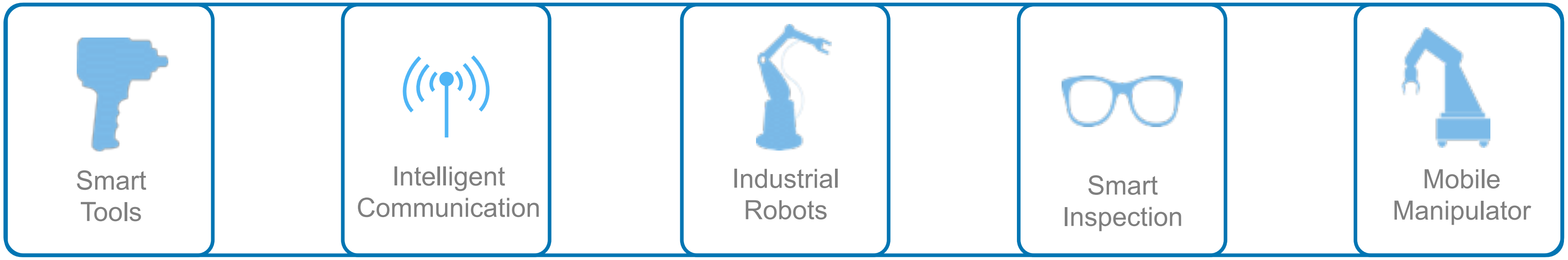


Enhanced Requirements for the IIoT

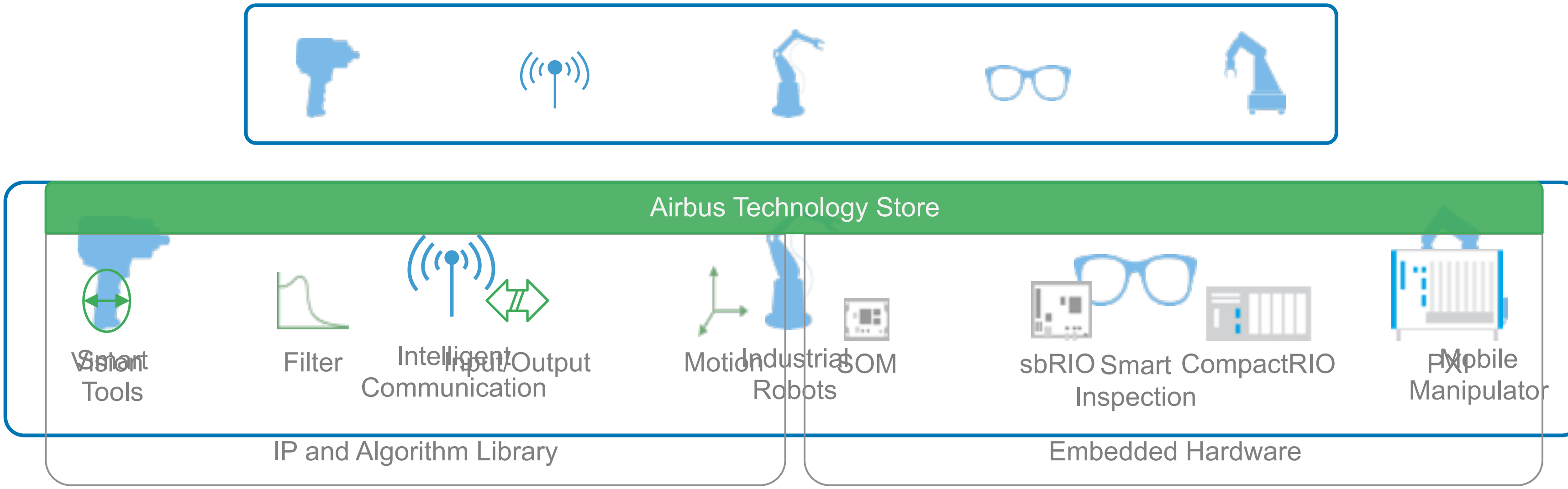
Reliability | Latency | Security | Upgradeability

Visual Servoing

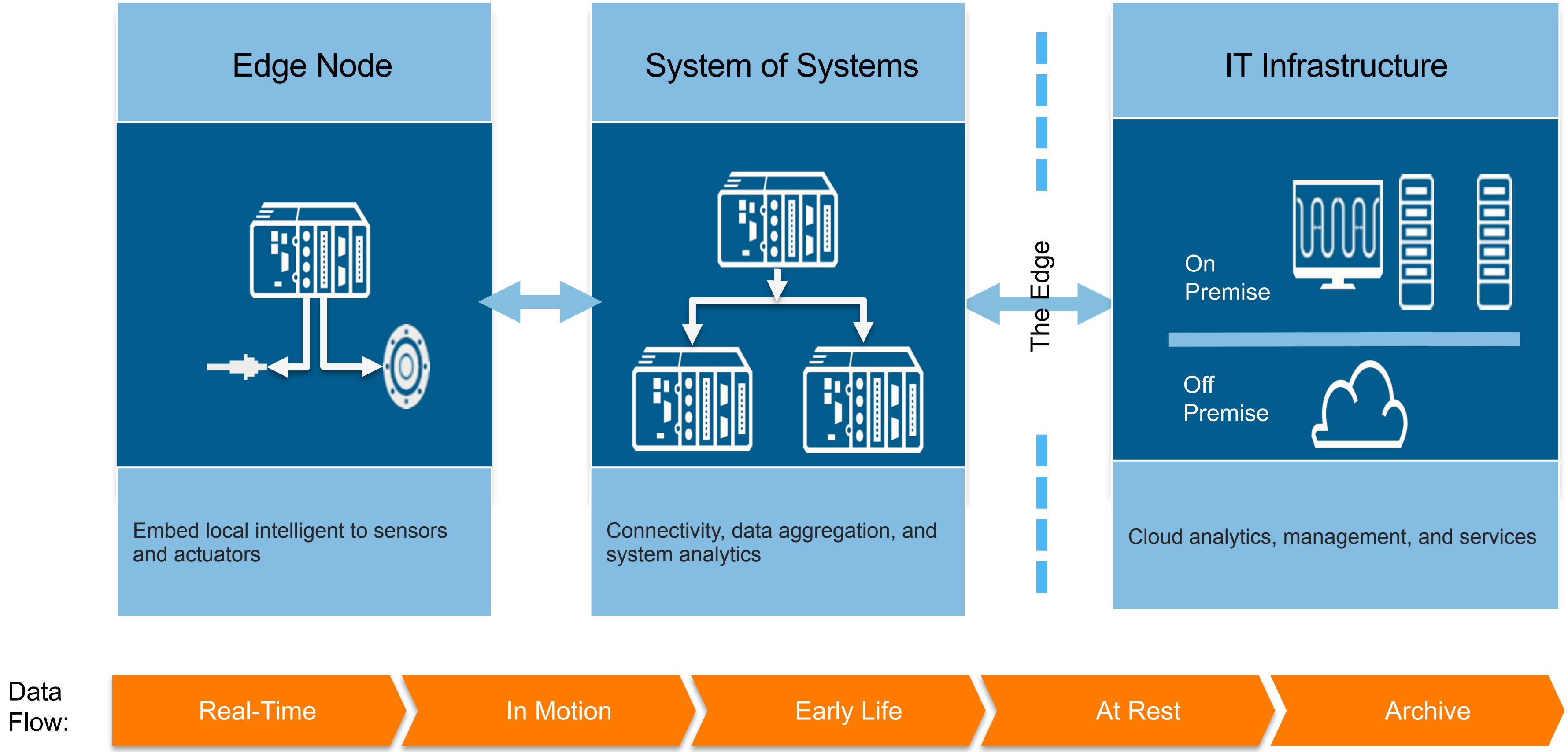
Factory of the Future



Factory of the Future

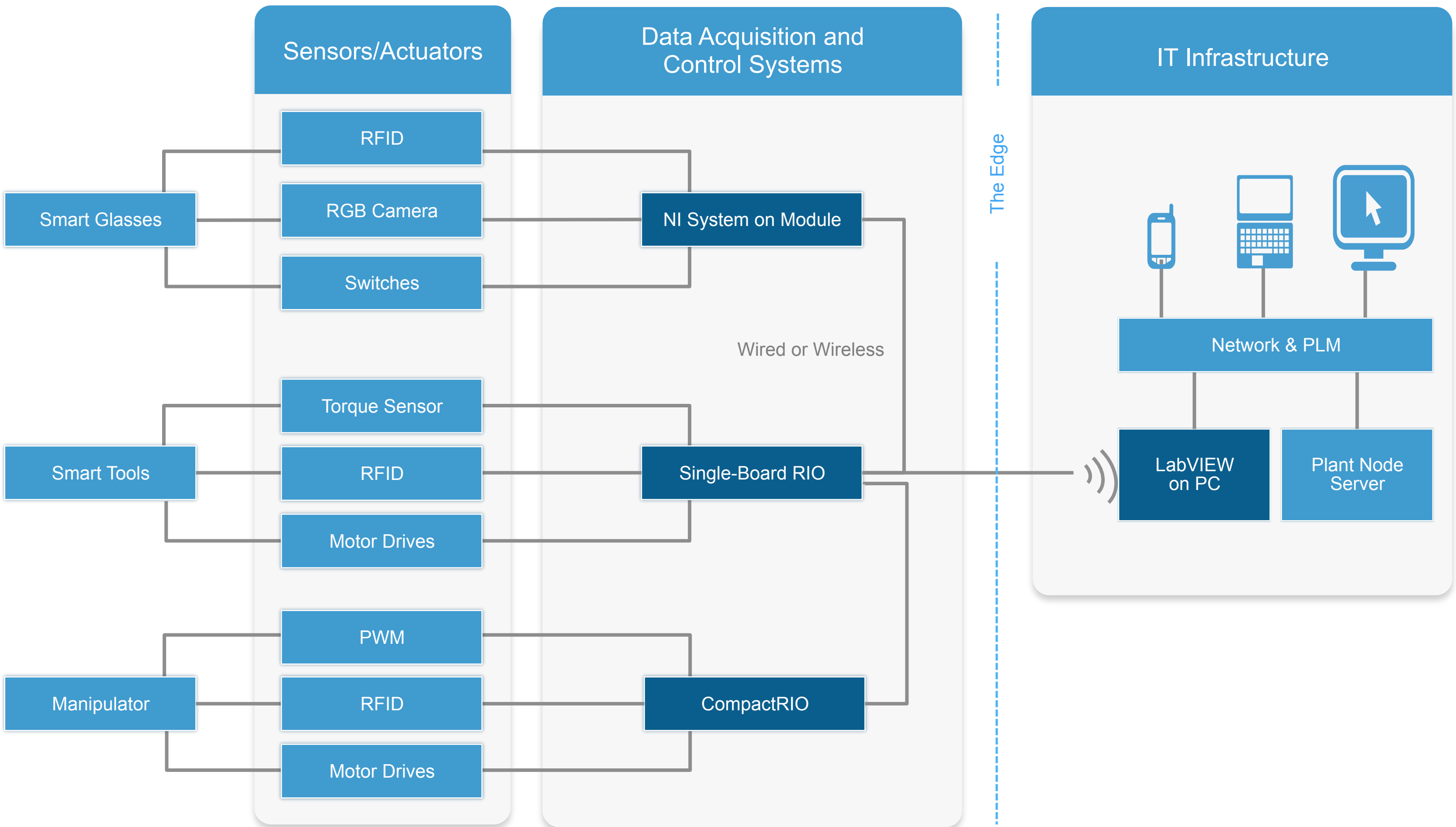


IoT: Generalized System Architecture



Example End-to-End Industrial IoT Solution

Factory of the Future: Factory-Wide Online Monitoring and Control



Factory of the Future

- ❑ Cyber-physical production systems
  - **Real-time** information from design to production
  - “Smart” components will communication with automated machines
- ❑ **Human-centered** enhancement through
  - Smart wearable devices
  - Smart production robots
  - Smart tools
- ❑ Connected factory with **high data volumes** through safety standards


Business Analytics
Internet of Things
BIG ANALOG DATA
INTERACT
COMPUTE
CONNECT
BIG DATA
Internet of Services
Social Web

Vision 2025

- Every object will be smart
- The ensemble is the function!
  - Function determined by availability of sensing, actuation, connectivity, computation, storage and energy
  - Collaborating to present unifying experiences or to fulfill common goals

A humongous networked, distributed, adaptive, hierarchical, hybrid control problem

www.ni.com/research