Perspectives from Industrial IoT and Medicine

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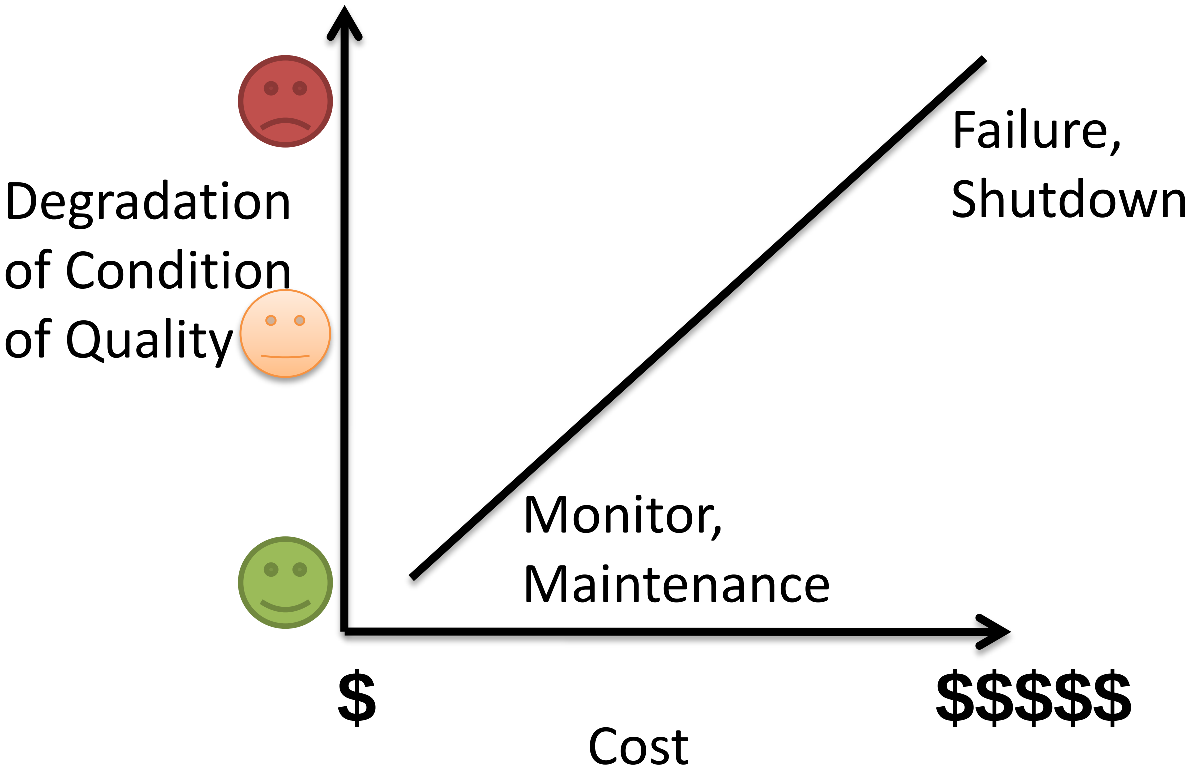
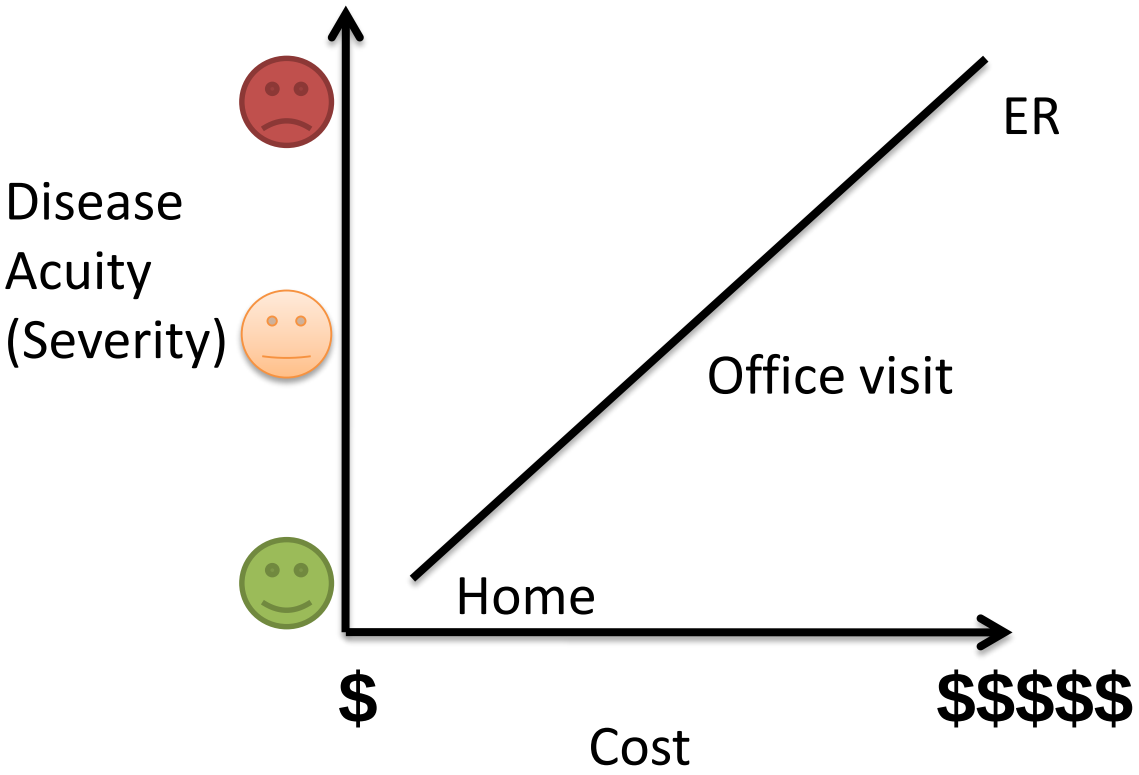
Need

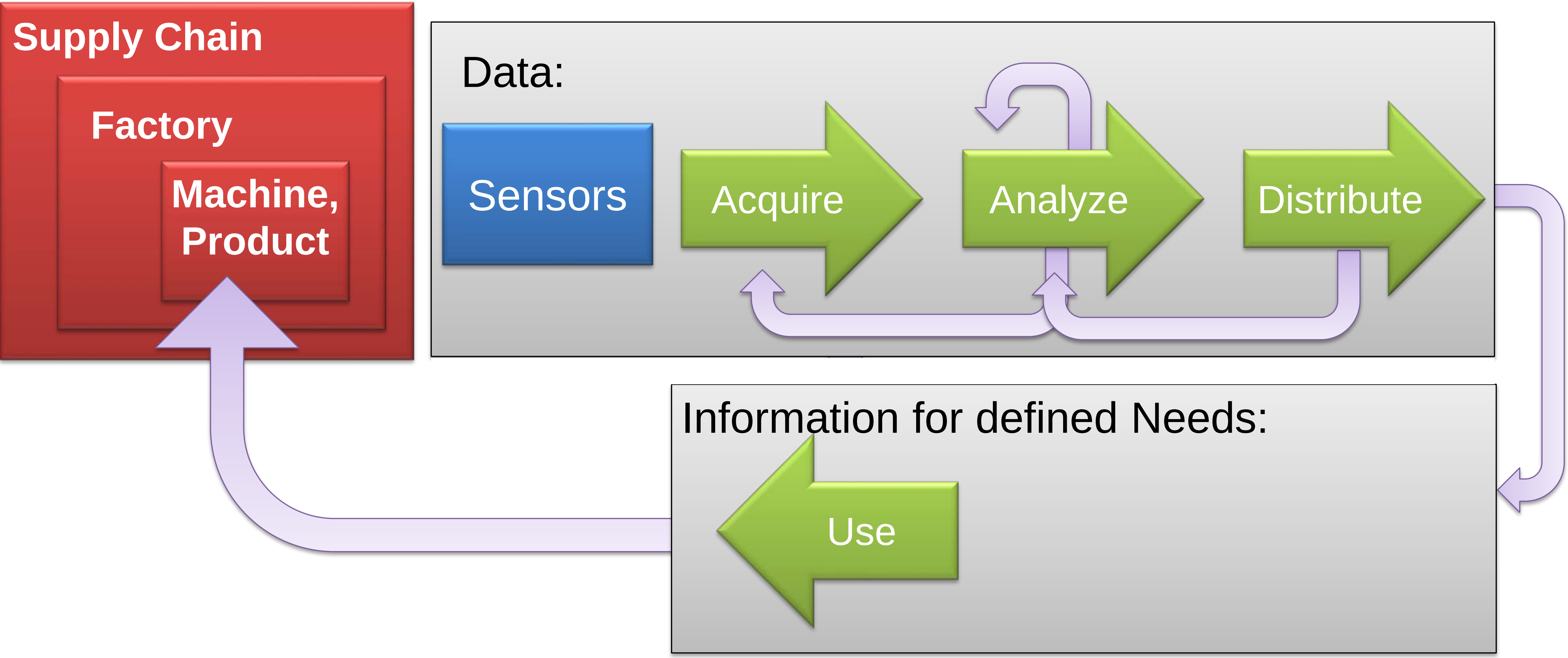


Product Realization (Design, Manufacturing, Support) System

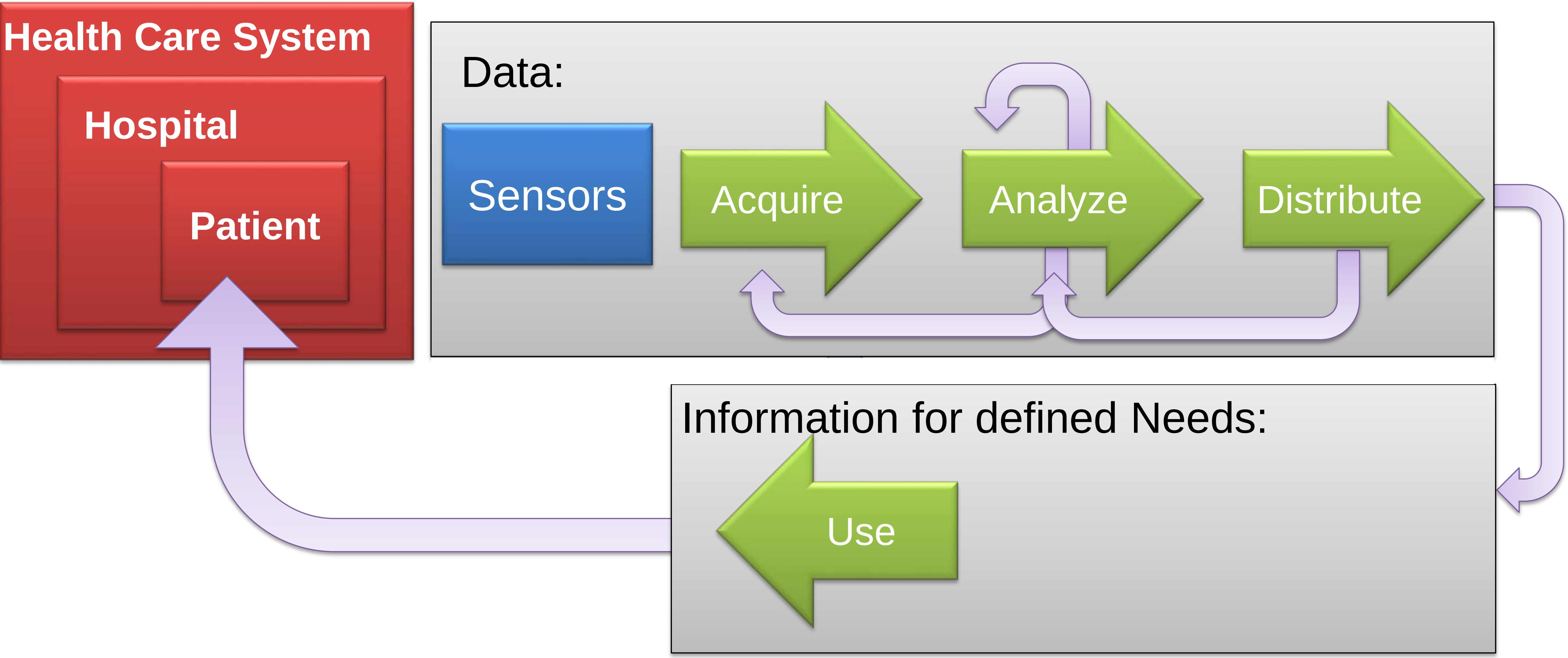


Health Care System

Data, through Analytics, to Actionable Information



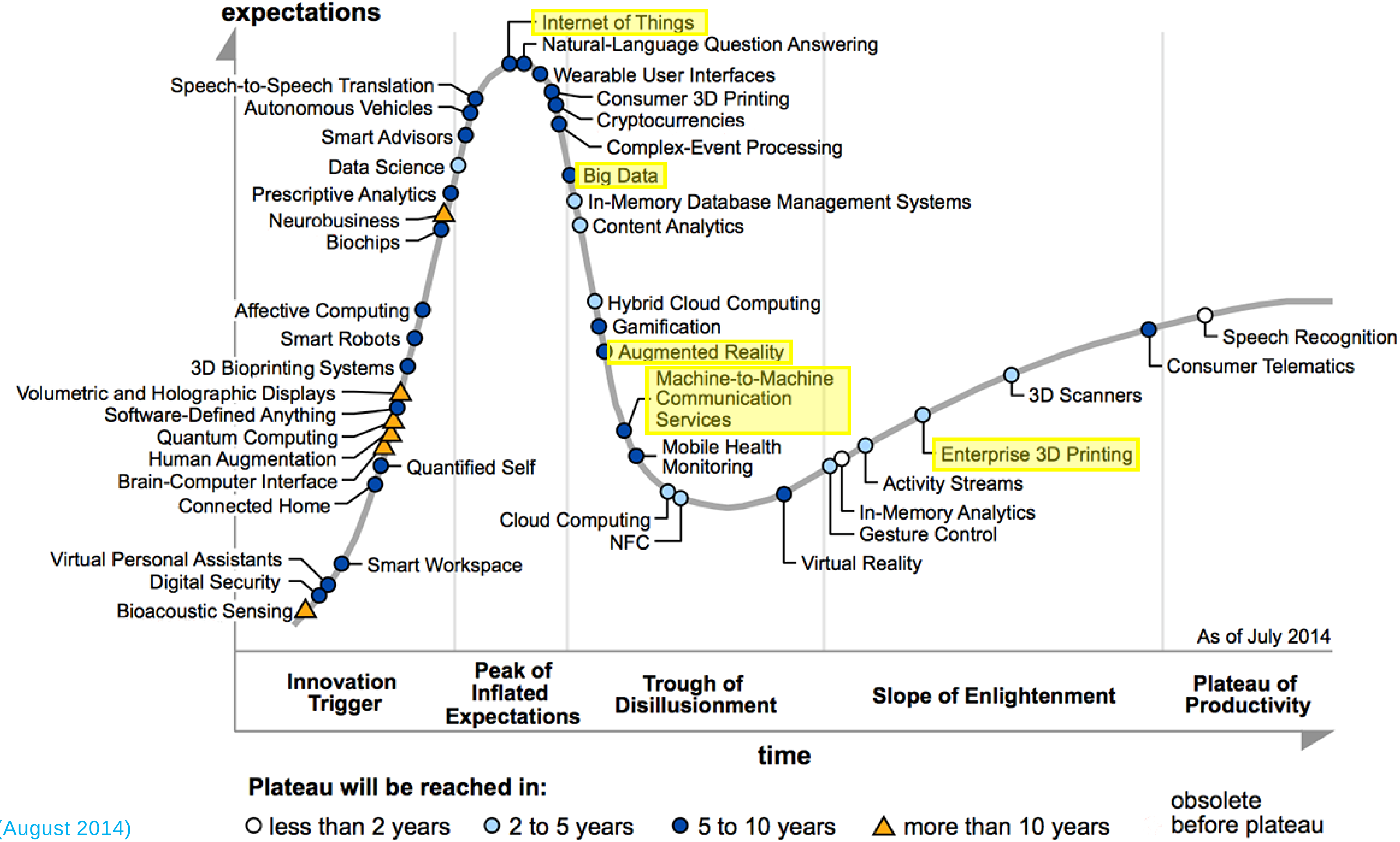
Data, through Analytics, to Actionable Information



IoT/Smart Manufacturing

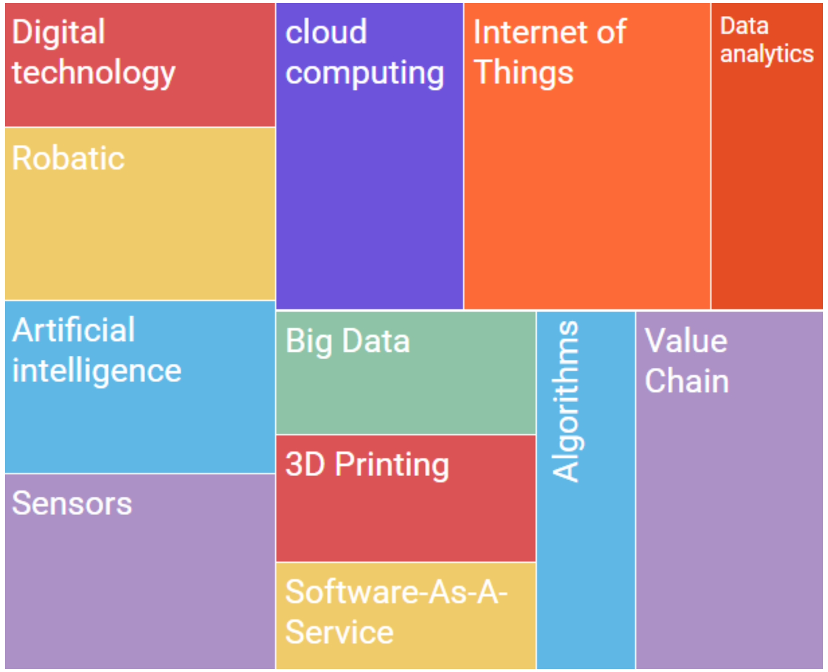
Smart Manufacturing Technologies --the systems for and around Smart Manufacturing.

Emerging Technology Hype Cycle



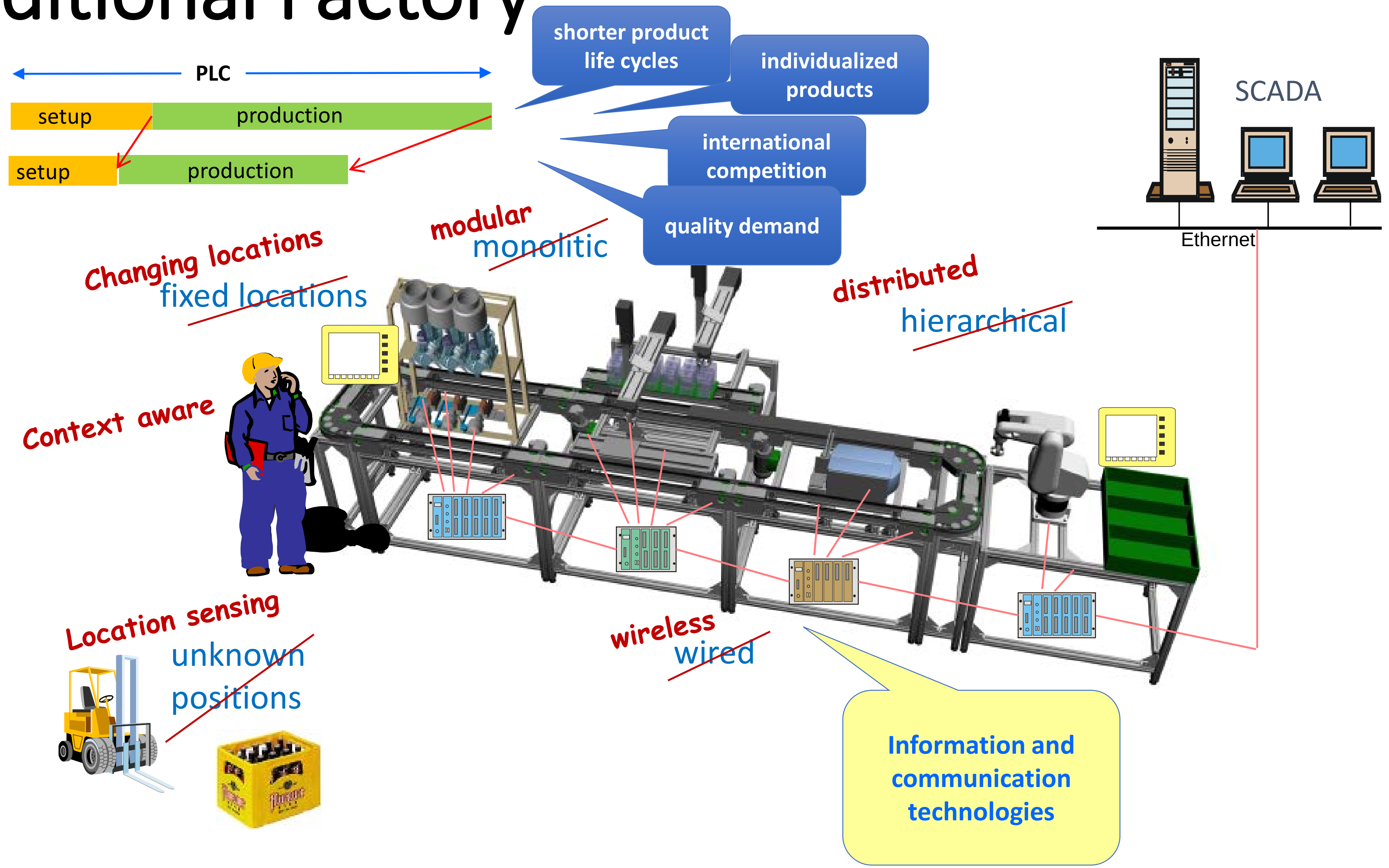
SOURCE: Gartner (August 2014)

Smart Manufacturing

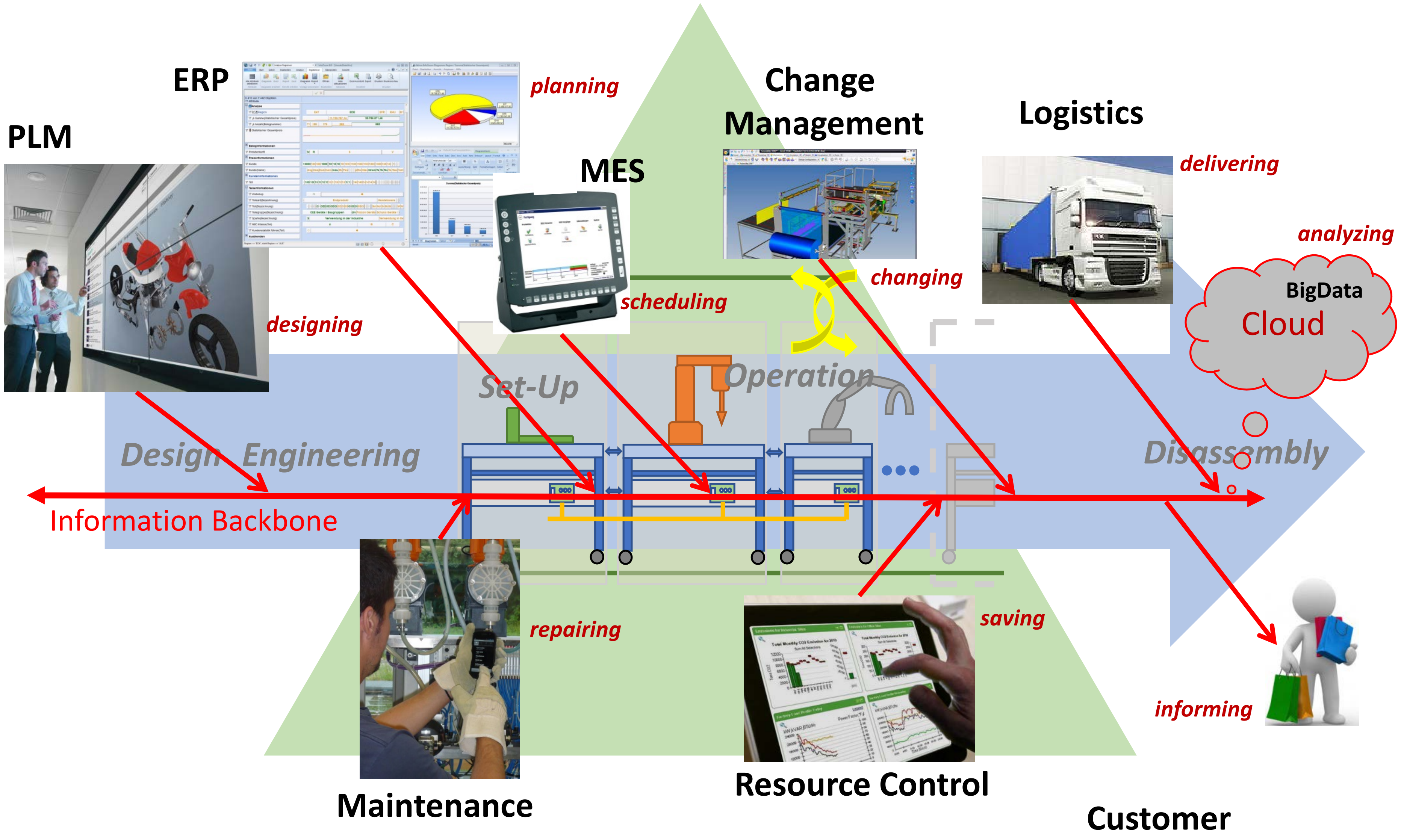


Smart Manufacturing is a highly connected, knowledge-enabled industrial enterprise where all business and operating actions are connected (optimized) to achieve substantially enhanced productivity, energy / sustainability, and economic performance.

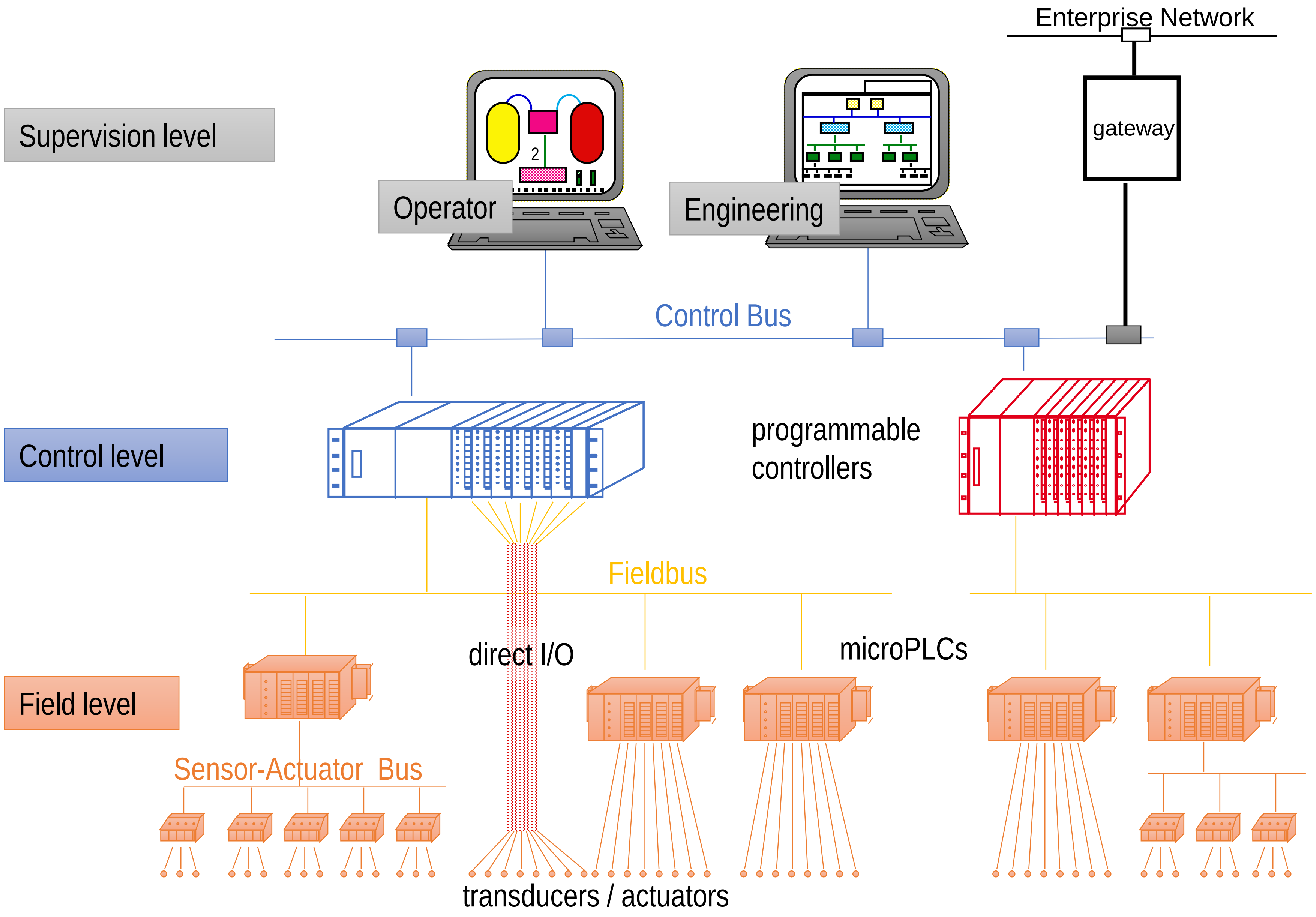
The traditional Factory



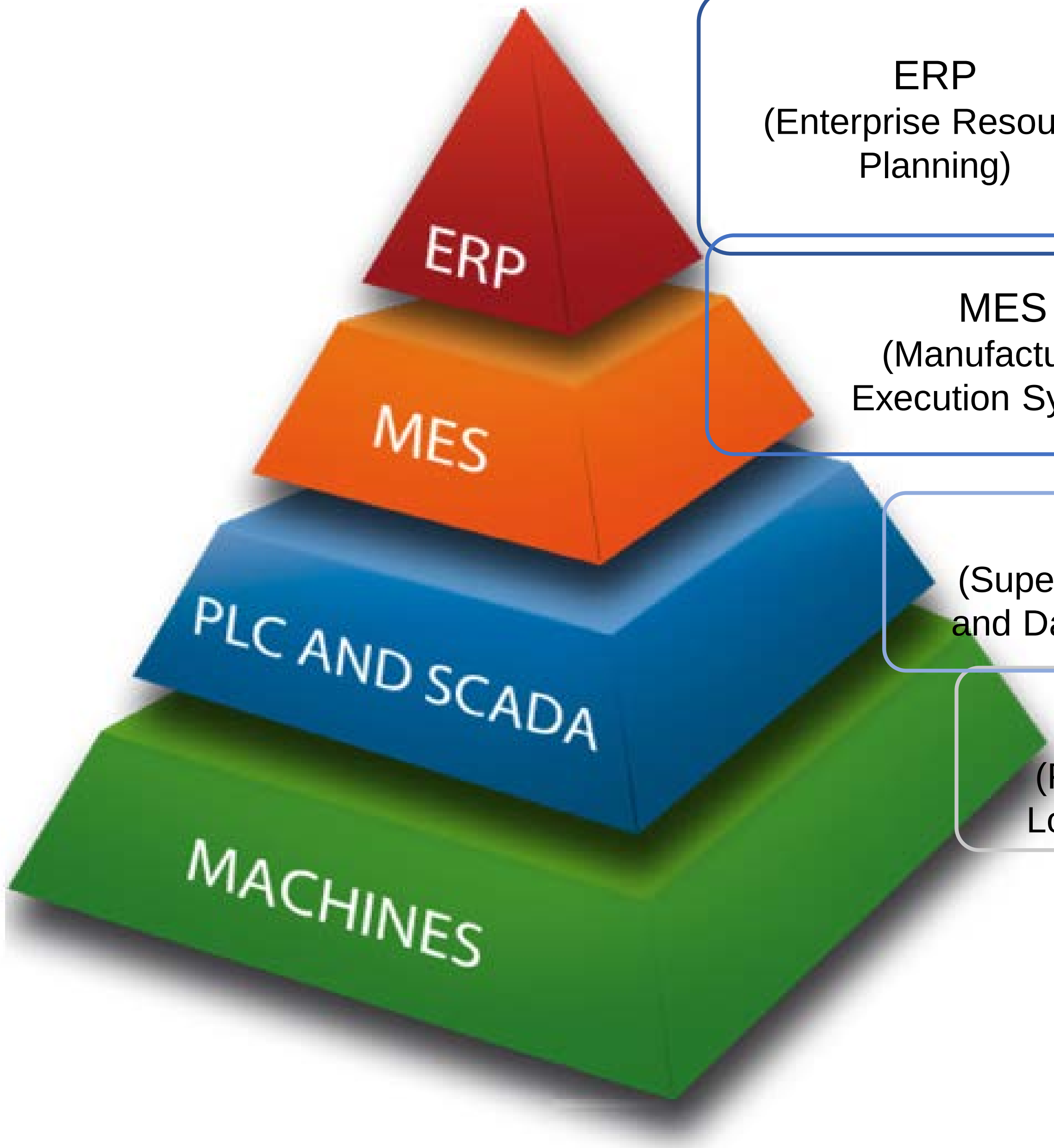
...affecting the lifecycle



Factory Hierarchy



Standardized Framework

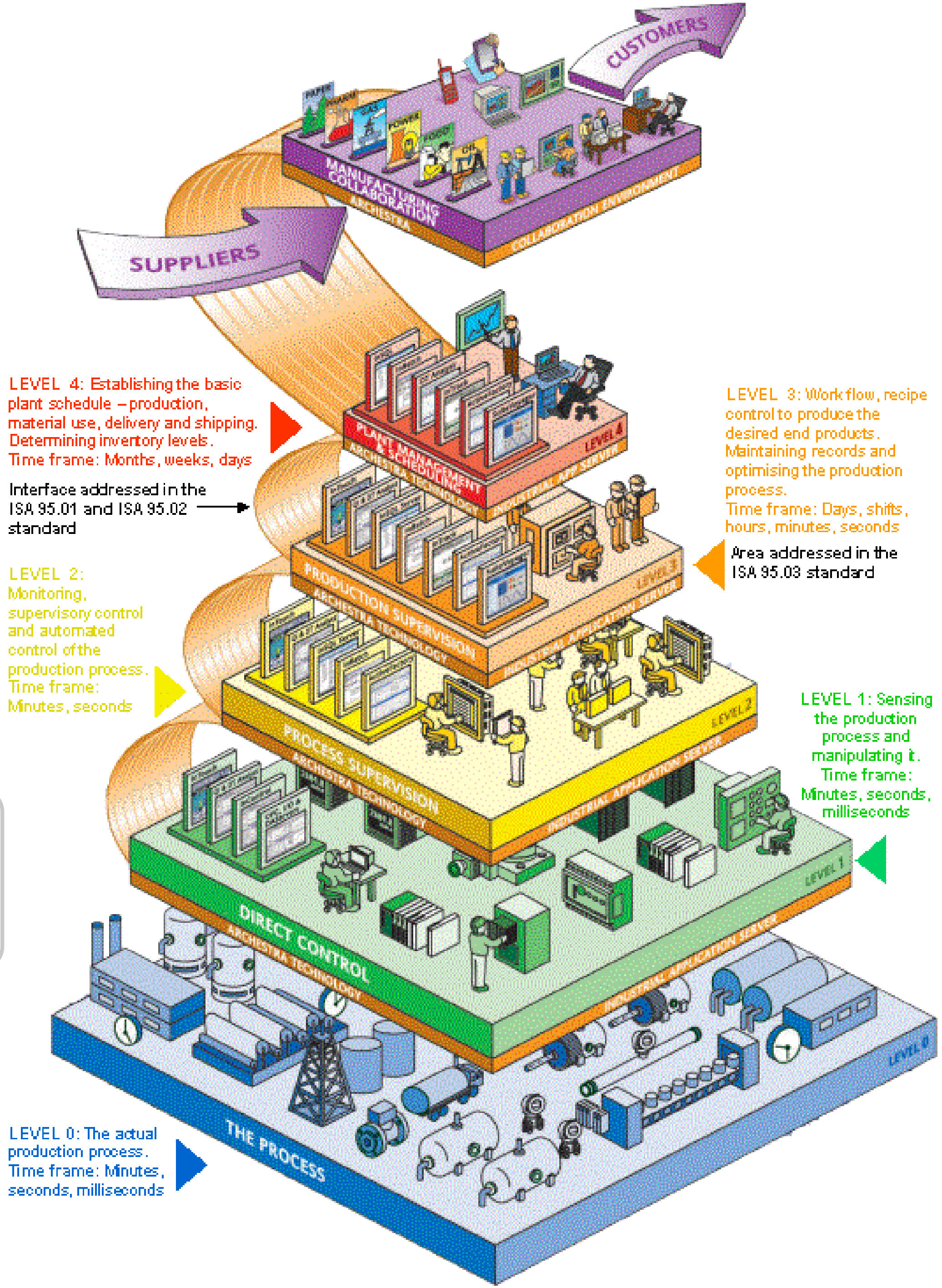


ERP
(Enterprise Resource Planning)

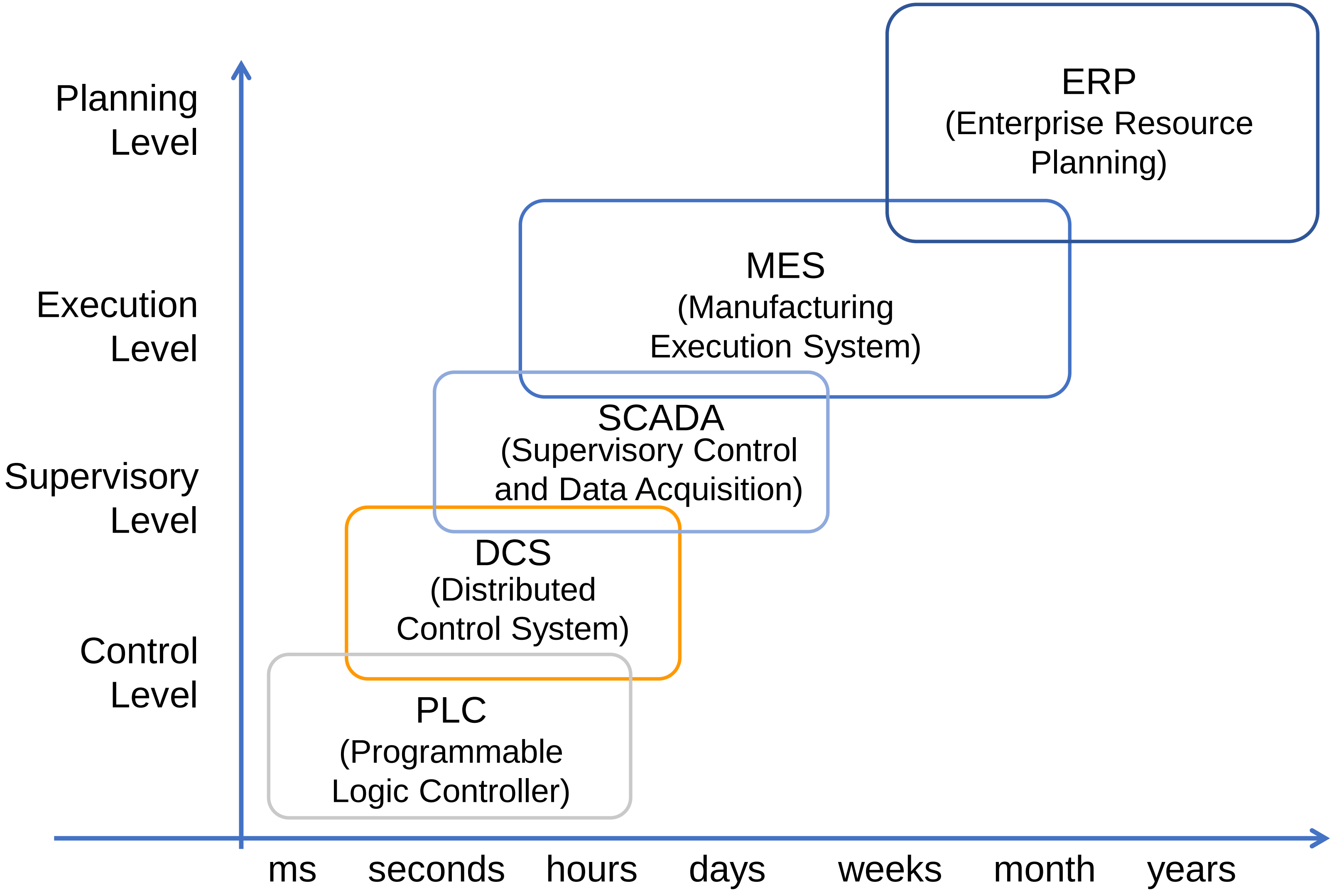
MES
(Manufacturing Execution System)

SCADA
(Supervisory Control and Data Acquisition)

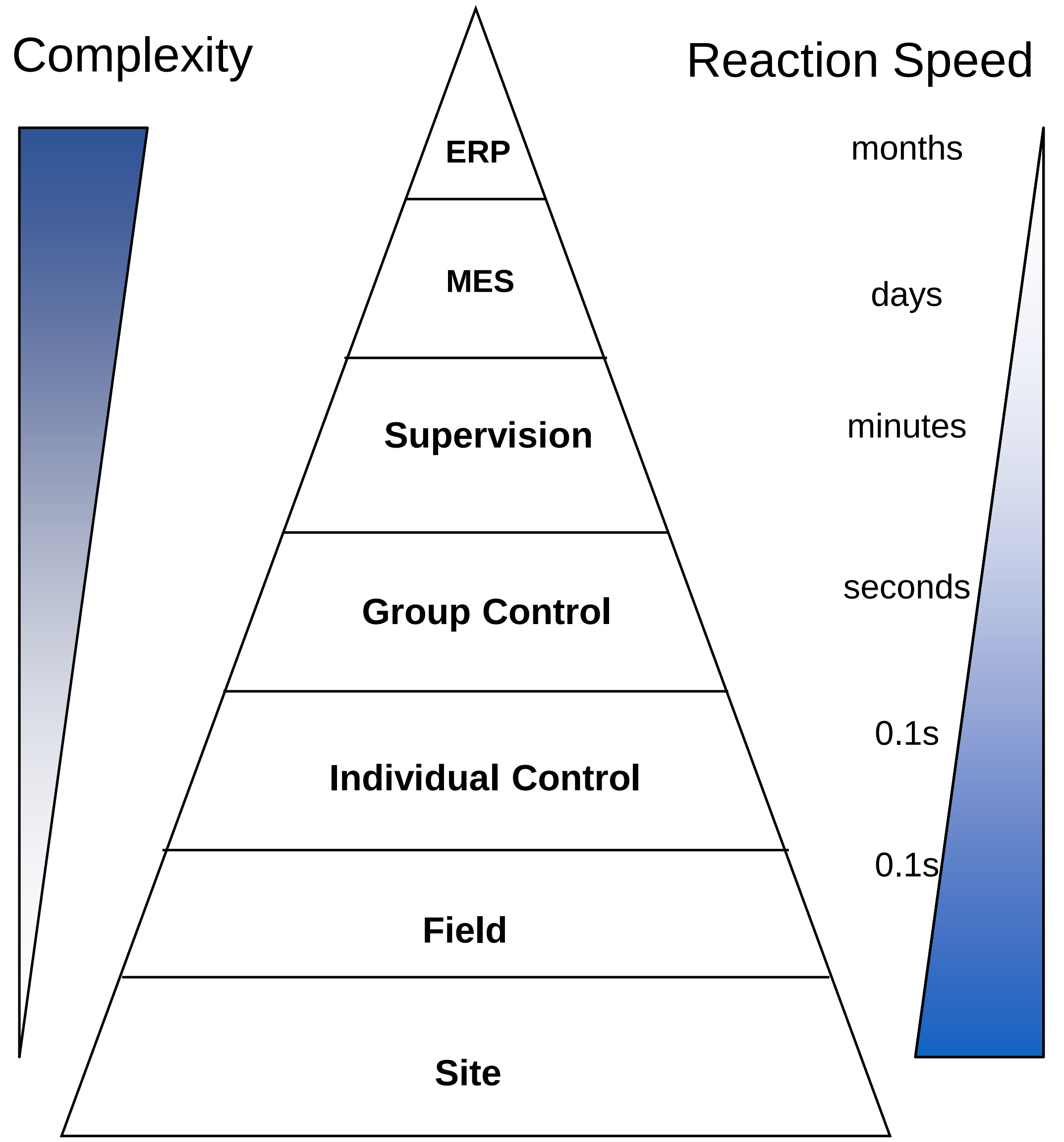
PLC
(Programmable Logic Controller)

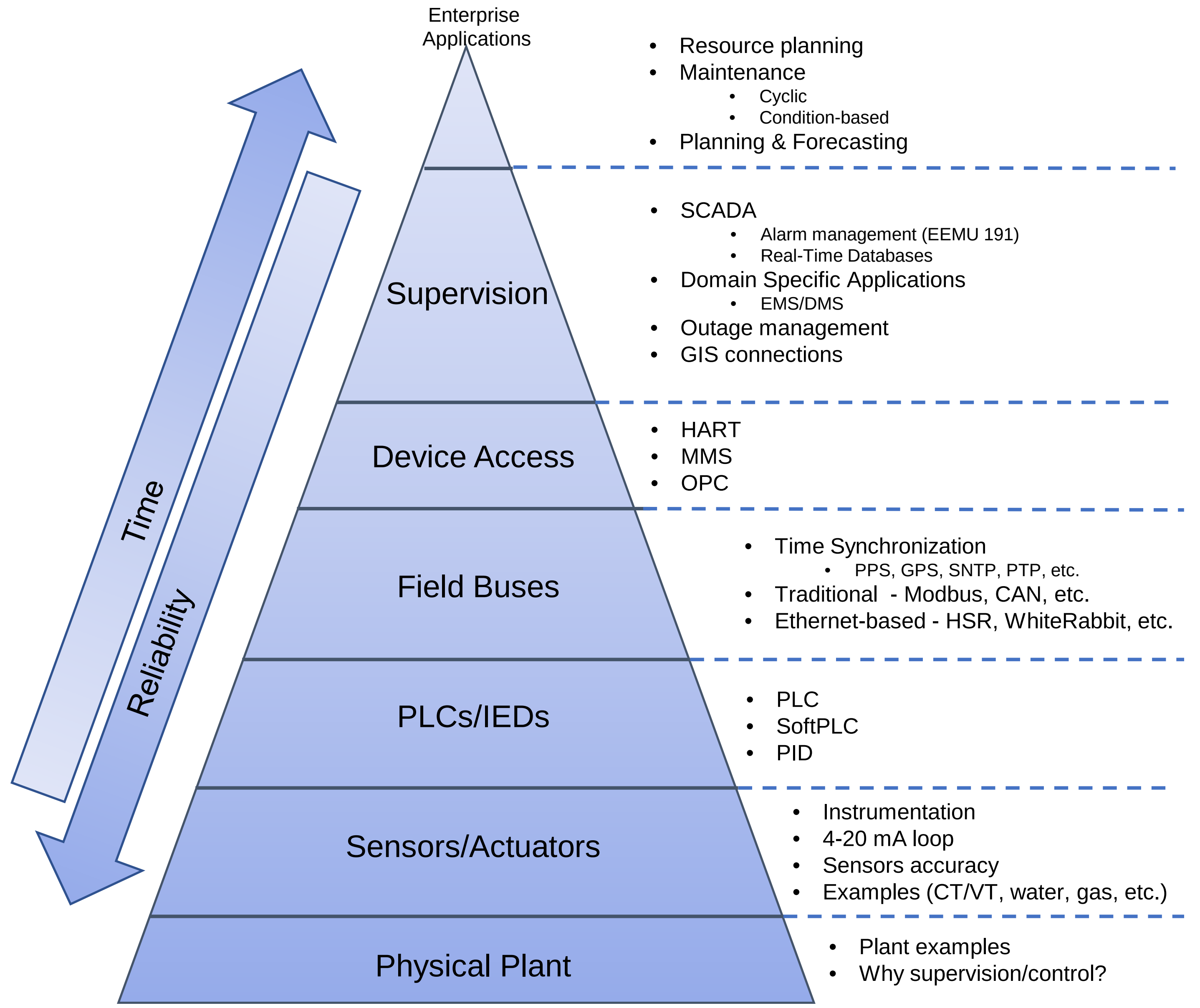


Response time and hierarchical level



Complexity and Hierarchical level

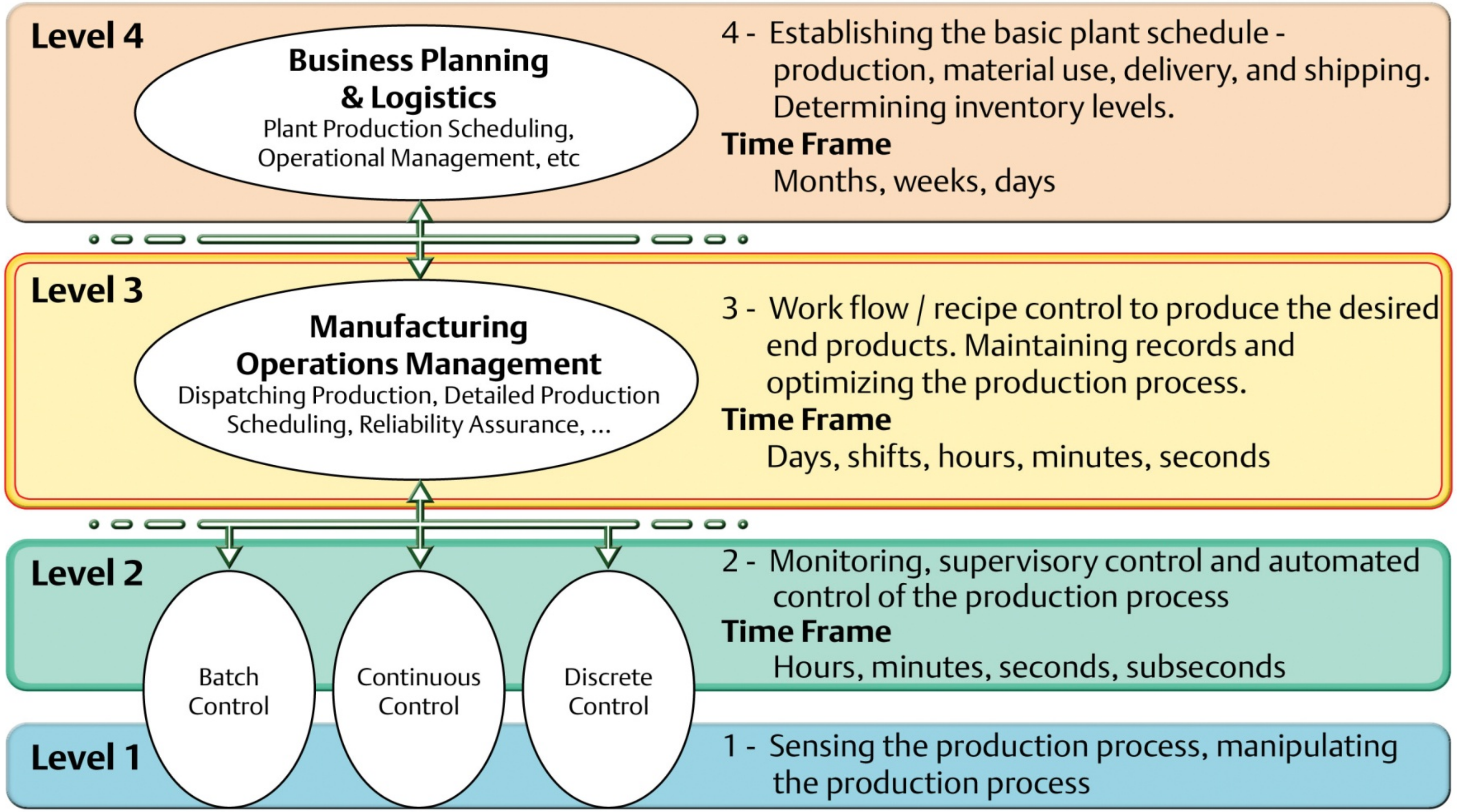




Reliability and Dependability
- Calculation
- Architectures
- Protocols

Manufacturing Operation System Levels*

ANSI/ISA 95 standard classification



*Levels are references to ISA-95, "Enterprise-Control System Integration"

Data in Context

Data is needed to design and operate modern factories. But data is only valuable if :

- It is accurate
- It is accessible
- It is relevant
- We know what to do with it

Modern information technology provides the first two.

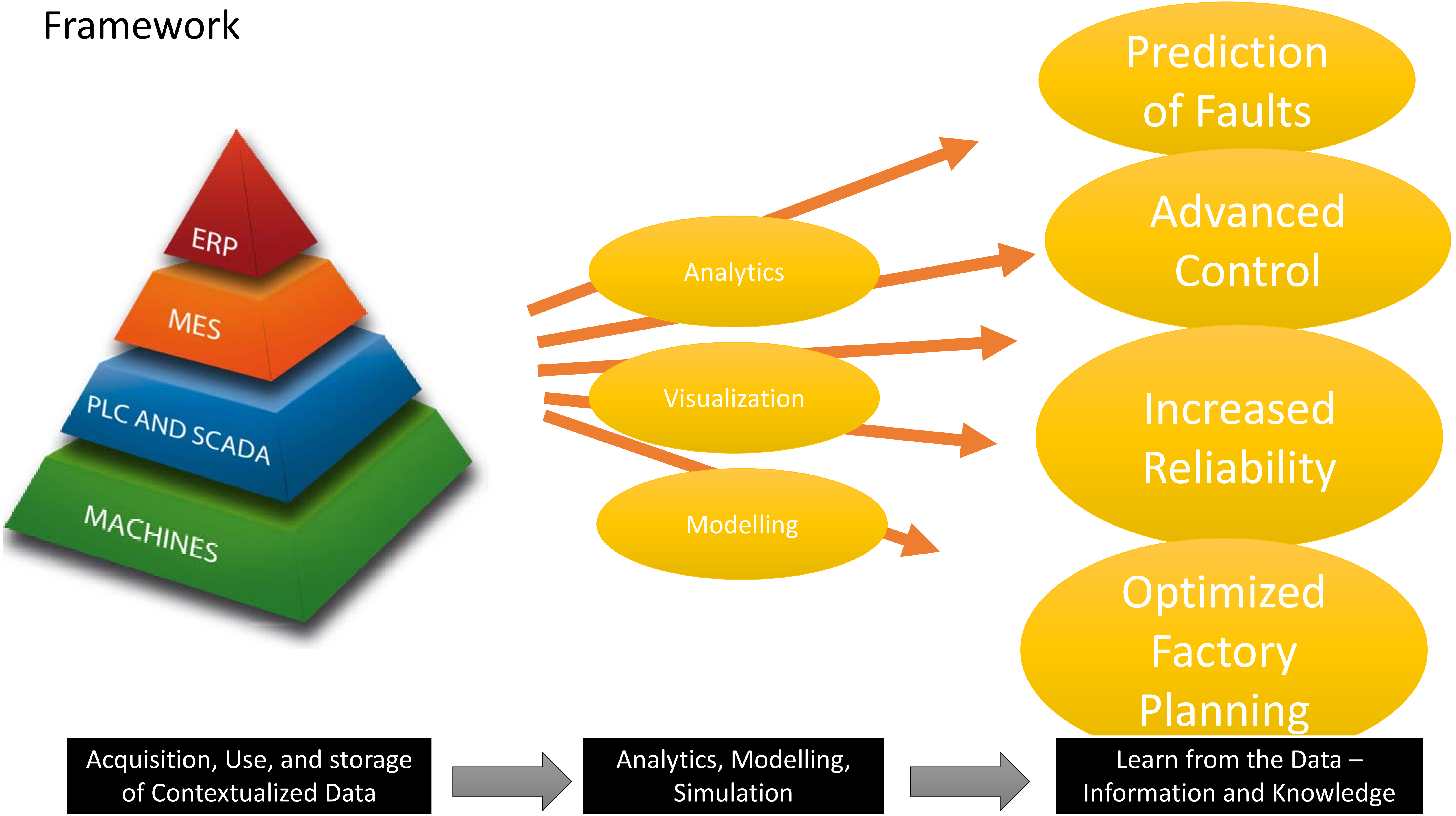
Manufacturing experts provide the second two.

Data in Context

Manufacturing experts know the processes and machines.

With context knowledge, manufacturing experts have the intuition to help explain data, to identify the question to ask, and to help to develop models to explain, provide context to, data.

Framework


ERP
MES
PLC AND SCADA
MACHINES
Analytics
Visualization
Modelling
Prediction of Faults
Advanced Control
Increased Reliability
Optimized Factory Planning
Acquisition, Use, and storage of Contextualized Data
Analytics, Modelling, Simulation
Learn from the Data – Information and Knowledge

Why Smart/IoT now?

- What Has Not Changed
  - Process Physics
  - Transformation Methods and Energy Sources
  - Random Effects
  - Equipment Capability
    - Control Authority
  - Need for Appropriate Process Models
    - Global Modeling (Simulation)
    - Local Modeling
    - Control Modeling for Feedback Stability and Performance
    - Local Small Variation Causal Models
    - Models of Process Randomness

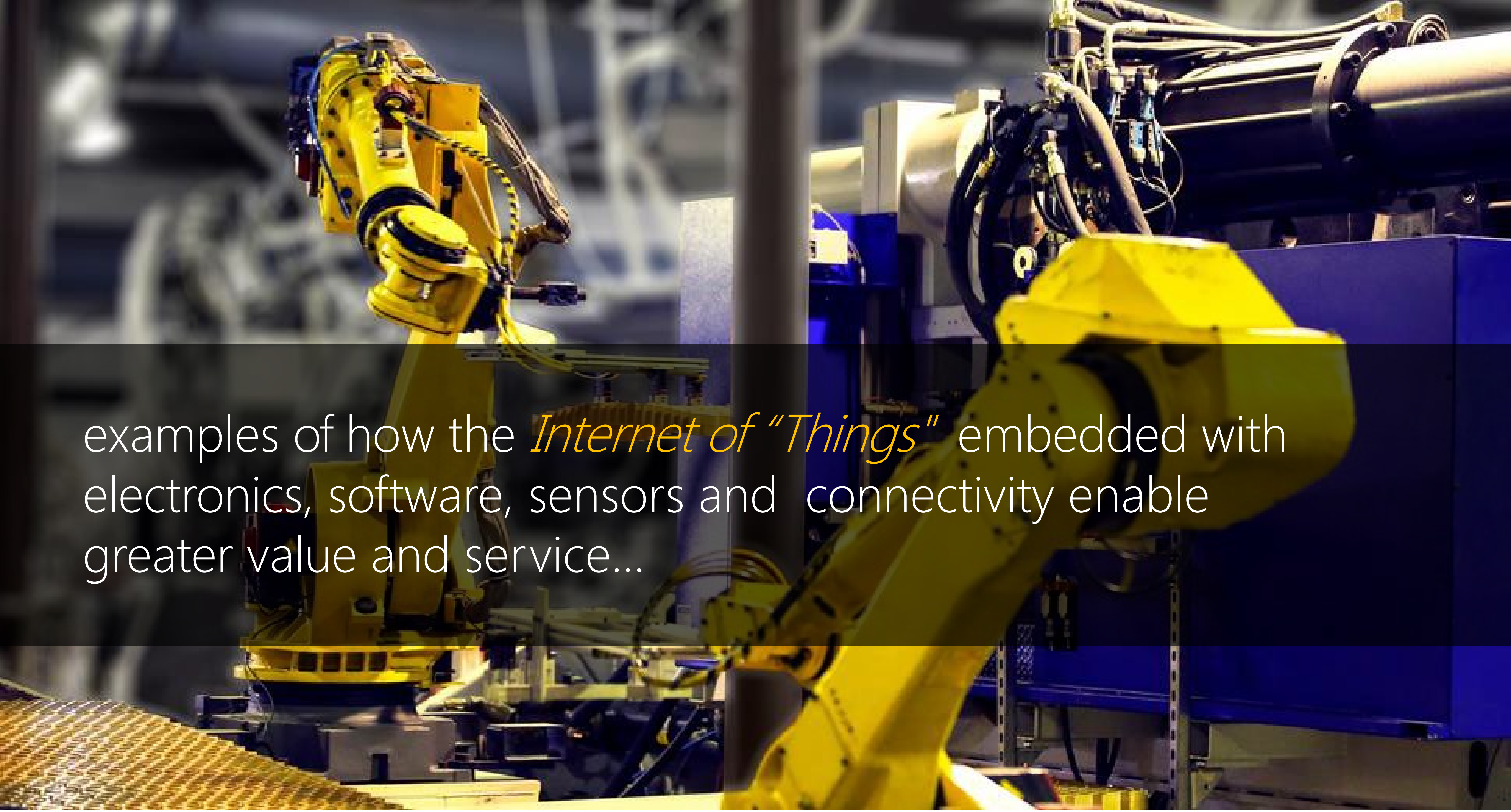
Why Smart/IoT

- What Has Changed?
  - Cost and Ubiquity of Sensing
  - Communication and Data Processing
  - Rise of "Universal" Models (Big data/deep learning)
  - Standards for Data and Communications

Manufacturing Trends

The Smart Factory
The Smart Lifecycle

Smart Examples



examples of how the *Internet of "Things"* embedded with electronics, software, sensors and connectivity enable greater value and service...

Data Integration

King's Hawaiian, a family-owned and operated bakery, supports a centralized data-collection system that collects vast amounts of data – about everything from oven temperatures and bake times to scale weights and maintenance operations to ensure anticipated and reliable outcomes.

Troubleshooting

Toyota uses real-time software for error corrections in the plant. With improved troubleshooting capabilities and error correction, Toyota has minimized rework and scrap rates in its Alabama plant, which has resulted in an annual cost saving of $550,000.

Floor Visibility

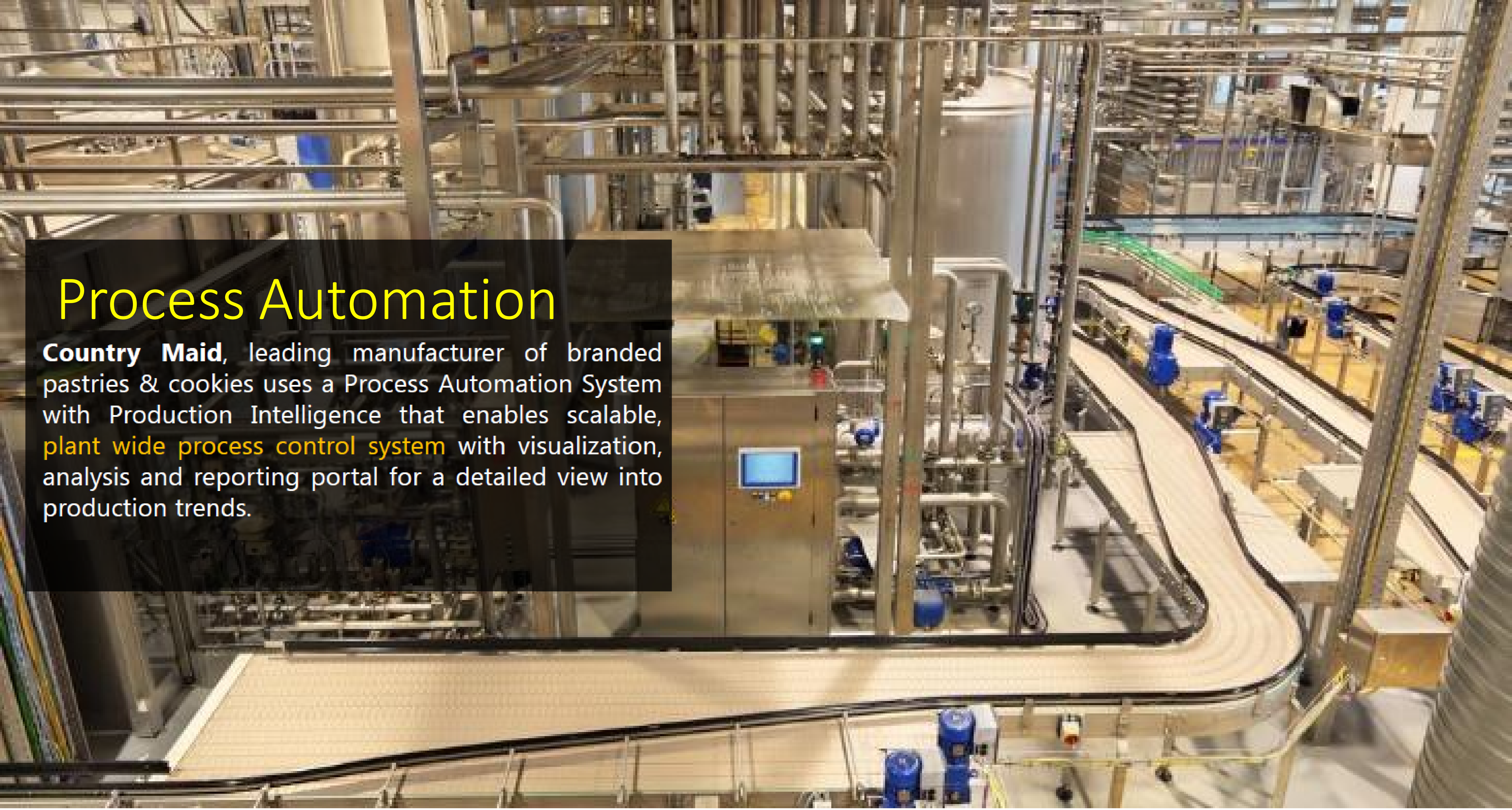
GM uses sensor data to decide if it's too humid to paint an automobile. If the system defines the conditions are unfavorable, the automobile will be routed to another area of the manufacturing process, reducing repainting and maximizing plant uptime.

Reduced Time to Decision

GE mobile-enabled SCADA applications enable mobility to display performance data and status updates on handhelds, traditionally only available from processor-intensive analytical tools, thereby enabling faster decisions.

Proactive Maintenance

Harley-Davidson's has an installed software to monitor and track performance of equipment, such as the speed of fans in the painting booth. The software automatically detects issues if a measurement, such as fan speed, temperature, or humidity has deviated from acceptable ranges and adjusts itself.

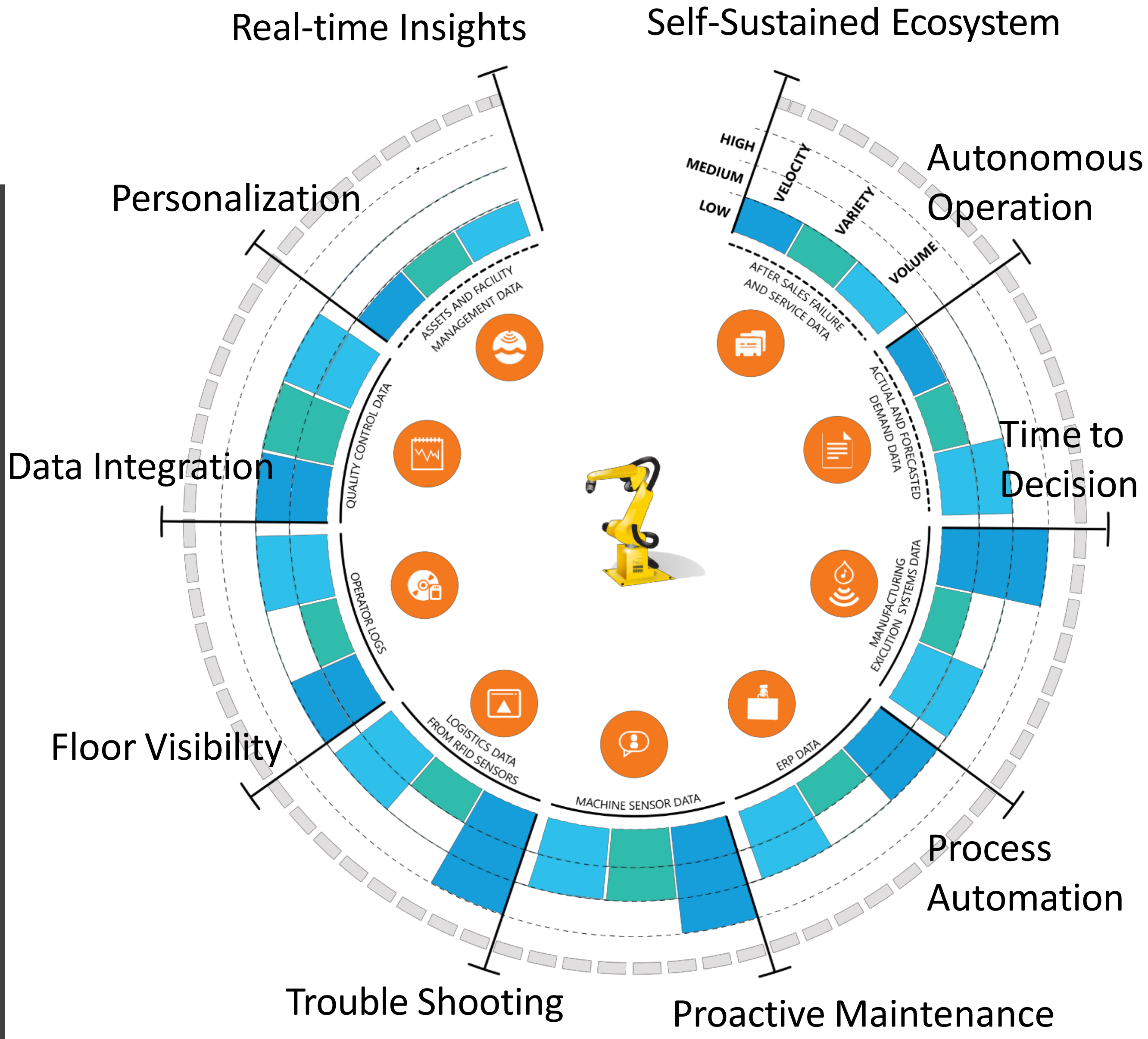


Process Automation

Country Maid, leading manufacturer of branded pastries & cookies uses a Process Automation System with Production Intelligence that enables scalable, plant wide process control system with visualization, analysis and reporting portal for a detailed view into production trends.

THE FACTORY FLOOR and SUPPLY CHAIN AS A DATA PLATFORM

Informatics, telematics, predictive analytics... huge opportunities for disruption



Smart Medicine

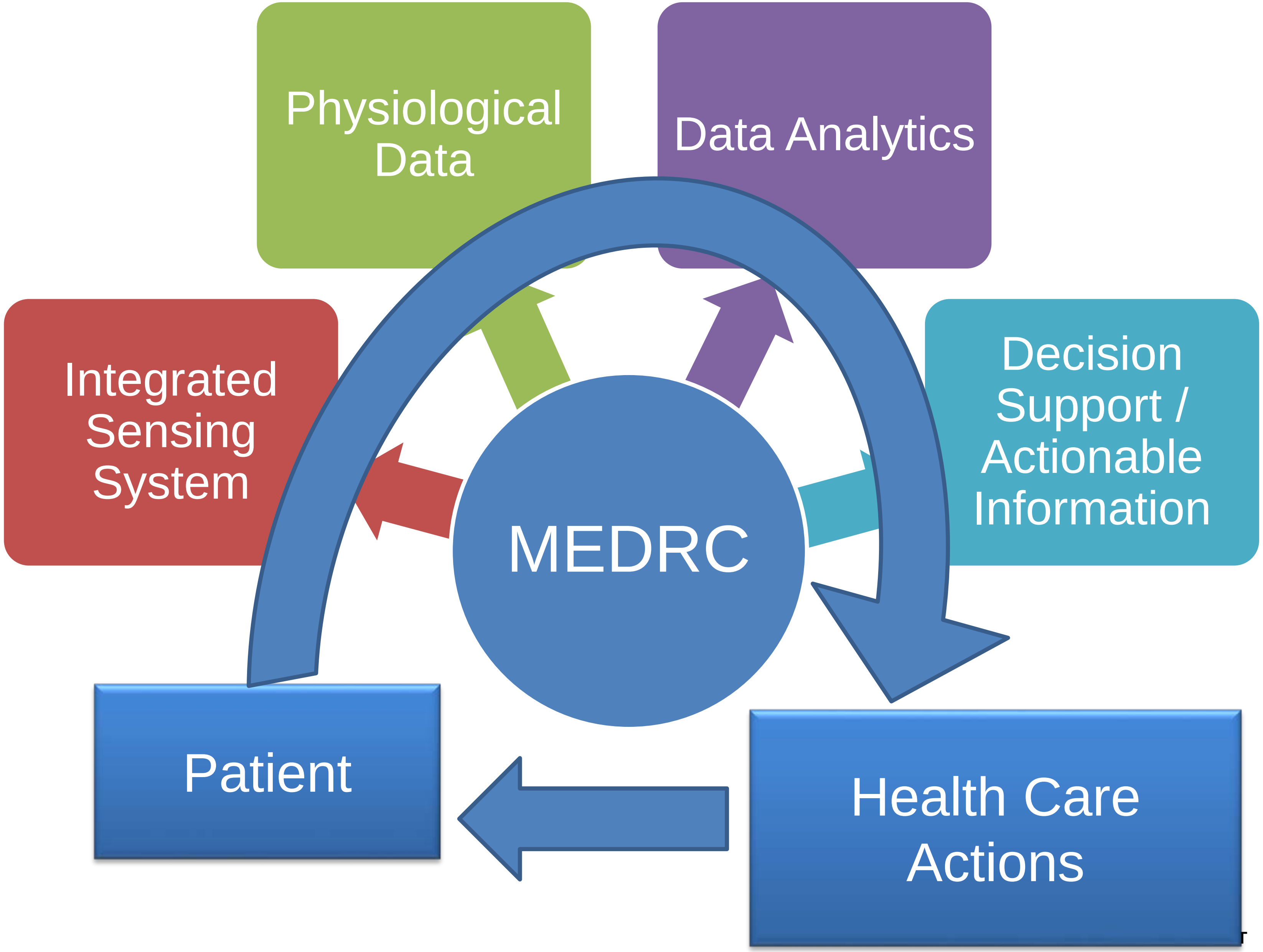
Opportunity is the same, but system is different…

Medical is Different – opportunity is the same. But:

- Harder to standardize communication, data acquisition protocols, data storage.
- Data is harder to acquire.
- Harder to quantify success
- Focus on the sensors and local systems.

Medical Electronic Device Realization Center

Solving clinical needs, by innovating user-centric manufacturable devices, leveraging the power of the microelectronics industry and Boston / Cambridge Ecosystem.

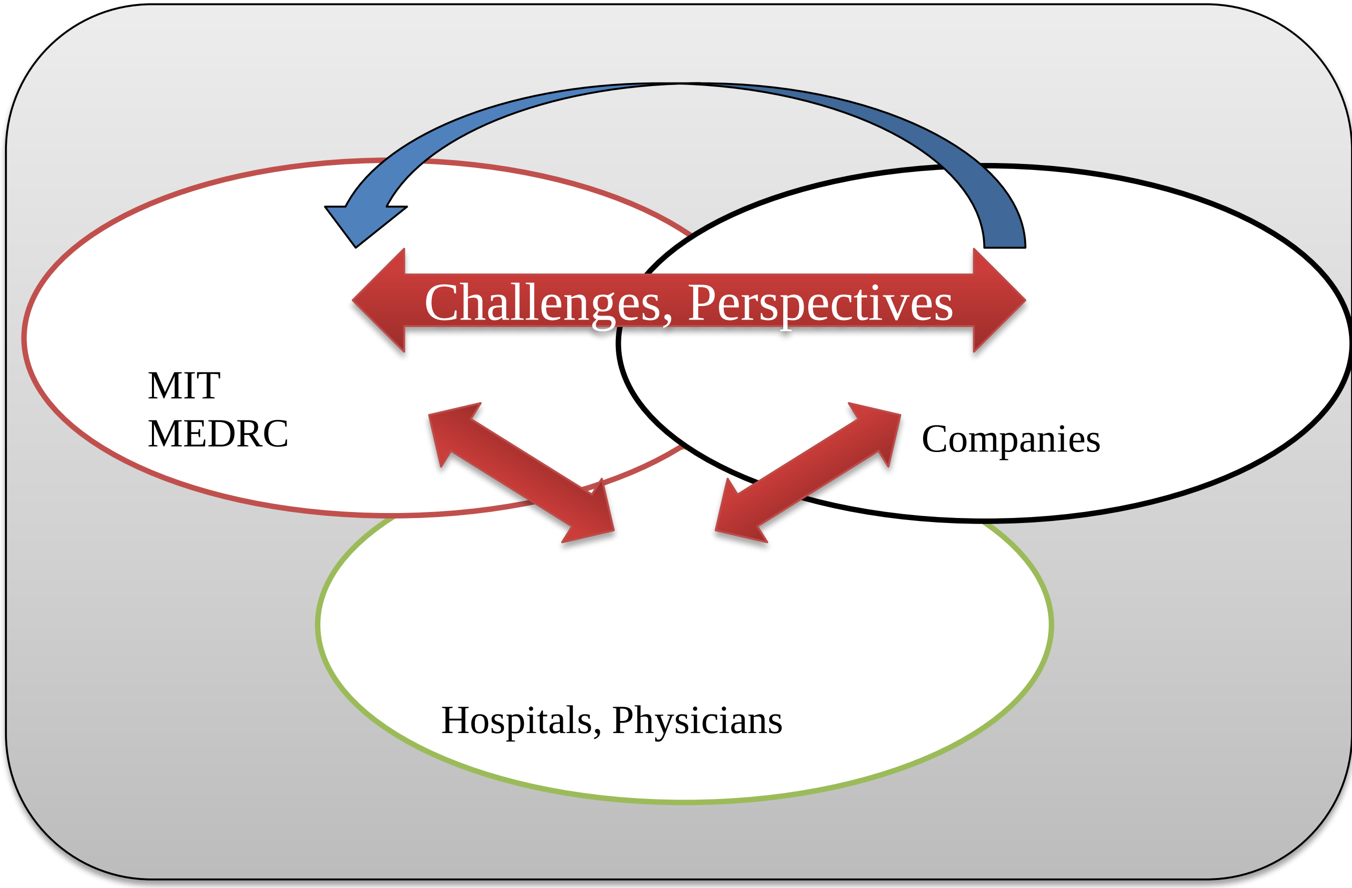


MEDRC - Model

MEDRC at MIT does Medical Electronic Device Research with **strong interaction** between companies and physicians/clinicians.

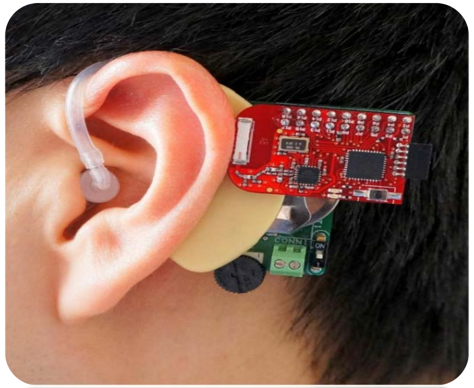
for Context

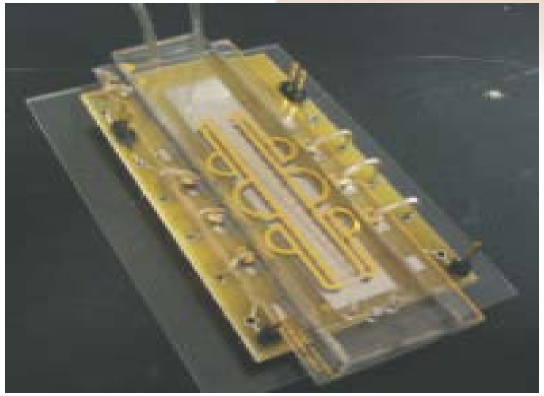
- *jointly created* by industry, academics, and clinicians ➔ maximizes chance of project success.
- prototypes placed in “customers” (clinicians) hands in parallel with research technology development.

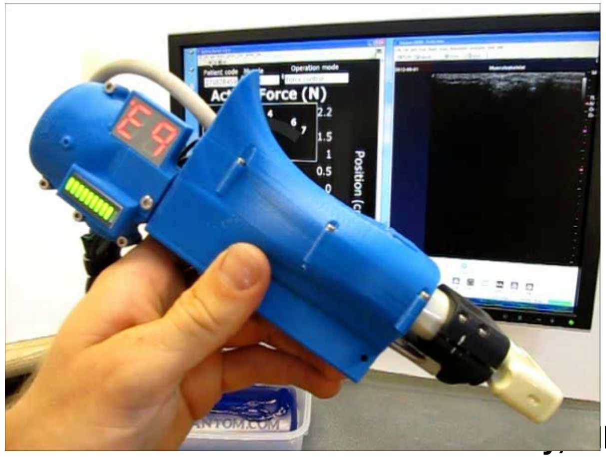


Application Areas and Technology Examples

- Wearable Devices
  - Vital signs monitors including cuffless blood pressure
- Minimally Invasive Monitors
  - EEG measurements for Epilepsy patients
- “Point of Care” Instruments
  - “Lab on a Chip” for blood, urine, saliva analysis
- Imaging
  - Smart Ultrasound
- Data Communication
  - Body Area Network
- Pharma
  - Clinical trial of the future

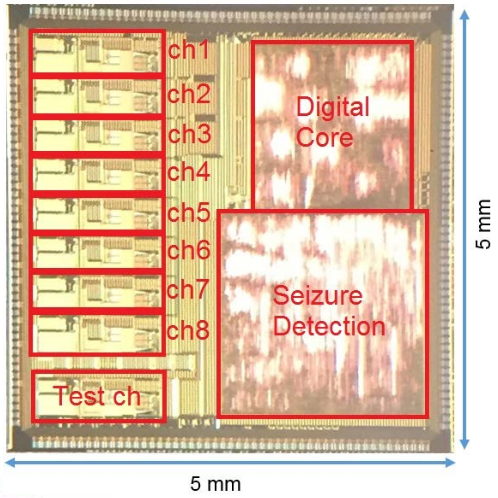


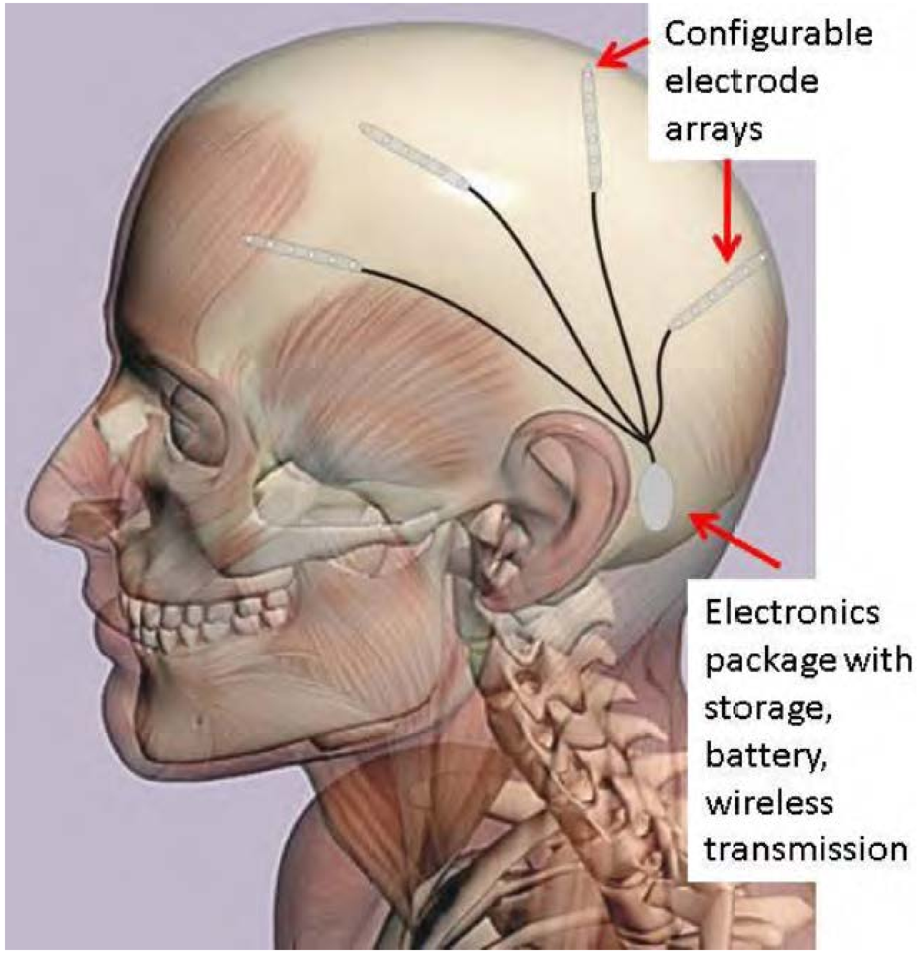




Long-Term, Subdermal Implantable EEG Recorder and Seizure Detector

- 8 EEG Channels
- 3.5 cm x 3.5 cm X 5 mm (electronics package)
- Wireless data transmission and battery recharging
- External device (not shown) for power and data transmission





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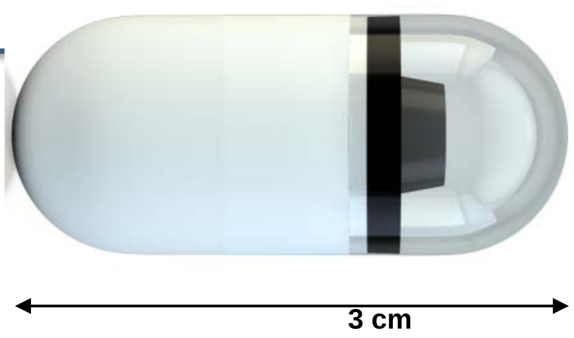
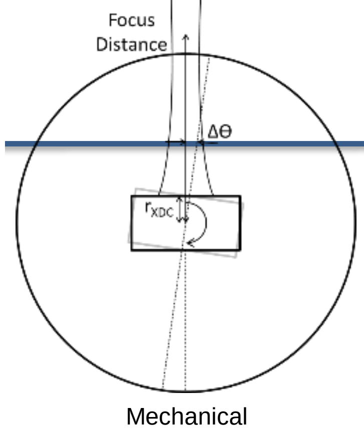
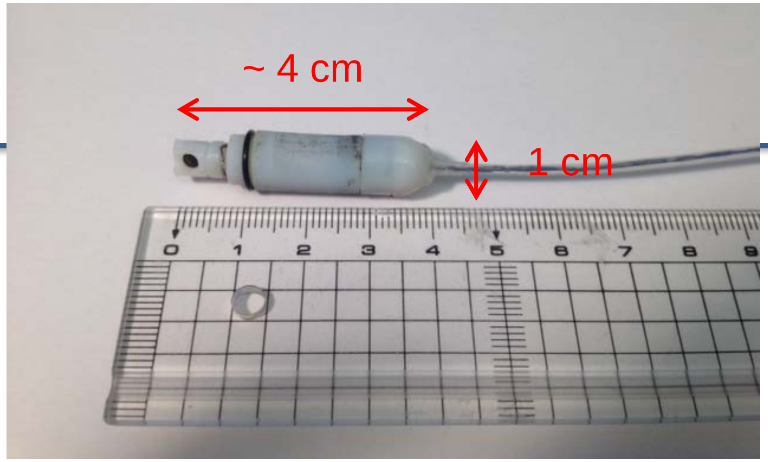
MEDICAL ELECTRONIC DEVICE REALIZATION CENTER

With Bruno Do Valle, Jason Yang, and Charlie Sodini
MIT Microsystems Technology Laboratories

Small Intestine Imaging – US Pill



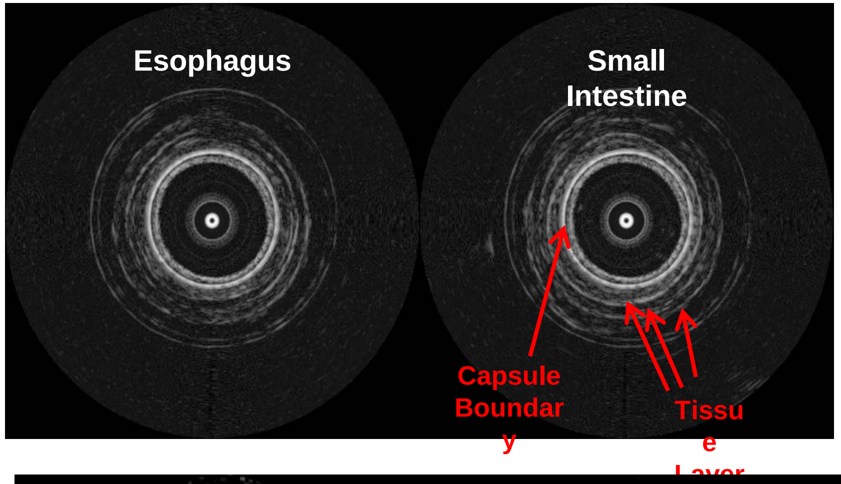




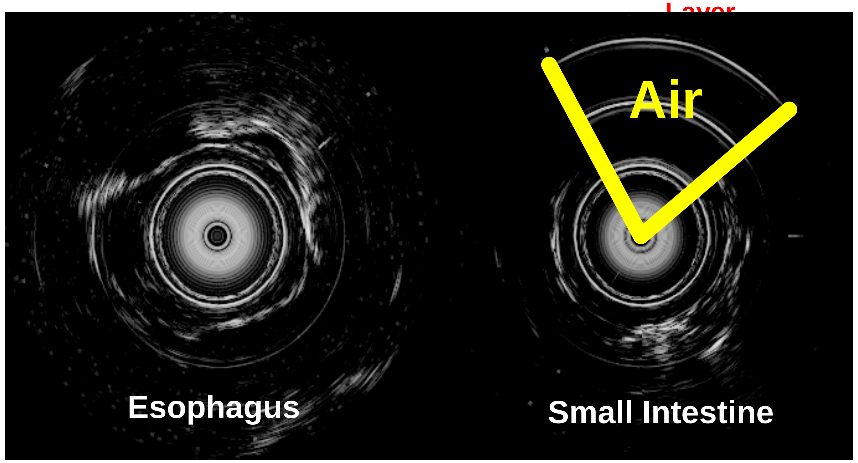
Needs:

- ❑ Wireless
  - ❑ Low power: need to run on button cell battery
  - ❑ Limited computation capability
  - ❑ Minimize radio transmission
- ❑ Small
  - ❑ Limited by what GI tract can pass
- ❑ Disposable
  - ❑ Cheap: one time use only
  - ❑ Manufacturability

ex vivo



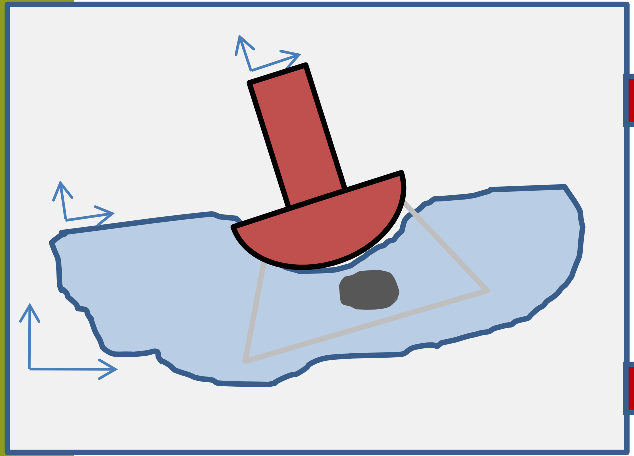
In vivo



MEDRC MEDICAL ELECTRONIC DEVICE REALIZATION CENTER

Ibarra, Lee, Anthony

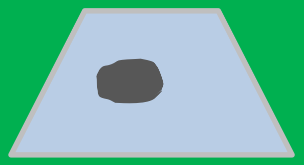
Ultrasound System Flow



Contact State

$\hat{F}_{contact}, \hat{x}_{rel}, \hat{\theta}_{rel}$

Imagery



Analysis

Diagnostics

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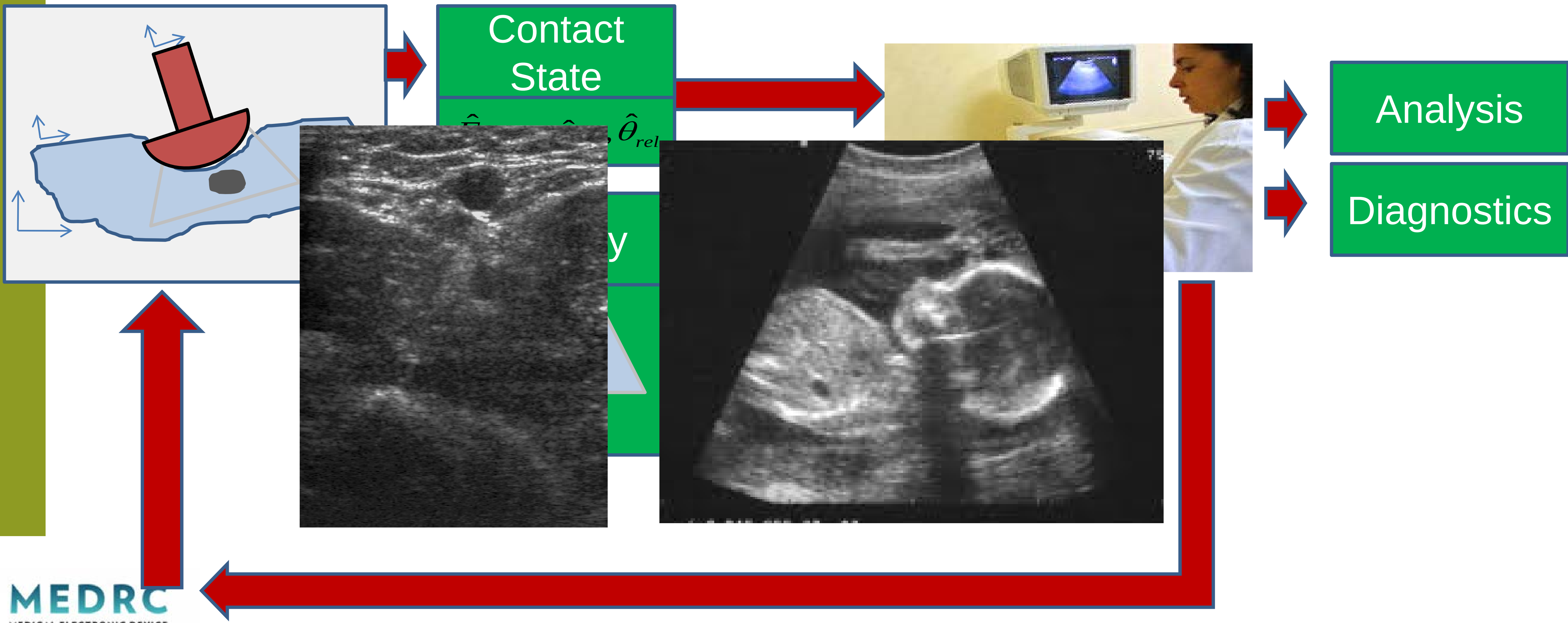
Ultrasound System Flow



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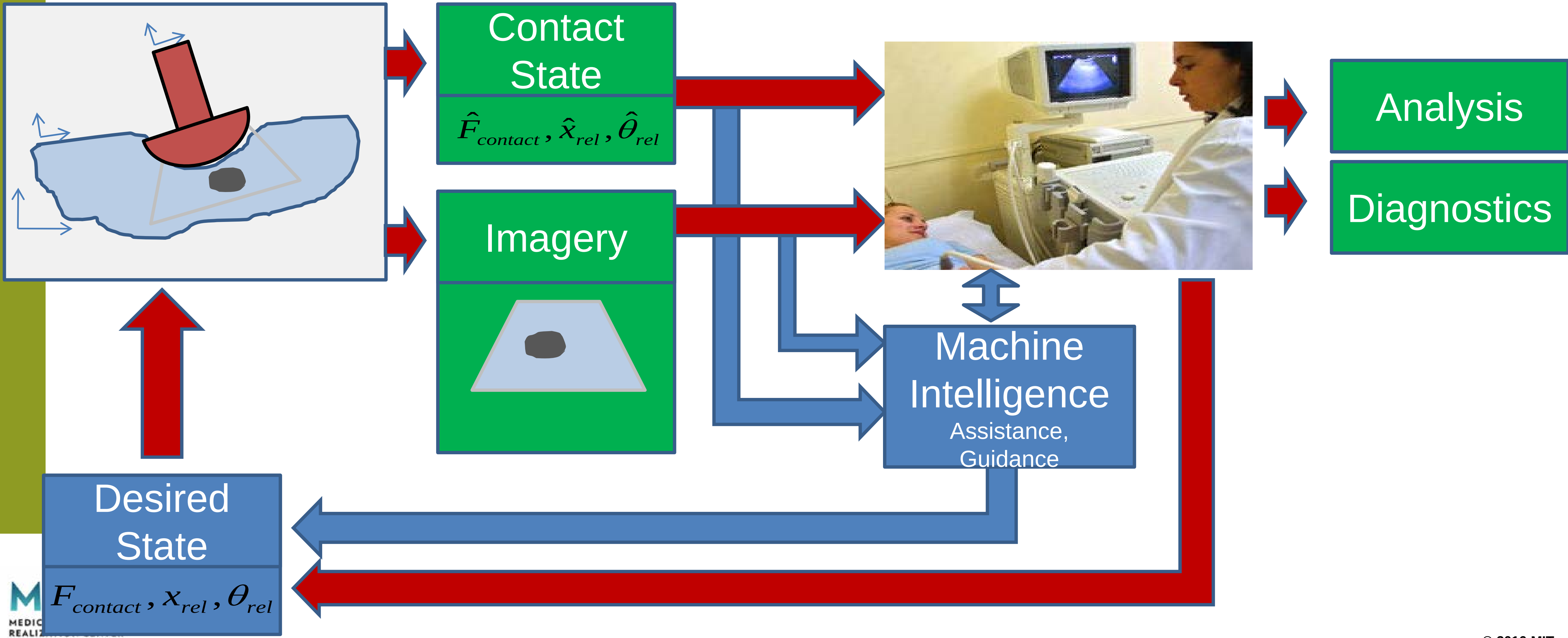
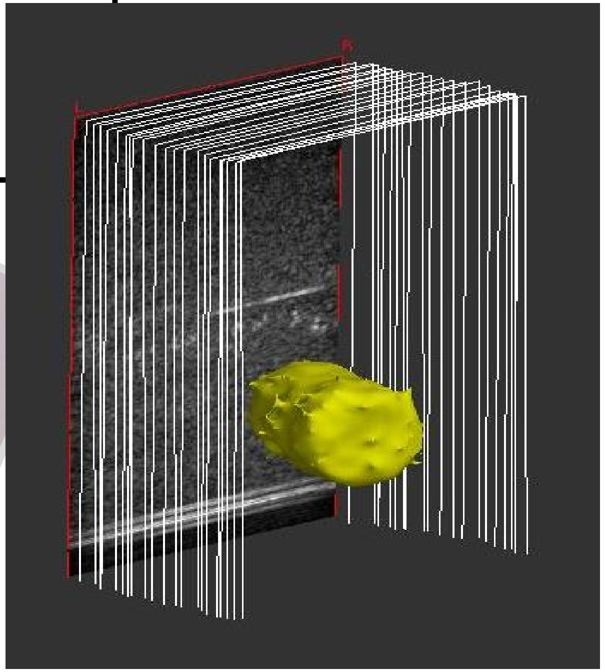
Ultrasound System Flow

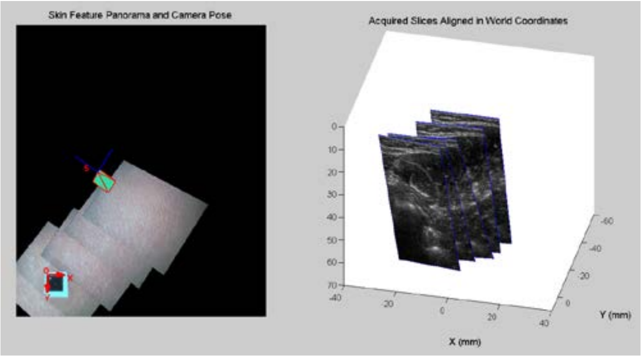
Enhanced

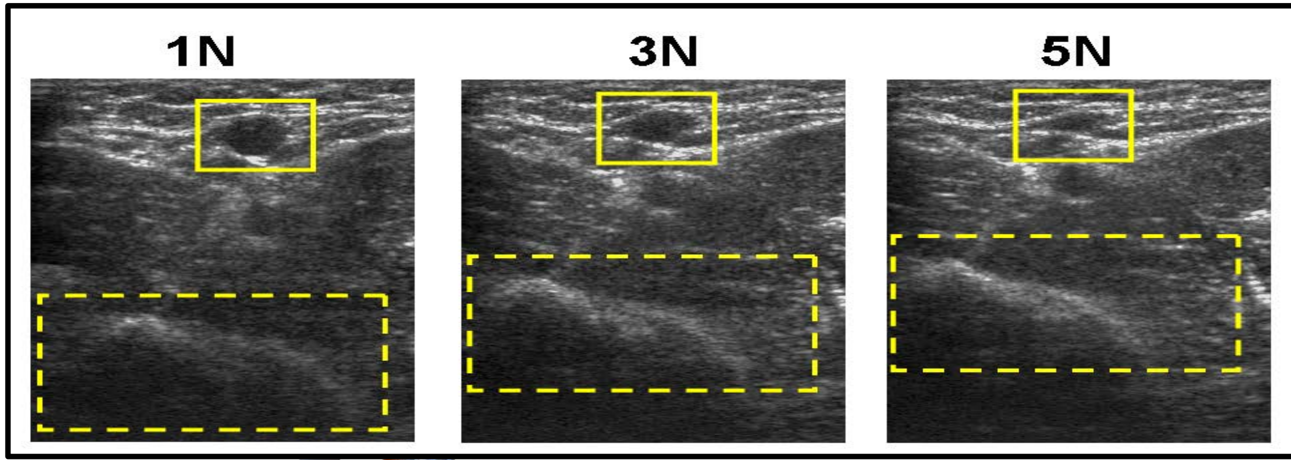


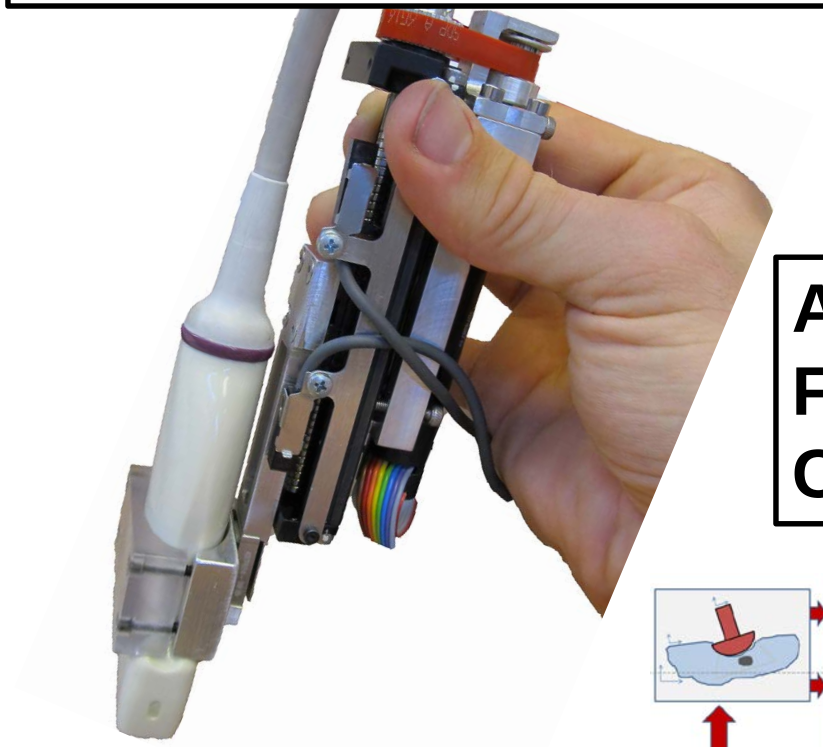
Enhanced Ultrasound Probes

Human-in-the-loop Position and Orientation Control

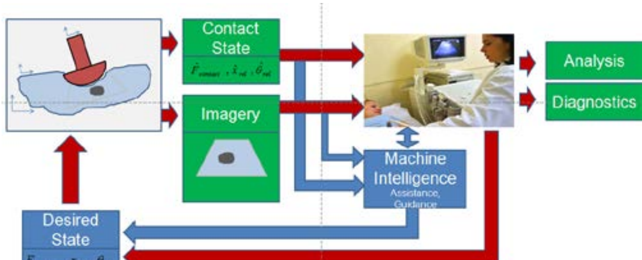






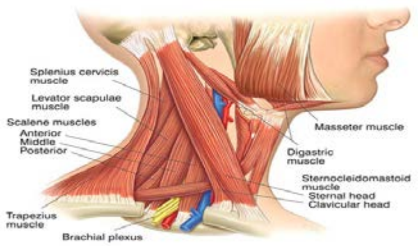


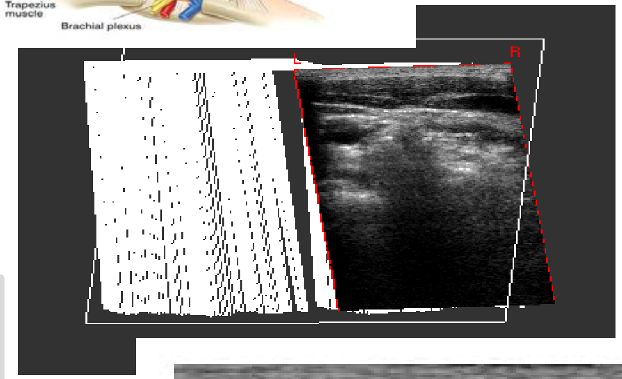
Automatic Force Control

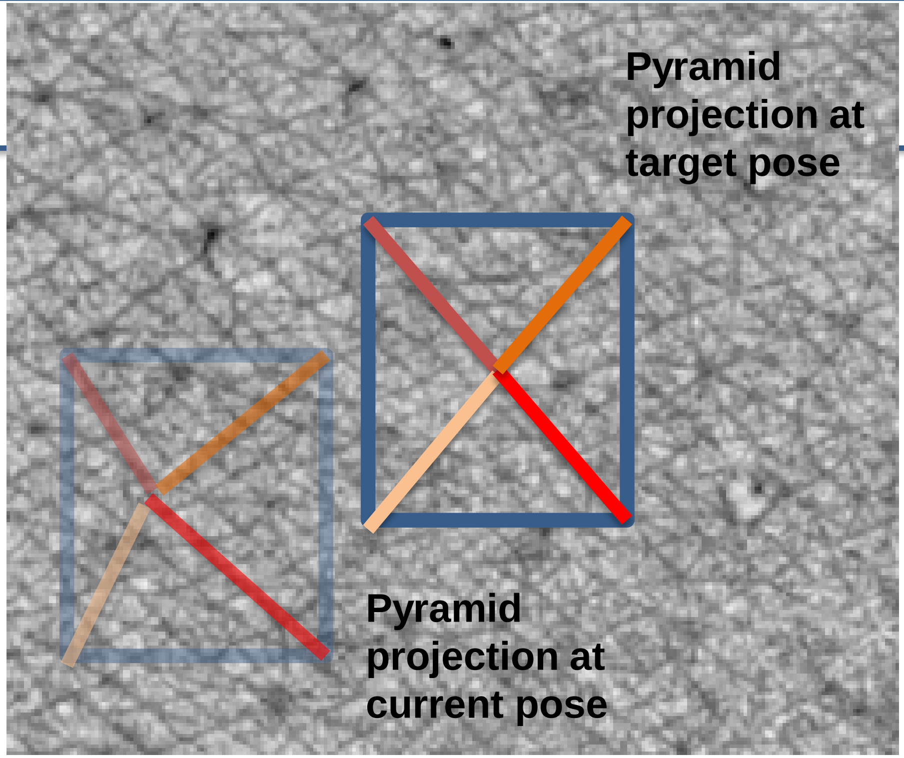


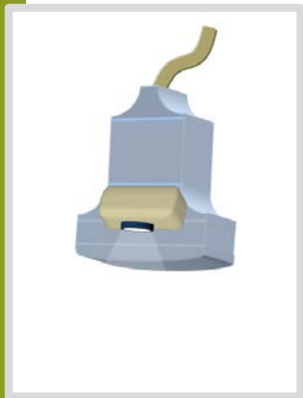
Human Robot Cooperation – Freehand 6-DOF Ultrasound Probe Tracking (via Skin Mapping)

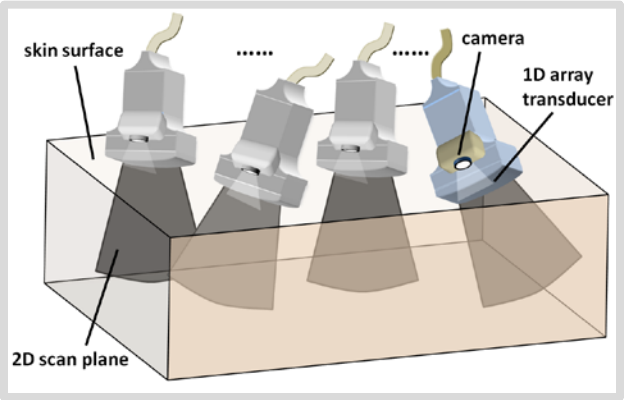
Freehand 3D Ultrasound



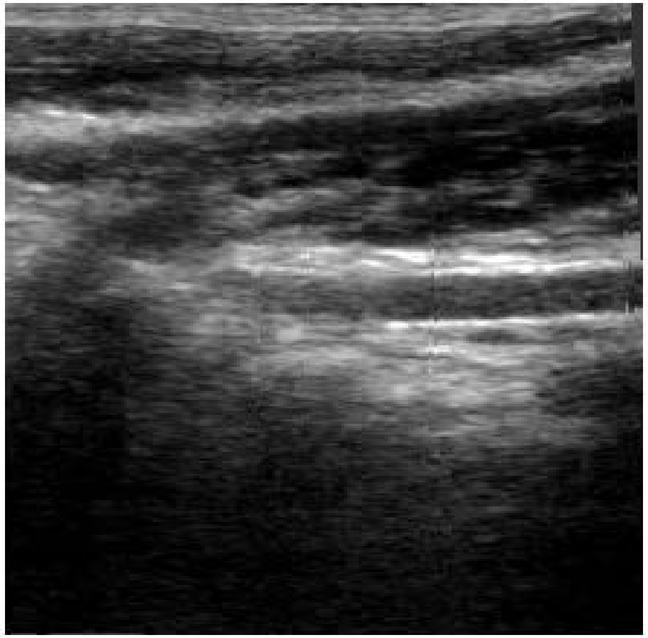


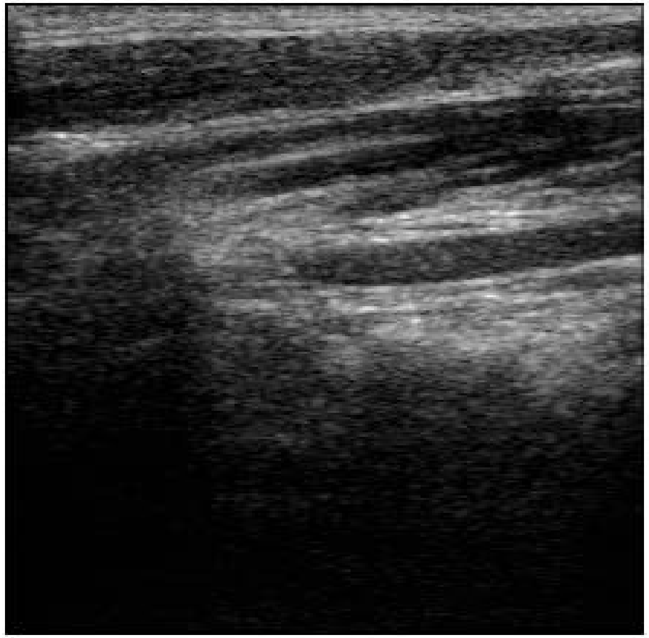






Computer-Guided Ultrasound Realignment





Shih-Yu Sun, Matthew W. Gilbertson, and Brian W. Anthony, Probe Localization for Freehand 3D Ultrasound by Tracking Skin Features, IEEE Transaction on Medical Imaging , 2013.

Takeaways

- Standards are enabling
- Lots of useless data is easy to acquire
- Context - Even simple models (physics, physiological,) are powerful tools for guiding data acquisition strategies and analysis
- Physics Driven vs Data Driven
- Data + high computational power + domain knowledge = success
- Identify the sysem scale at which impact can be had.

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