Leveraging your Digital Twin: Subfab and Beyond…

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Intelligent Manufacturing Systems

https://ims.inficon.com

INFICON Global Presence & Software Deployments

504 Employees

507 Employees

234 Employees

- IMS Software Offices
- Sales and Offices
- Manufacturing Site

FPS - Most commercial fully scheduled fabs in the world!

FPS — 35+ Fabs (5 Backend)
FabGuard — 35+ Fabs (5 Backend)
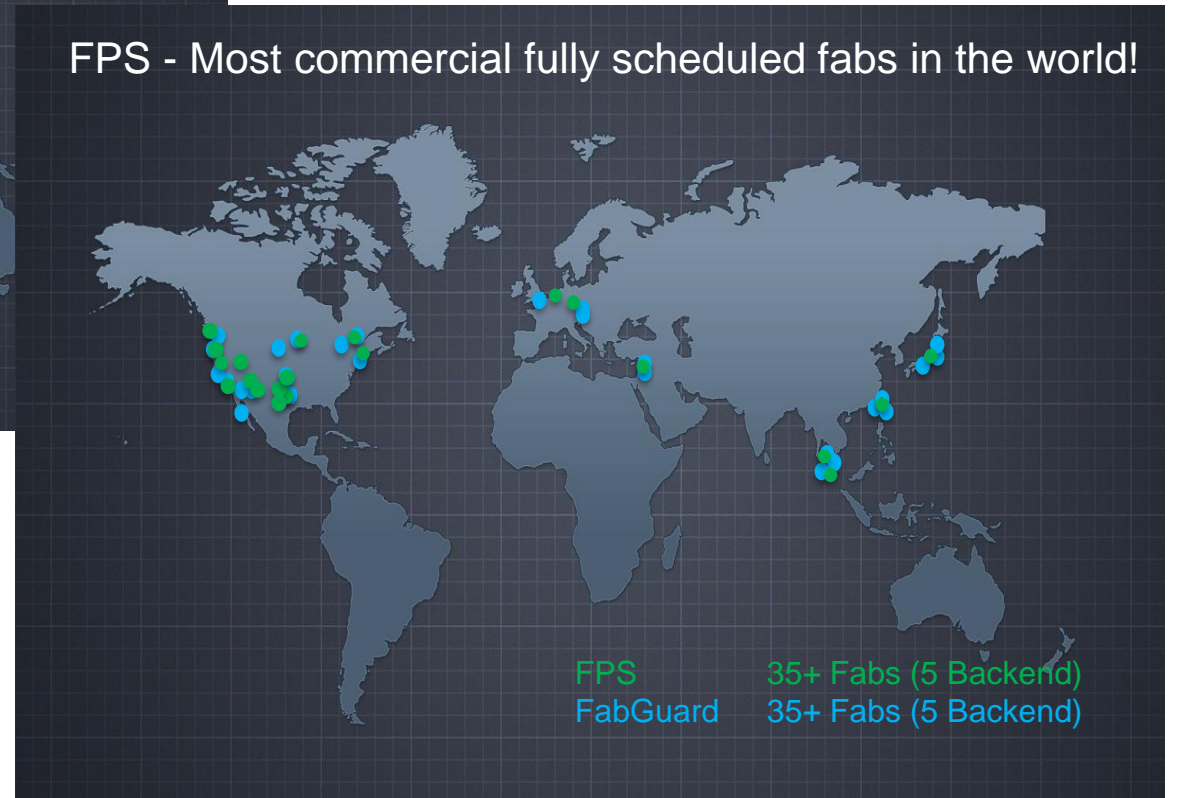
Proven Smart Solutions
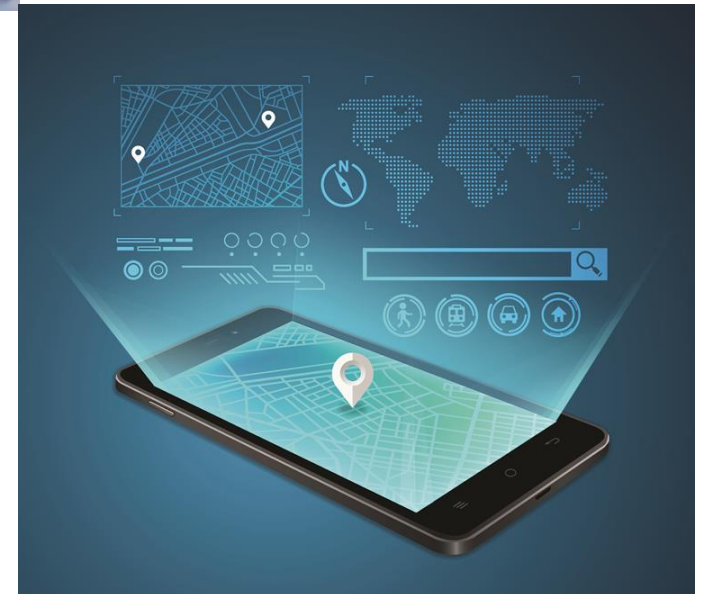
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A Digital Twin is NOT just Data

**A Digital Twin =
Data + Structure + Function**

The key strength of the Digital Twin is that it provides an accurate high fidelity representation of the factory built from past observations to **drive predictive applications that react to fab changes in near real time.**
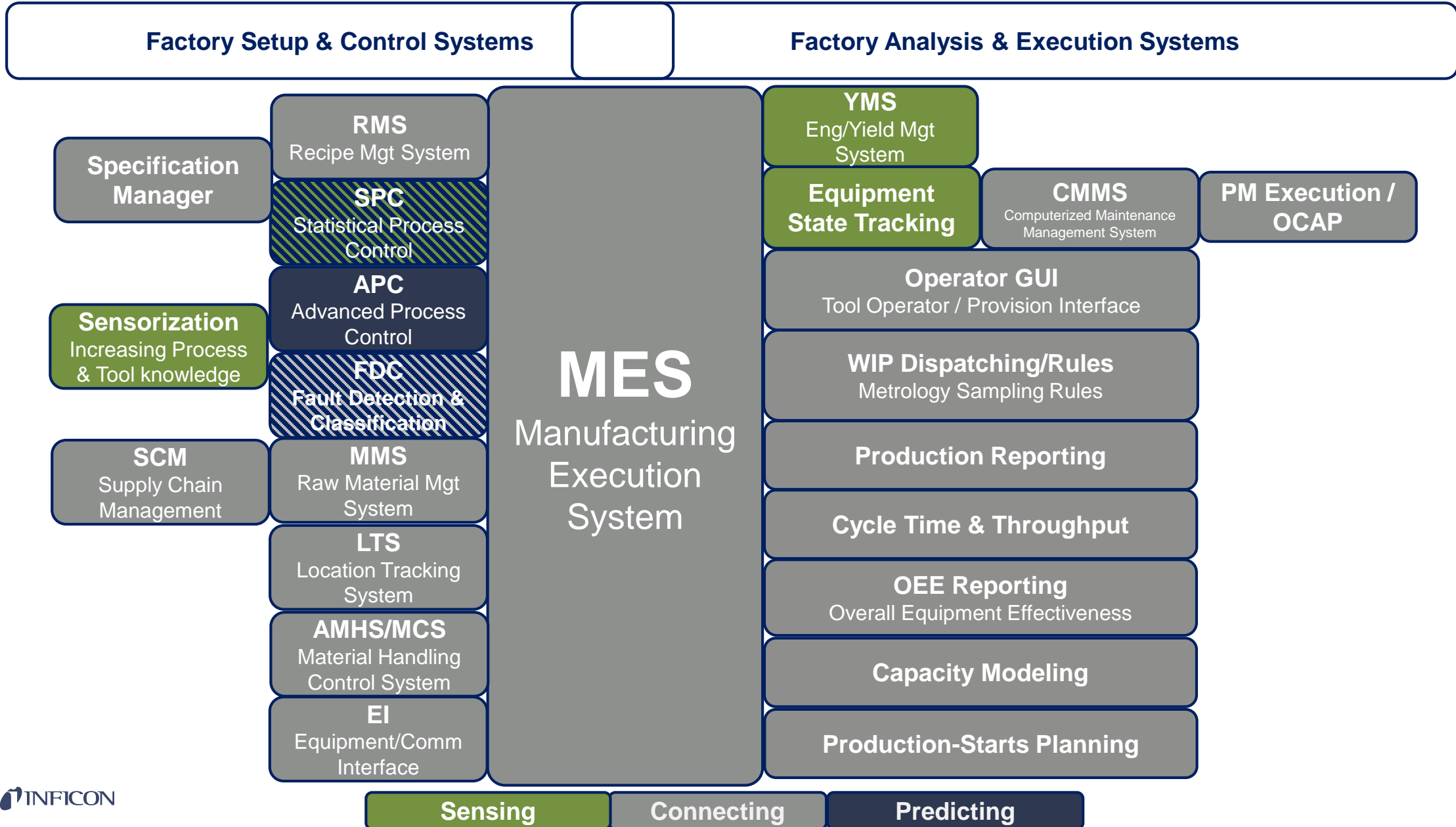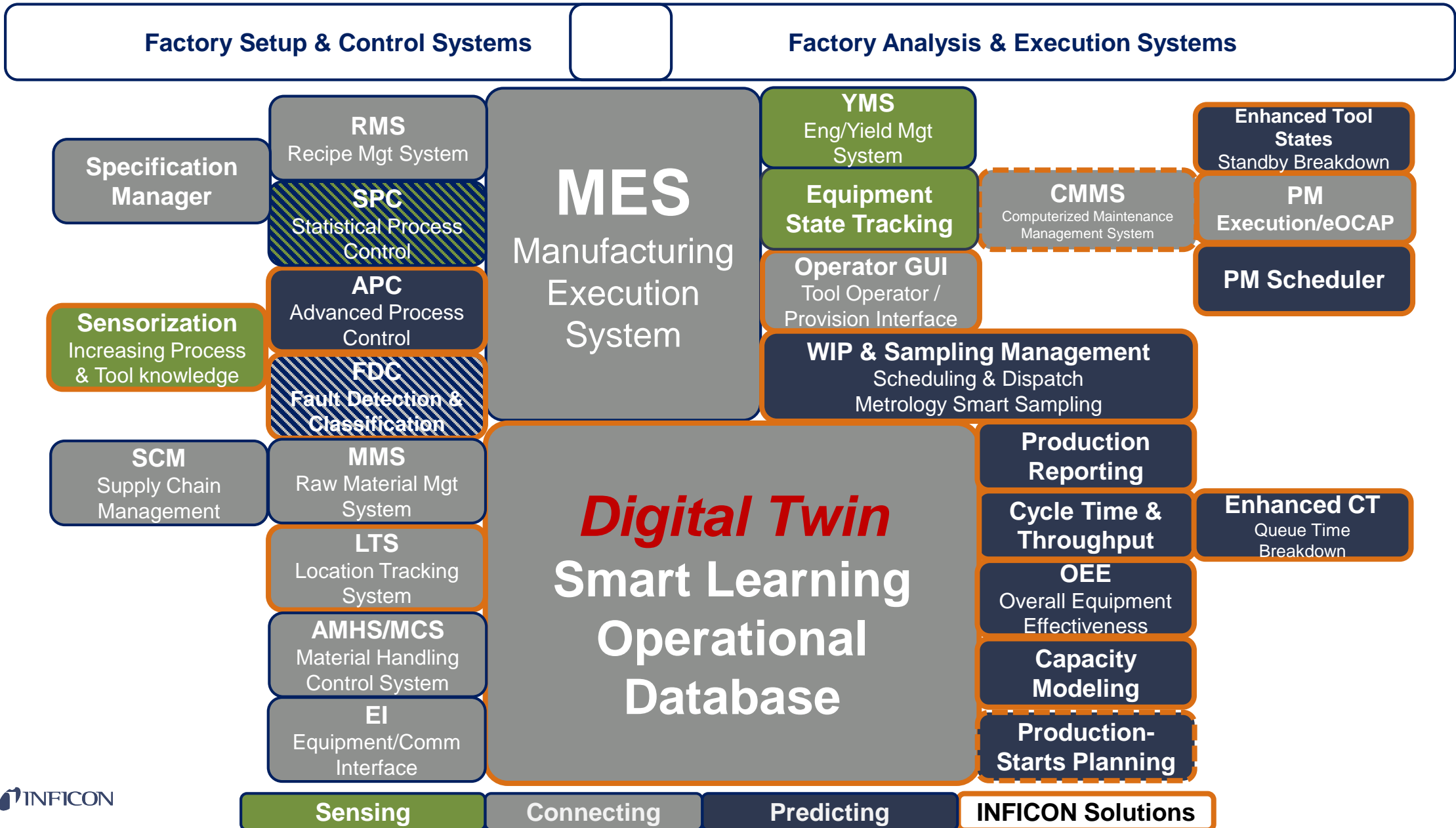

If a database is a *map*…

.. a Digital Twin is a smartphone that translate map data into the best route given current conditions.

Historical Factory Systems – Precursor to Digital Twins

Factory Setup & Control Systems		Factory Analysis & Execution Systems

Specification Manager

RMS
Recipe Mgt System

SPC
Statistical Process Control

APC
Advanced Process Control

Sensorization
Increasing Process & Tool knowledge

FDC
Fault Detection & Classification

SCM
Supply Chain Management

MMS
Raw Material Mgt System

LTS
Location Tracking System

AMHS/MCS
Material Handling Control System

EI
Equipment/Comm Interface

MES
Manufacturing Execution System

YMS
Eng/Yield Mgt System

Equipment State Tracking

CMMS
Computerized Maintenance Management System

PM Execution / OCAP

Operator GUI
Tool Operator / Provision Interface

WIP Dispatching/Rules
Metrology Sampling Rules

Production Reporting

Cycle Time & Throughput

OEE Reporting
Overall Equipment Effectiveness

Capacity Modeling

Production-Starts Planning

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Sensing	Connecting	Predicting

INFICON's Digital Twin & Integrated Smart Solutions

Factory Setup & Control Systems

Factory Analysis & Execution Systems

Specification Manager

RMS
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Increasing Process & Tool knowledge

MES
Manufacturing Execution System

YMS
Eng/Yield Mgt System

Equipment State Tracking

CMMS
Computerized Maintenance Management System

Enhanced Tool States
Standby Breakdown

PM
Execution/eOCAP

PM Scheduler

Operator GUI
Tool Operator / Provision Interface

WIP & Sampling Management
Scheduling & Dispatch
Metrology Smart Sampling

SCM
Supply Chain Management

MMS
Raw Material Mgt System

LTS
Location Tracking System

AMHS/MCS
Material Handling Control System

EI
Equipment/Comm Interface

Digital Twin
Smart Learning Operational Database

Production Reporting

Cycle Time & Throughput

Enhanced CT
Queue Time Breakdown

OEE
Overall Equipment Effectiveness

Capacity Modeling

Production-Starts Planning

Sensing | **Connecting** | **Predicting** | **INFICON Solutions**

Smart/Industry 4.0 Solutions for Subfab/Facilities

Sensing
- Accelerometer/Velocimeter
- Component integration (pumps, abatement, etc.)
- External gauges (pressure, flow, temperature, etc.)
- Chemical and concentration monitors

Connecting
- Factory and Tool Digital Twin
- WIP Scheduling
- Fault Detection and Classification
- Statistical Process Control

Predicting
- Predictive failure
- Predictive maintenance
- Operations/WIP movement enhancement

Digital Twin

Connect → Analyze → Explore → Learn → Enhance →

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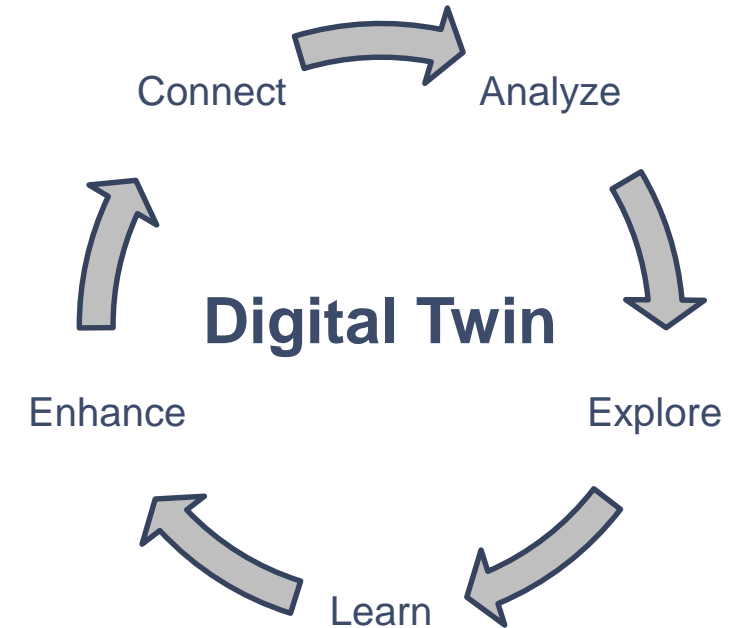
Why Integrate the Subfab into Digital Twins?

Smart control to create energy savings

- Reduced energy usage by linking tool states to facilities

Reduced use of consumables/chemicals/gases

- Migrate to condition-based consumption (reduction of 15-35% typical)

Regulatory compliance and reporting

- Lower CO, CO_2, NOx etc. emissions
- Cumulative consumption reporting to agencies

Increase FDC tool awareness by adding support equipment data and state

Smart/predictive Maintenance Scheduling

Enhanced WIP Scheduling based upon better Tool Digital Twin

Financial

Environmental

Regulatory

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Typical Facilities and Subfab Components

Pumps and Vacuum Components

   Operational parameters

   Vibration, Temperature, Pressure

Abatement and Scrubbers

   Operational parameters

   Consumable usage

Heaters and Chillers

   Current monitoring for heaters

   In-Line Thermocouple

Exhaust and Pneumatic Lines

   Differential pressure monitoring

Chemical Delivery (Gas, Liquid, Solid)

   Flow control

   Purity monitoring

Water and Wastewater Monitoring

   In-Line VOC and contamination monitoring
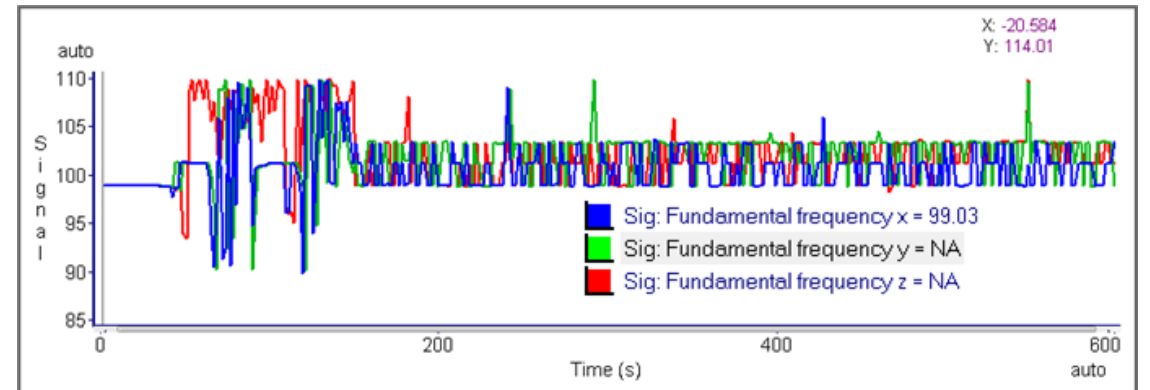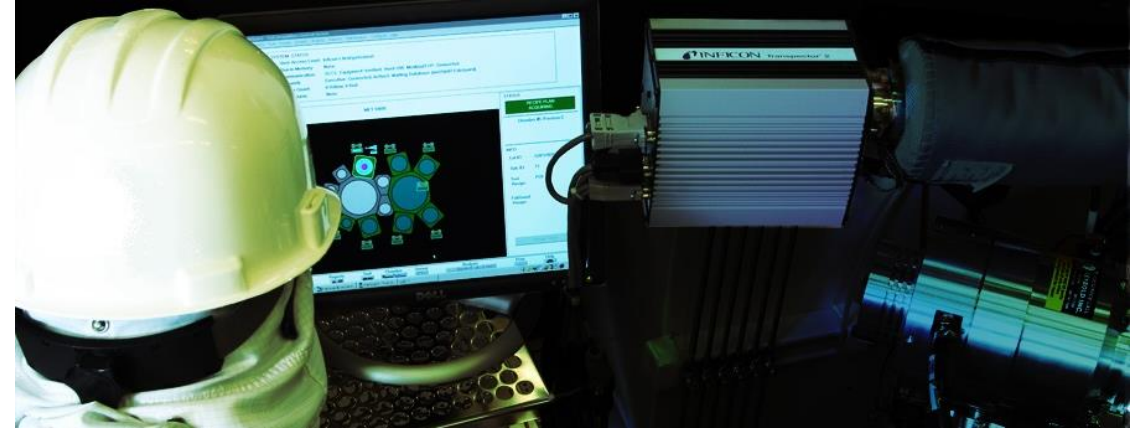
Facilities Monitoring and Control

FDC Management

Factory Automation
Equipment Integration

WIP Scheduler

Equipment State and
Schedule Information

Factory

Tool and Sensor Data

Subfab

Pumps | Chillers | Abatement | Chemical and Water

Support Equipment - Subfab
(pumps, chillers, abatement, etc)

Facilities Data

Facilities Monitor
Facilities Monitoring
Subfab Digital Twin
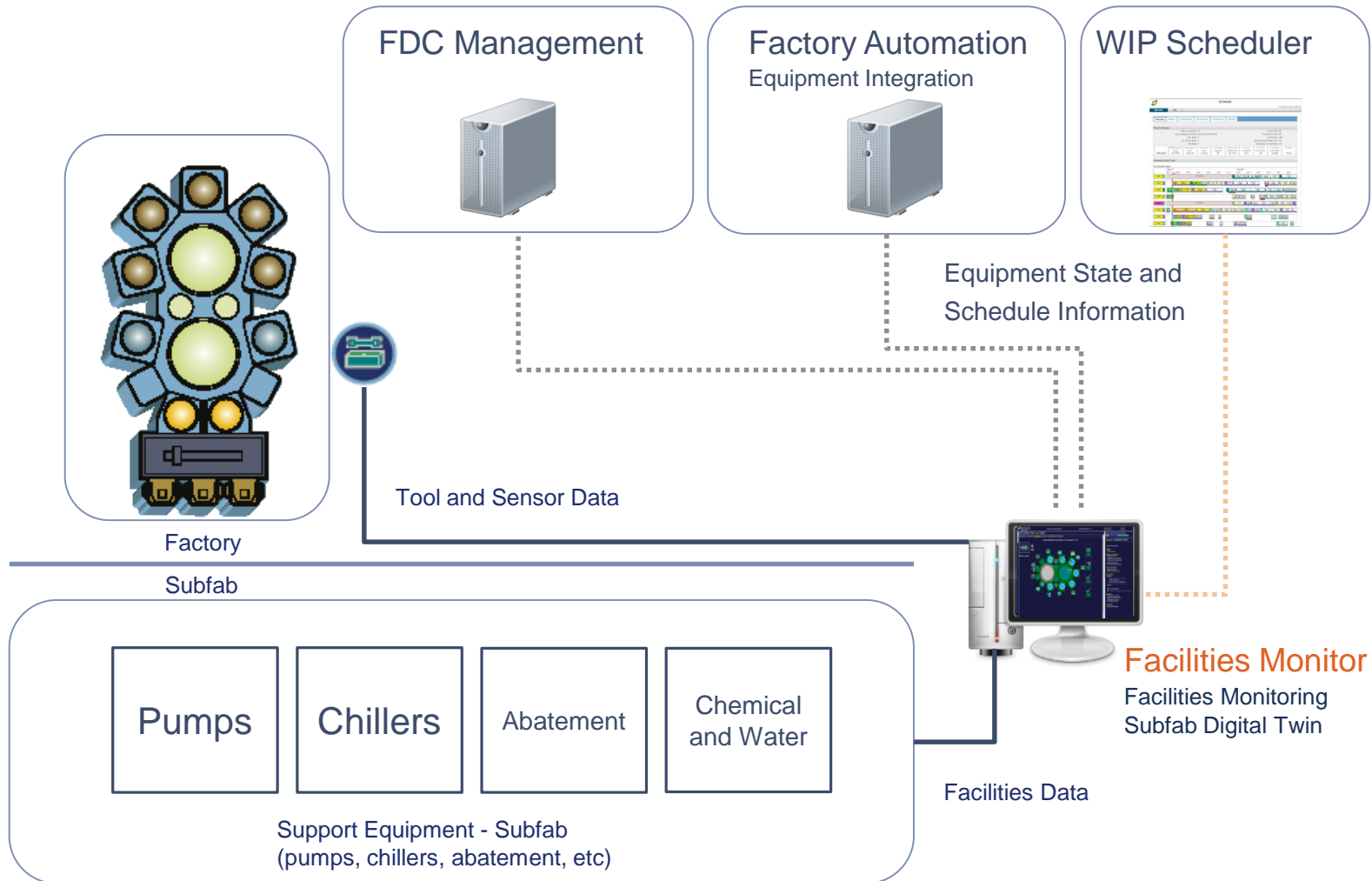
Facilities Monitor
- Connect to:
  - Process Equipment
    - State Information
  - Facilities Equipment
    - State information
    - Control (on, off, idle)
  - Automation and Scheduling
    - Determine actual tool idle time and duration
- Monitor Facilities for excursions and issues

Benefits
- Lower Consumable usage
  - Power, Natural Gas, Water, etc.
- Provide better regulatory reporting
- Detect excursions
  - Schedule PM
  - Reduce down time

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Direct Pump Integration - Example

Provide pump data to the FDC system to combine with process and state information to allow for better predictability of future failure

Direct connection to pumping system
- Monitor for real-time changes
- Correlate to process changes

Additional sensors and gauges for enhanced monitoring
- Vibration

Provide data to other systems
- Factory Digital Twin
- Maintenance Planning System
- WIP Scheduling

Integrated Control of Pumping Systems

Different pump models and vendors monitored/controlled with the same software package

Pumps that support "green" or "idle" mode control, are managed to reduce power consumption when the tool is in an idle state

- Managed based upon physical tool load
- The scheduling system communicates to the controller that tools will be idle for specific time periods
- Savings in N2 Purge and Power

https://youtu.be/Z94mevmVR58
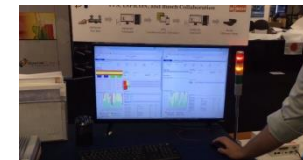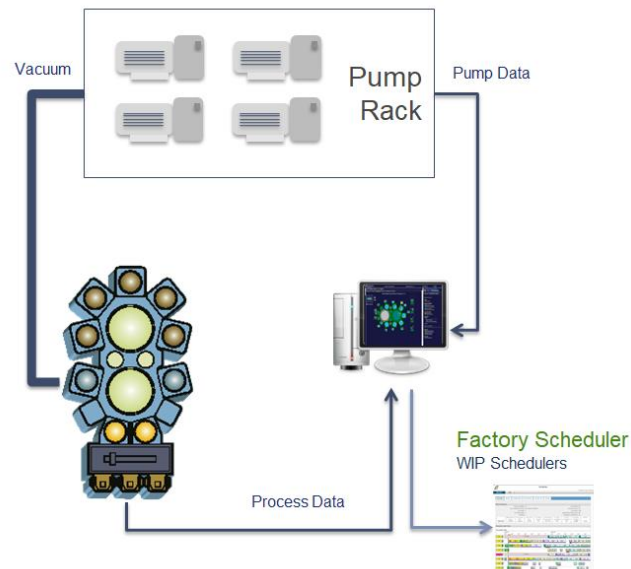
FDC alarm or tool down condition adjusts WiP scheduling and tools without WiP can have subfab components idled

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Real-Time and Trend-Based Monitoring

Real-Time Process Monitoring

Long Term Monitoring
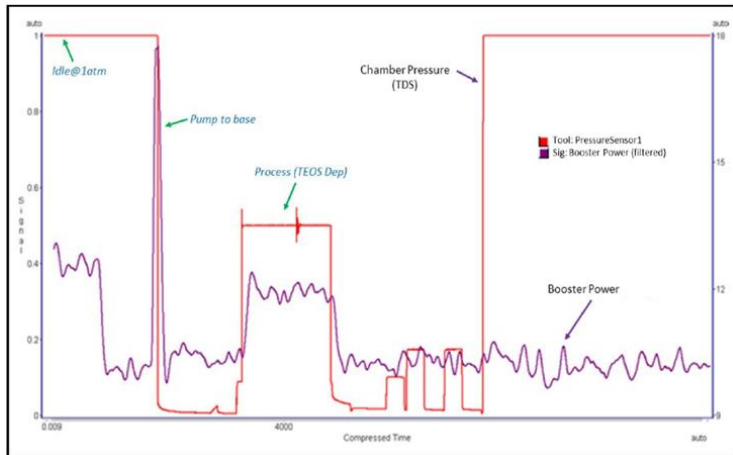
Process correlation with pump data
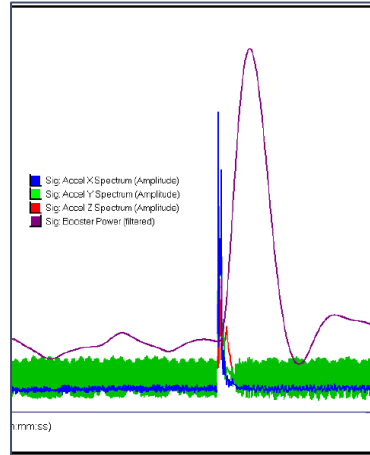
High-Speed vibration data correlated with pump data
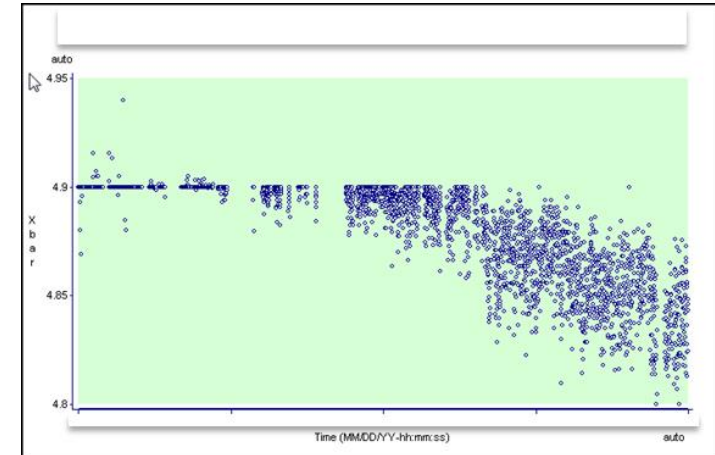
Create predictive analyses

Real-Time Process Monitoring   SPC Trend Monitoring   Predictive (Machine Learning and AI)

Requires a comprehensive tool Digital Twin

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Sensors Enhancing the Tool Digital Twin - Example

Quartz Crystal Microbalance Example

Monitor Process and Exhaust
- Monitor deposition and removal of materials
- Correlate with process information

Condition-Based Monitoring
- Sensing real-time process conditions
- Connecting data to FDC and factory systems
- Predicting failure and maintenance issues

Factory Digital Twin

Other Systems

QCM Chamber Location

Process Chamber

QCM Foreline Location

Dep 1   Dep 2

Foreline Pressure

Dns 1   Dns 2

QCM Response
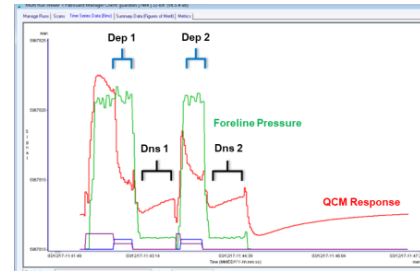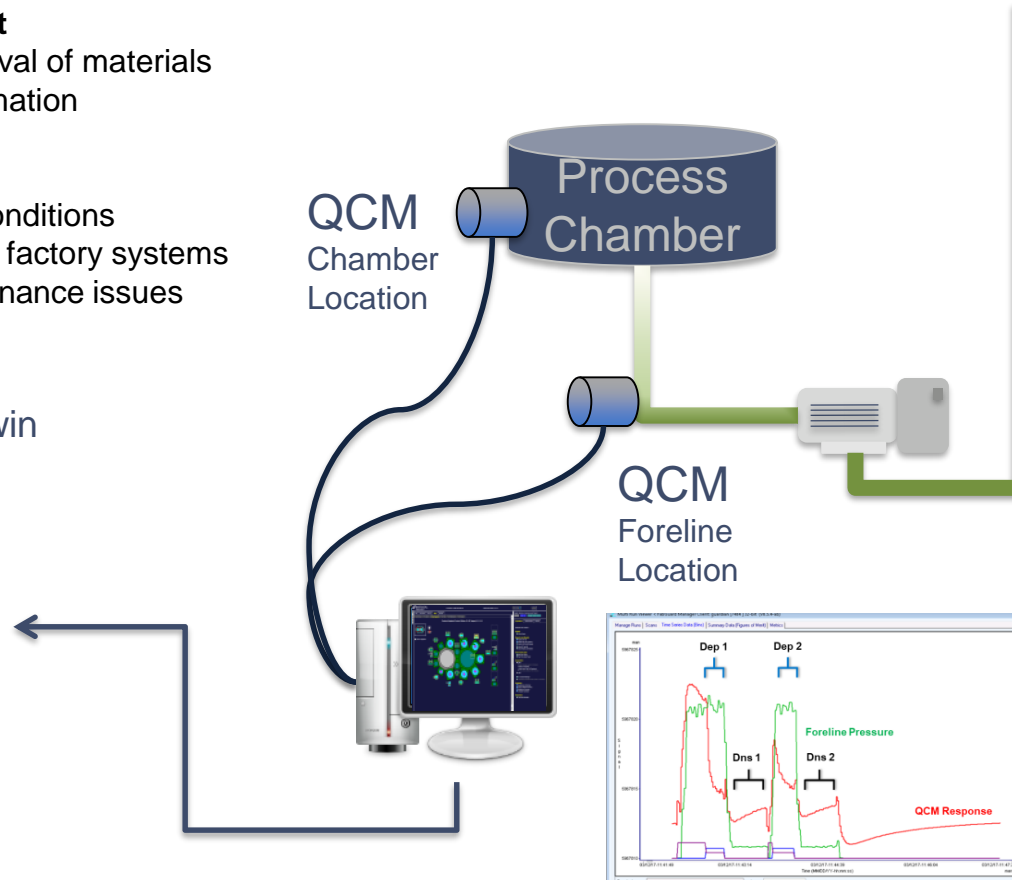
Inputs: Process Gases
           Wafer Heating
           RF Power

Target: Desired Changes to Wafer
           Desired Changes to Chamber
           • Conditioning
           • Cleaning

Leftover: Unconsumed Process Gases
           Reaction Byproducts
                • Gases that pump away
                • **Solid Material Accumulation (Chamber and Foreline deposition)**

Digital Twin Integration Benefits
Factory
     • Coating impact on part mix and WIP Schedule
     • Predictive maintenance input
Tool

     • Real-time process monitoring
     • Correlation to foreline pressure and impact

Integrating with the Factory Digital Twin

FDC systems provide full health and state information from tools and subfab/facilities components to the factory Digital Twin and WIP Scheduling system to provide optimal operational efficiency.

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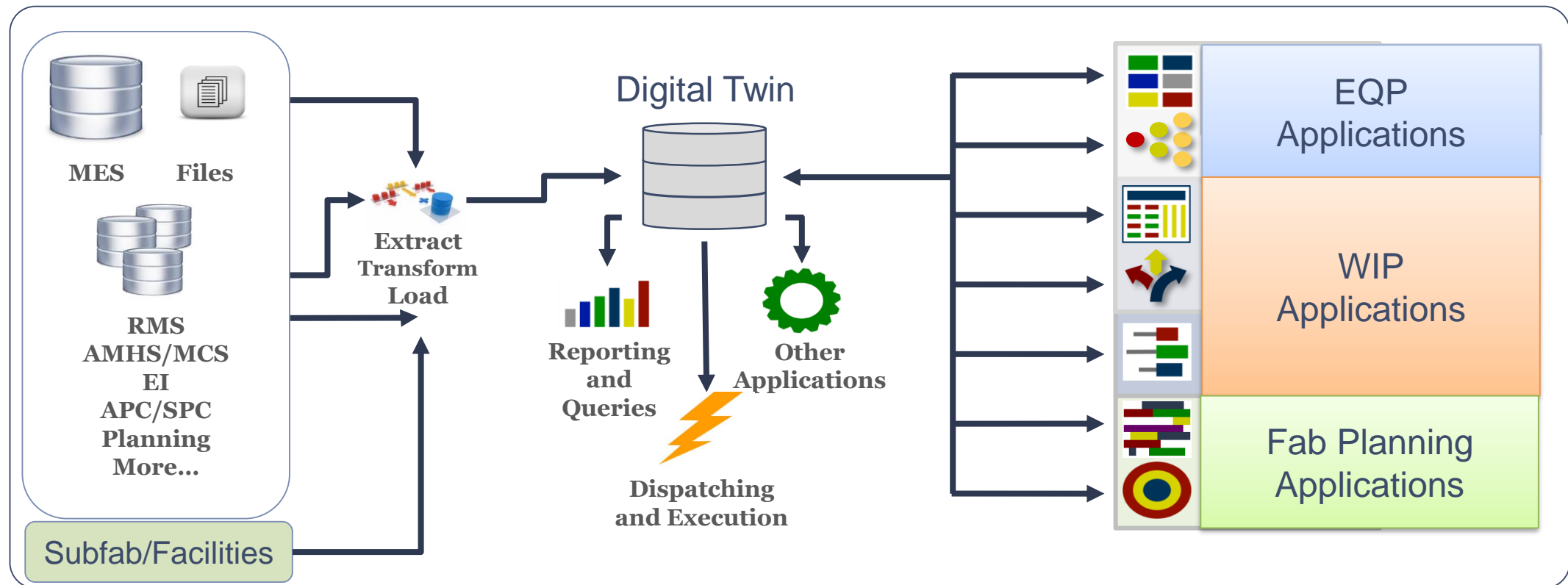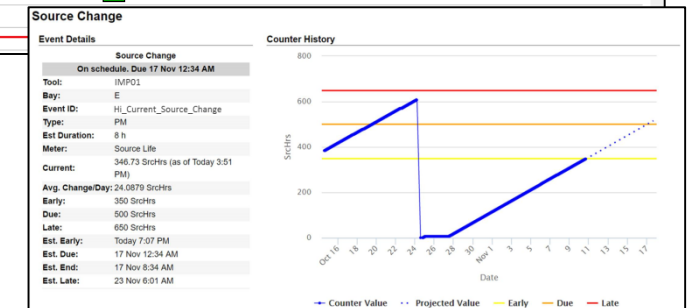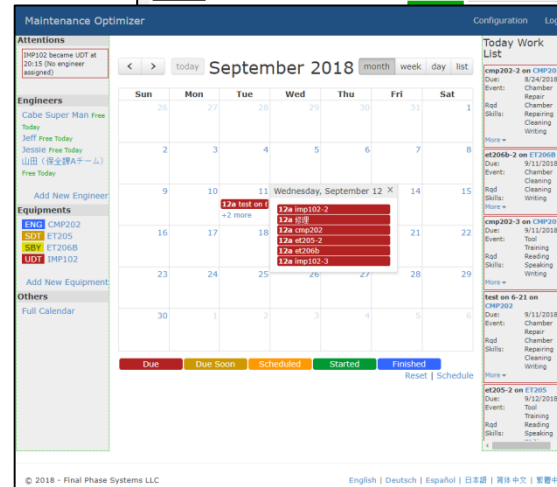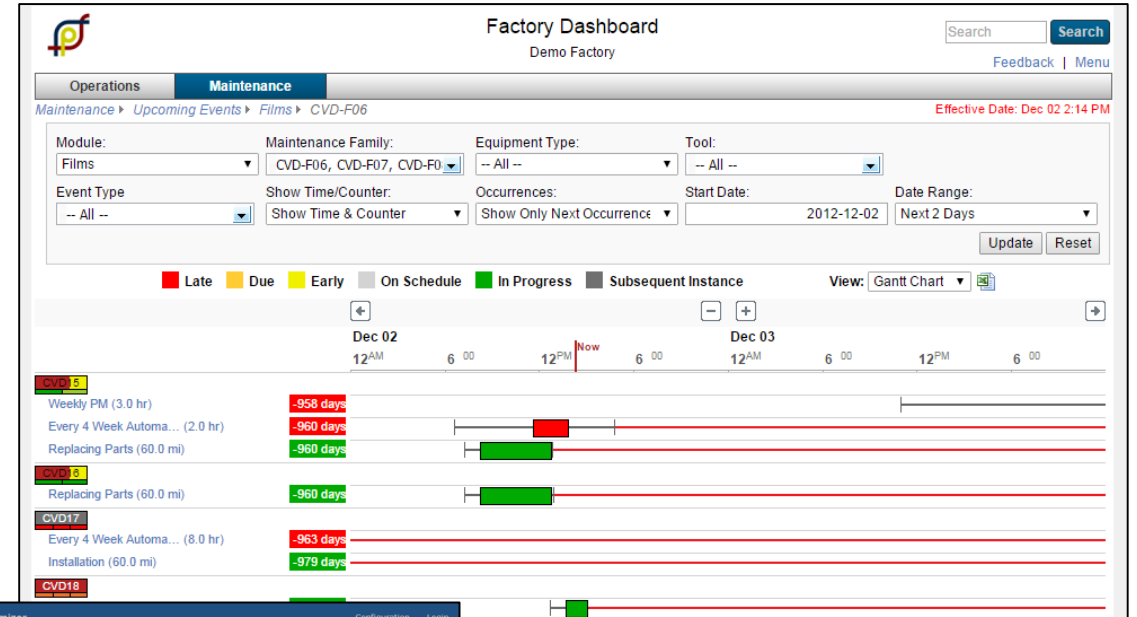
Digital Twin - Maintenance Tracking and Planning

Forecast maintenance intervals based on time, counters, or state

Show integrated data from the Digital Twin

- Maintenance schedules

- Summaries

- Tool state history
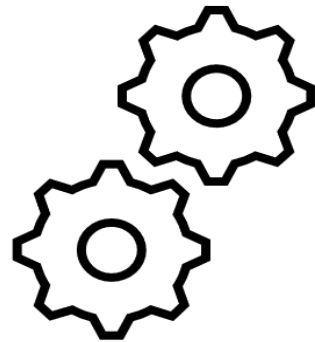
- FDC Tool health status reflecting subfab components

Coordinate maintenance activities with tool and subfab/facilities components

Communicate with WIP Schedulers to optimize maintenance schedules based upon WIP profiles
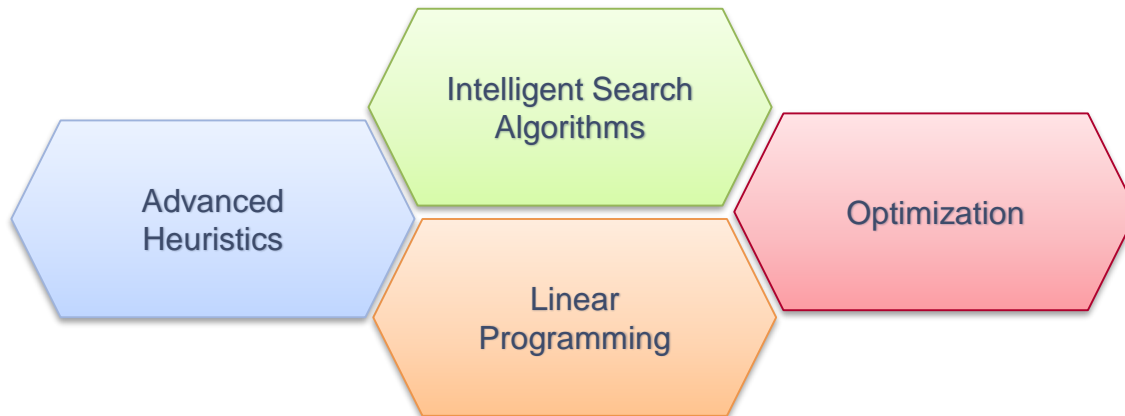

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INFICON Digital Twin Enabled Factory Scheduler

Our complete Scheduling solution uses various…

INFICON - Advanced Heuristics

Google OR-Tools

Microsoft® Solver Foundation

planimize - Academic Partner
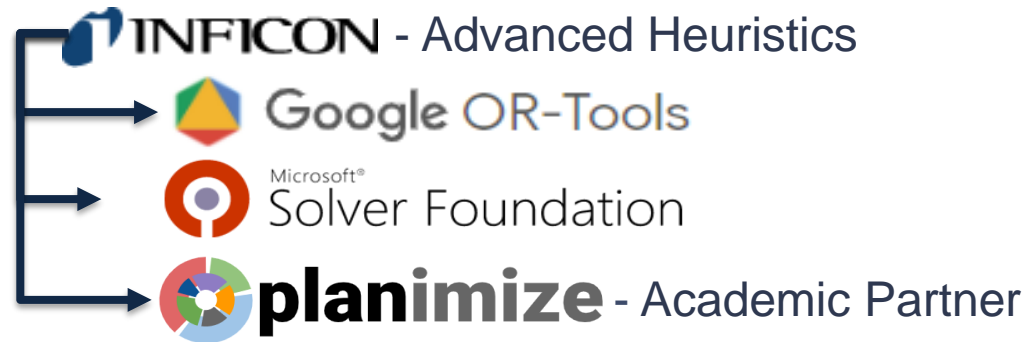
optimization techniques to create a ROBUST schedule.

Advanced Heuristics

Intelligent Search Algorithms

Linear Programming

Optimization

Subfab/Facilities Aware WIP Scheduler

Enable scheduled control of subfab components

- Non-Productive time can be used to idle equipment
- Proactively determine when there may be long idle times
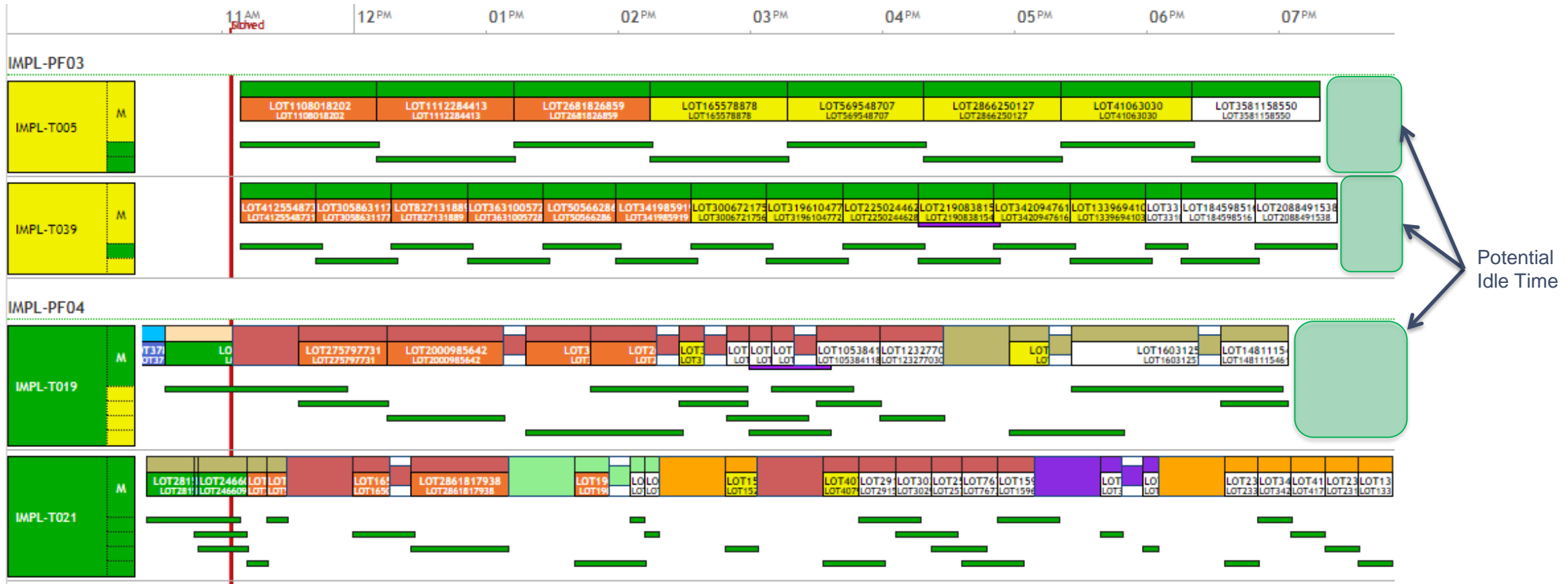- Scheduler can be configured to maximize green operation of equipment

Route critical WIP

- Re-direct high priority WIP to tools where the equipment <u>AND</u> subfab health is good
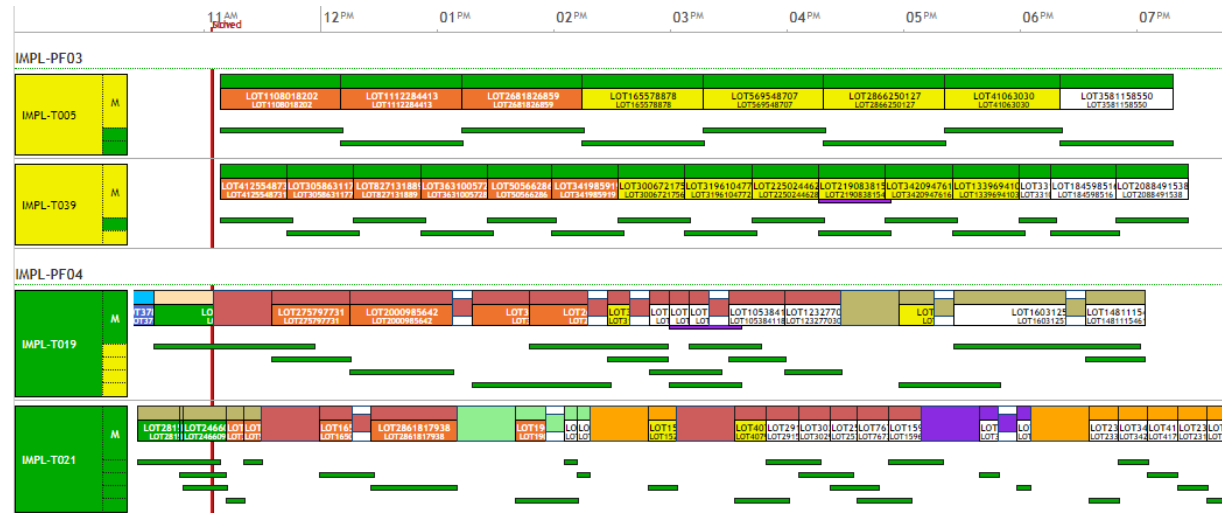
Advanced Scheduler to Optimize Facilities and Subfab

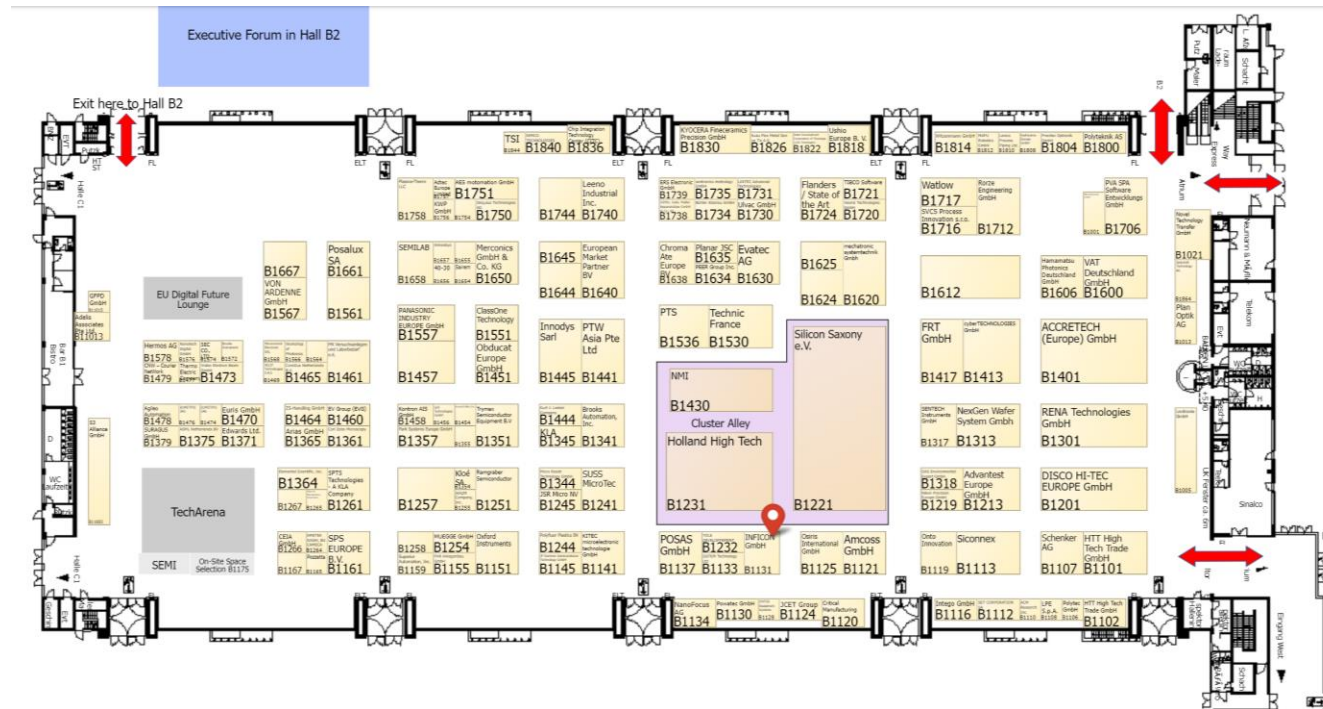Non-Scheduled time can trigger idling pump and abatement usage

For more information…

See us at our booth **B1.131** and speak with our staff or visit https://ims.inficon.com

Contact John at john.behnke@inficon.com

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Inspired by visions. Proven by success.

INFICON believes that a deep understanding of our customers' challenges and their visions for success are paramount to everything we do. These long-standing partnerships and the commitment to see our customers succeed inspire our dedicated, talented employees to develop and build market-leading instruments that are a winning combination of outstanding innovation and proven performance. And we value the trust our customers have in us to take risks, move fast and continue learning as we push the limits of technology to help them succeed.