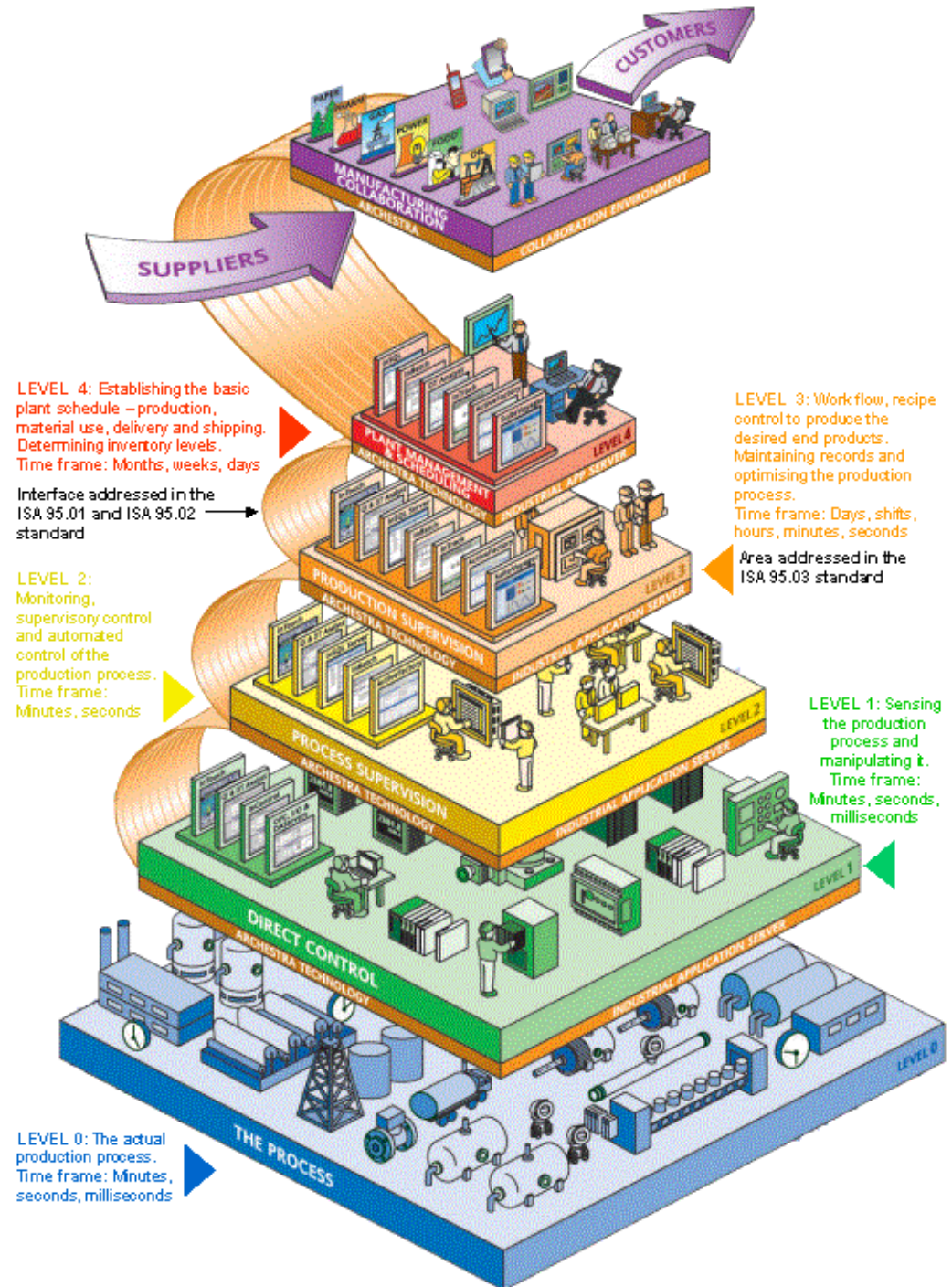# Industrial Automation Architectures

Nenad Ivezic & Vijay Srinivasan

NIST

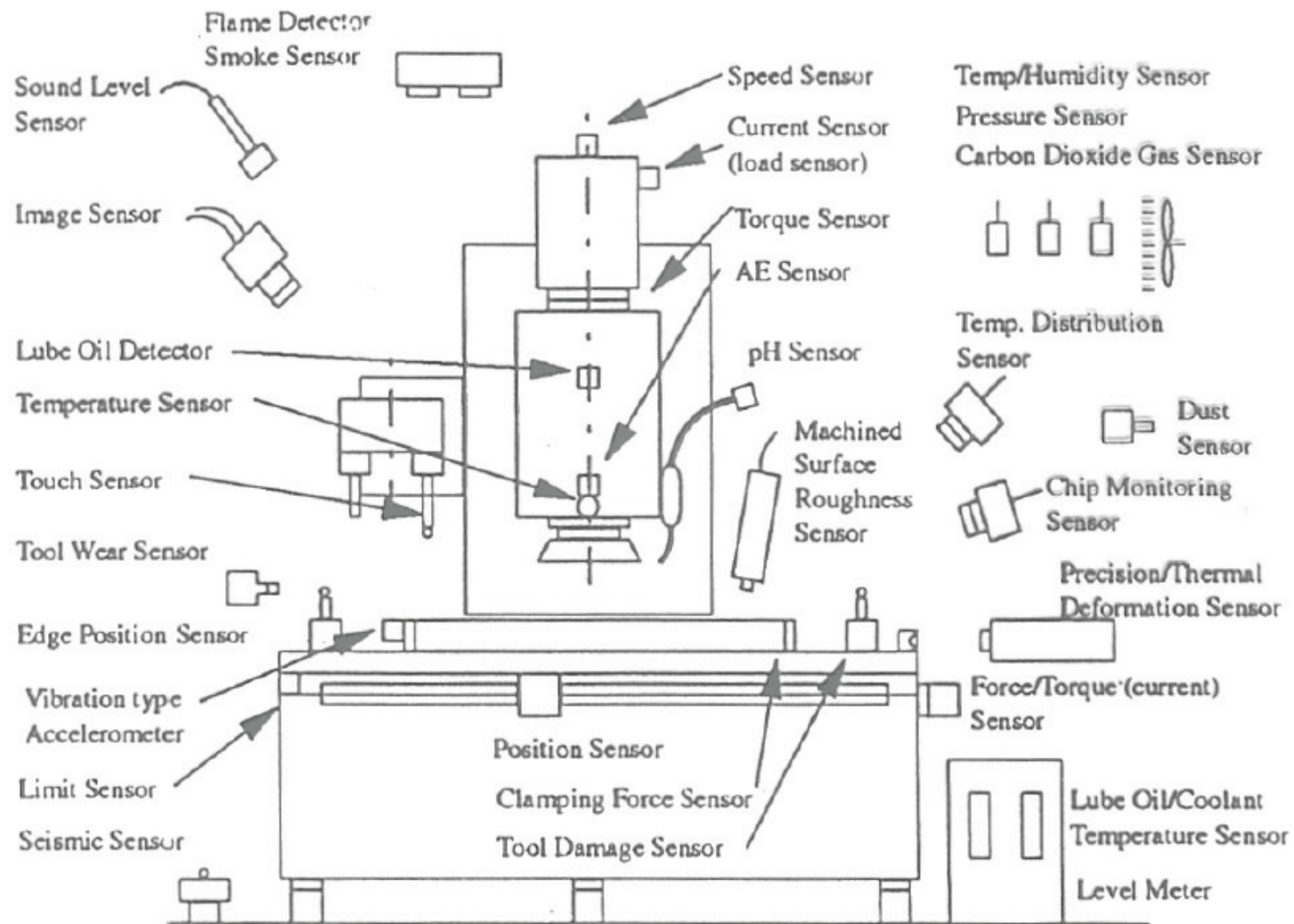CPS Reference Architectures Workshop at NSF; March 26, 2014

ISA-95 Architecture

- ISA: International Society of Automation
- Widely used reference architecture standard for industrial automation
- Based on 'Purdue Enterprise Reference Architecture'
- Gave rise to IEC 62264
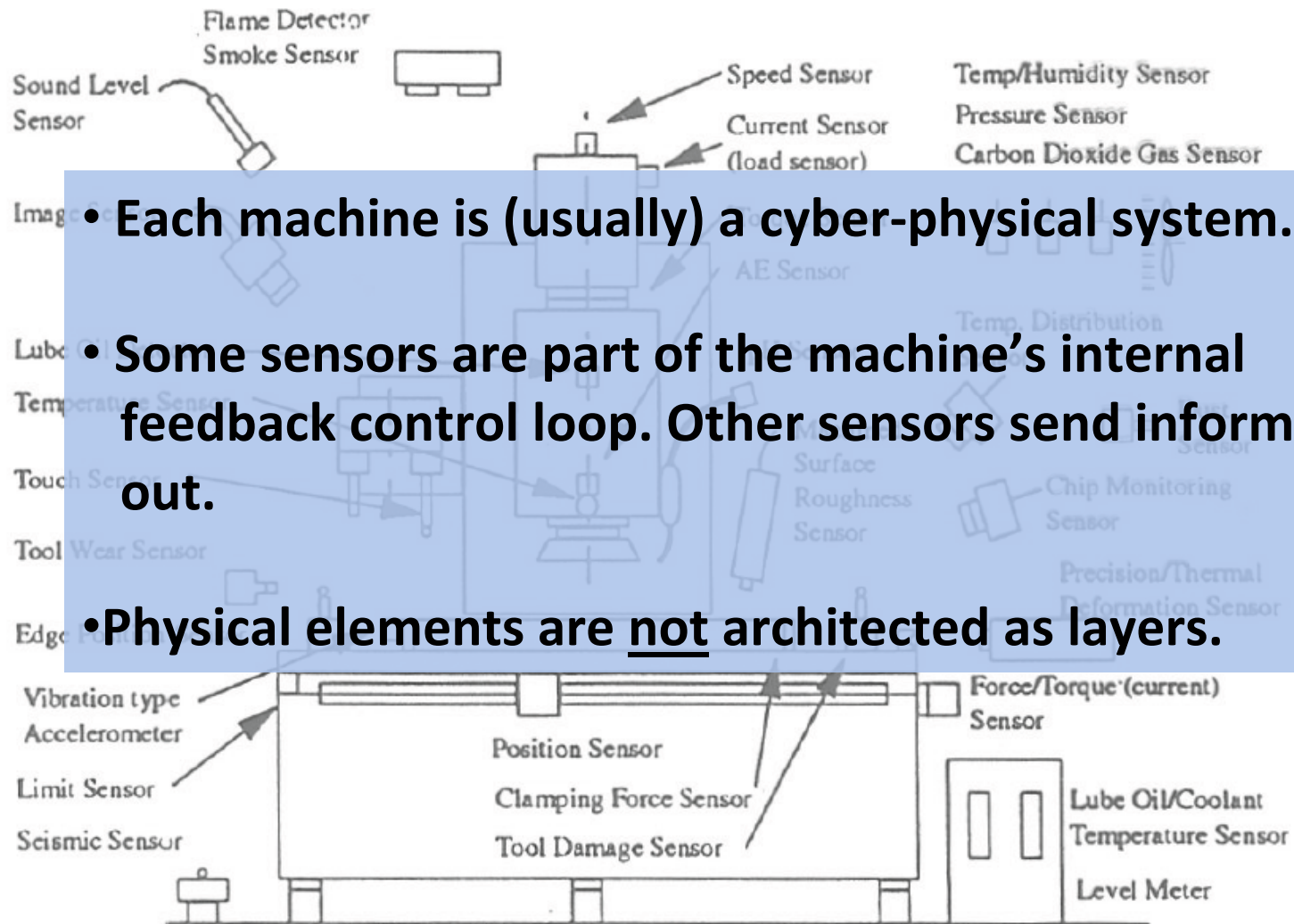- Production systems structured in a 5-level hierarchy.

LEVEL 4: Establishing the basic plant schedule – production, material use, delivery and shipping. Determining inventory levels. Time frame: Months, weeks, days

Interface addressed in the ISA 95.01 and ISA 95.02 standard

LEVEL 2: Monitoring, supervisory control and automated control of the production process. Time frame: Minutes, seconds

LEVEL 3: Work flow, recipe control to produce the desired end products. Maintaining records and optimising the production process. Time frame: Days, shifts, hours, minutes, seconds

Area addressed in the ISA 95.03 standard

LEVEL 1: Sensing the production process and manipulating it. Time frame: Minutes, seconds, milliseconds

LEVEL 0: The actual production process. Time frame: Minutes, seconds, milliseconds

ISA 95 Overview

Level 4: Enterprise Resource Planning (ERP)

Level 3: Manufacturing Operations Management (MOM)

Level 2: Monitoring, supervisory control, automated control of production processes

Level 1: Sensing and manipulating production processes

Level 0: The actual production process

Continuous, Batch, Discrete Productions.

DCS, SCADA, PLC

Level 0: Individual machines (1/2)

Level 0: Individual machines (2/2)

- **Each machine is (usually) a cyber-physical system.**

- **Some sensors are part of the machine's internal feedback control loop. Other sensors send information out.**

- **Physical elements are <u>not</u> architected as layers.**

Flame Detector
Smoke Sensor

Sound Level
Sensor

Speed Sensor

Current Sensor
(load sensor)

Temp/Humidity Sensor
Pressure Sensor
Carbon Dioxide Gas Sensor

Image

AE Sensor

Lube

Temp. Distribution

Temperature Sensor

Touch Sensor

Surface
Roughness
Sensor

Chip Monitoring
Sensor

Tool Wear Sensor

Precision/Thermal
Deformation Sensor

Edge

Vibration type
Accelerometer

Limit Sensor

Seismic Sensor

Position Sensor

Clamping Force Sensor

Tool Damage Sensor

Force/Torque (current)
Sensor

Lube Oil/Coolant
Temperature Sensor

Level Meter

Level 1: Collection of machines

- Production cell, manufacturing line
- Programmable Logic Controller (PLC) to monitor and control material flow through cell/line
- <u>PLC modules</u>: power supply, processor, I/O, communication
- <u>PLC programming</u>: Ladder diagram, Sequential function chart, Function block diagram, Structured text, Instruction list
- PLC has relatively longer use-phase life ≈ a decade

Level 2: Supervisory, distributed control

- Production floor, plant, factory
- SCADA: Supervisory Control And Data Acquisition
  - Software only, events-driven
  - Suitable for discrete production
- DCS: Distributed Control System
  - Hardware + software, process-driven
  - Suitable for continuous production

# Level 3: Manufacturing Operations Management

- Manufacturing Execution System (MES)
  - Production scheduling and tracking
- Laboratory Information Management System (LIMS)
- Warehouse Management System (WMS)
- Computerized Maintenance Management System (CMMS)

Level 4: Enterprise Resource Planning

- Manufacturing resources
  - Supply chain management, sales forecast, …
- Human resources
  - Recruitment, payroll, benefits, …
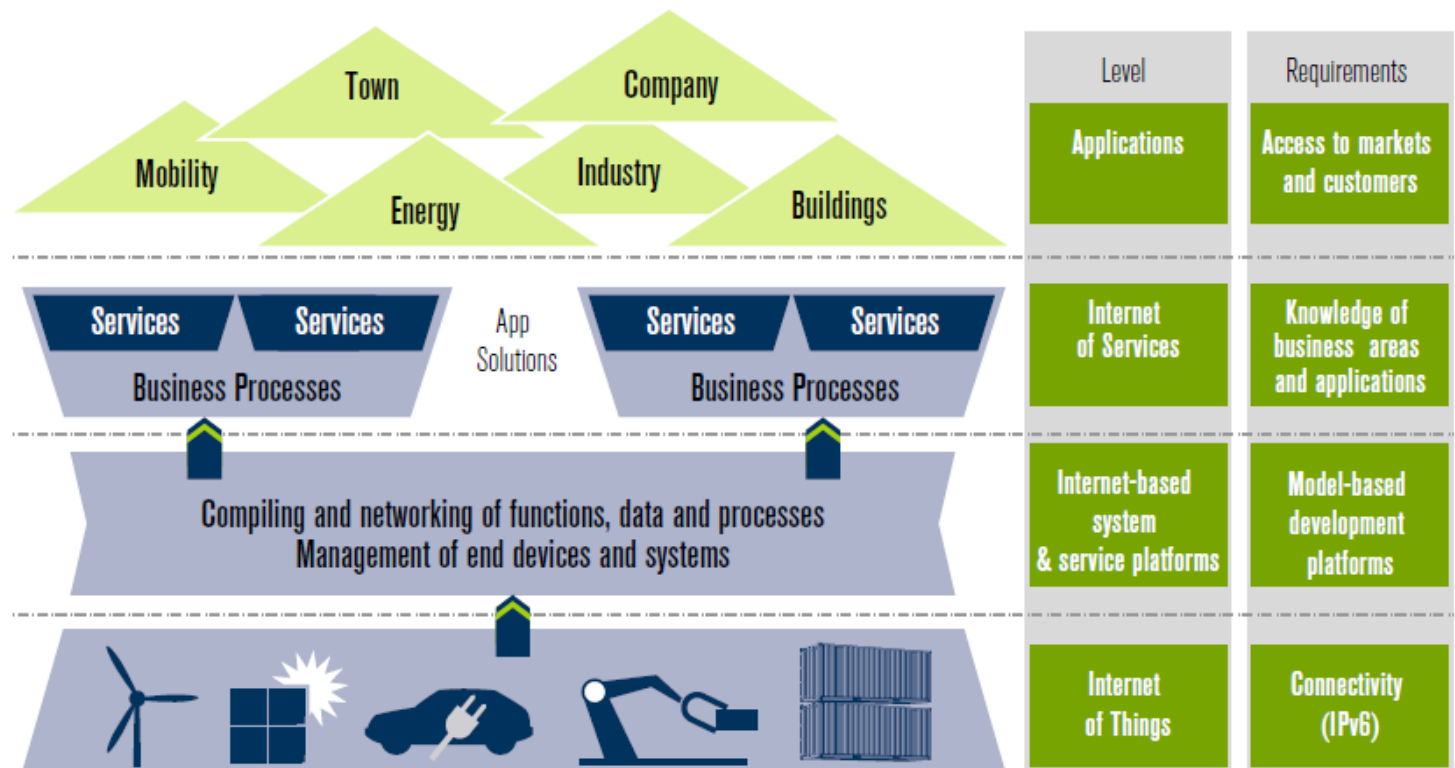- Financial resources
  - Budgets, billing, cash management, …

In Come the Clouds …
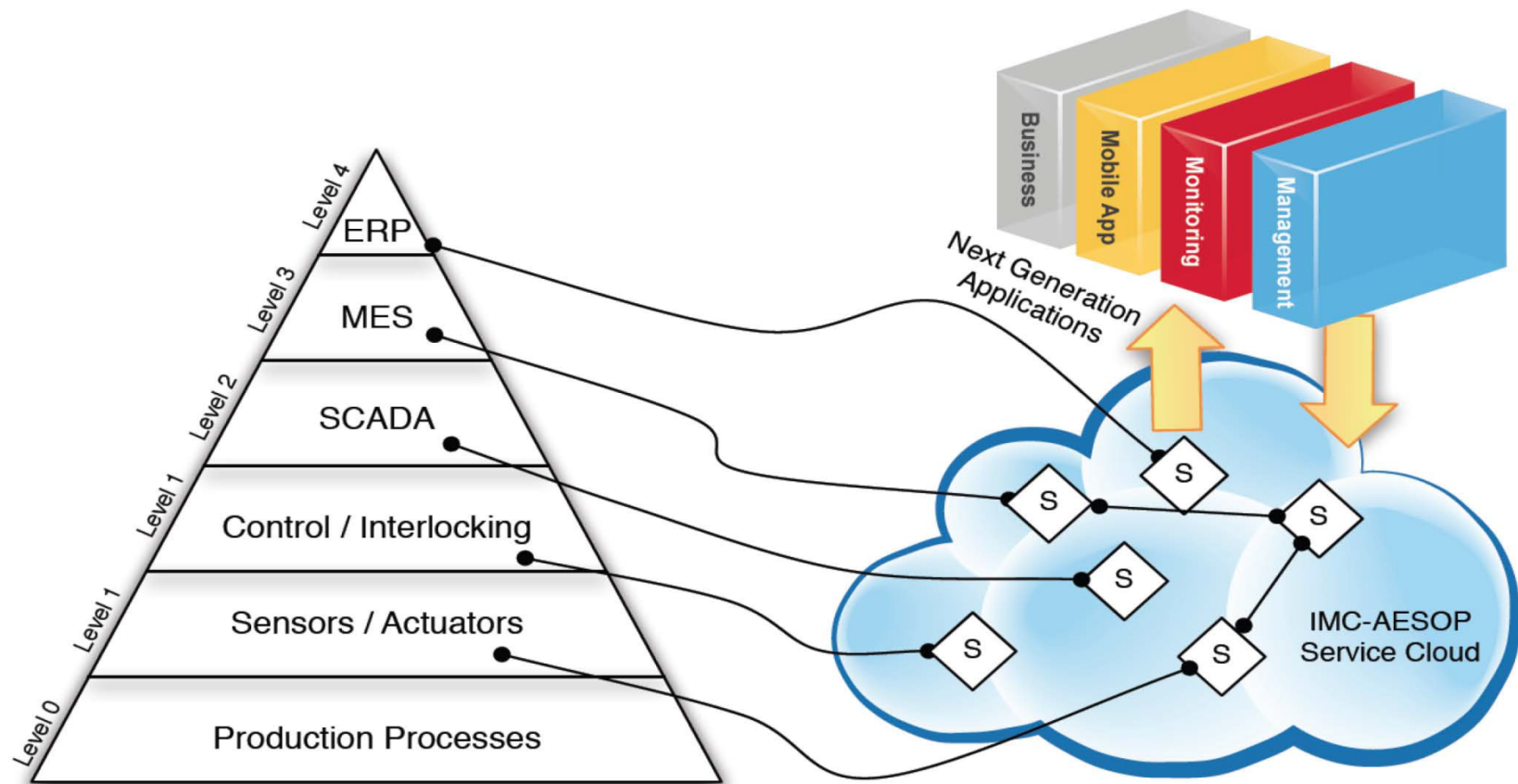
… and Services

Industrie 4.0

Figure 9:
Reference architecture for connecting the Internet of Things with the Internet of Services

Source: Bosch Software Innovations 2012

Thank You!