FSM Research: Challenges, Opportunities & Current Thrusts in Wafer Manufacturing

12th EMEA Academic Forum

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Fab Dynamics

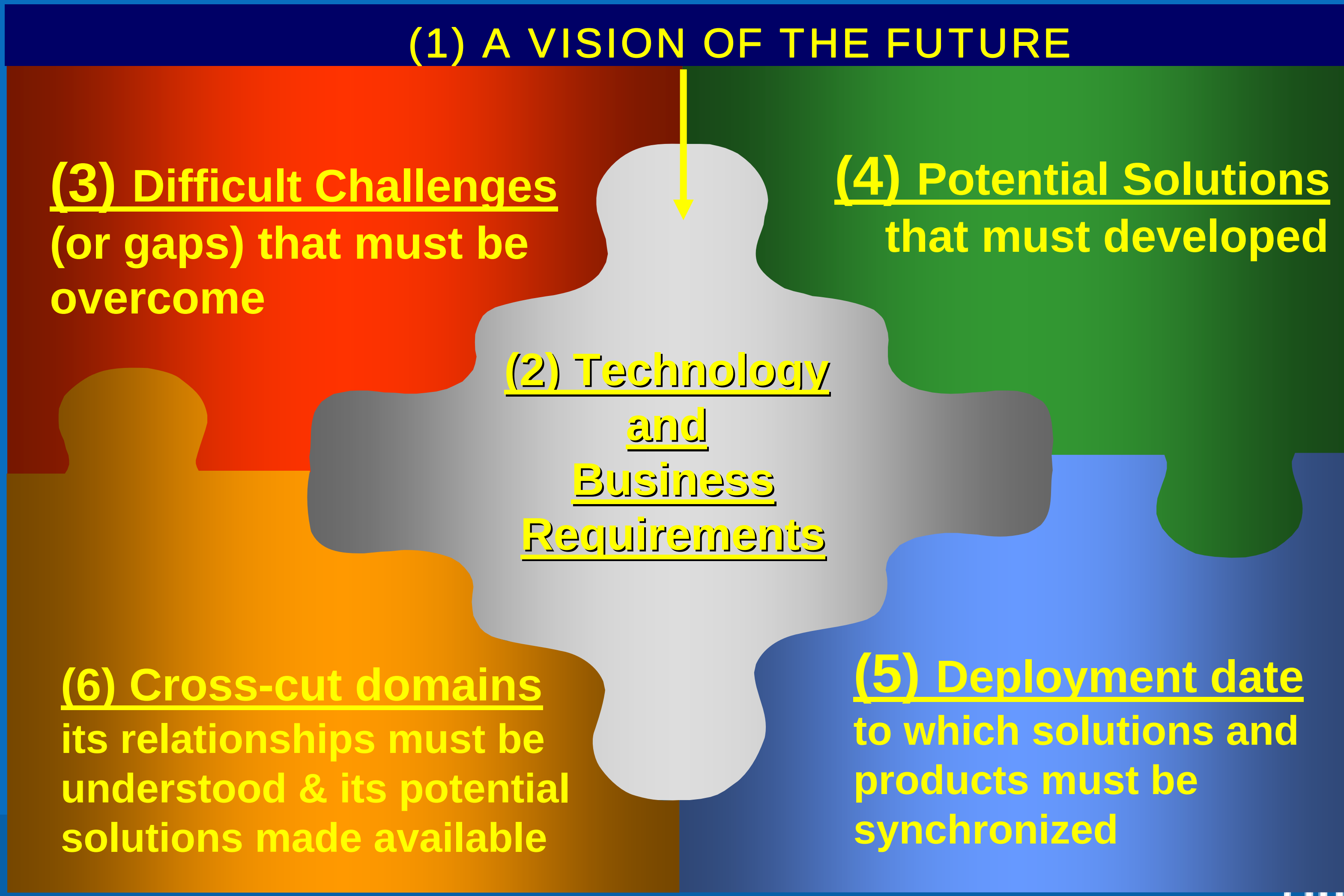
Factory is driven by Cost, Productivity, and Speed:

- ☞Reduce factory capital and operating costs per function
- ☞Faster delivery of new and volume products to the end customer
- ☞Efficient high volume production, high reliability, & high equipment reuse
- ☞Enable rapid process technology shrinks and wafer size changes

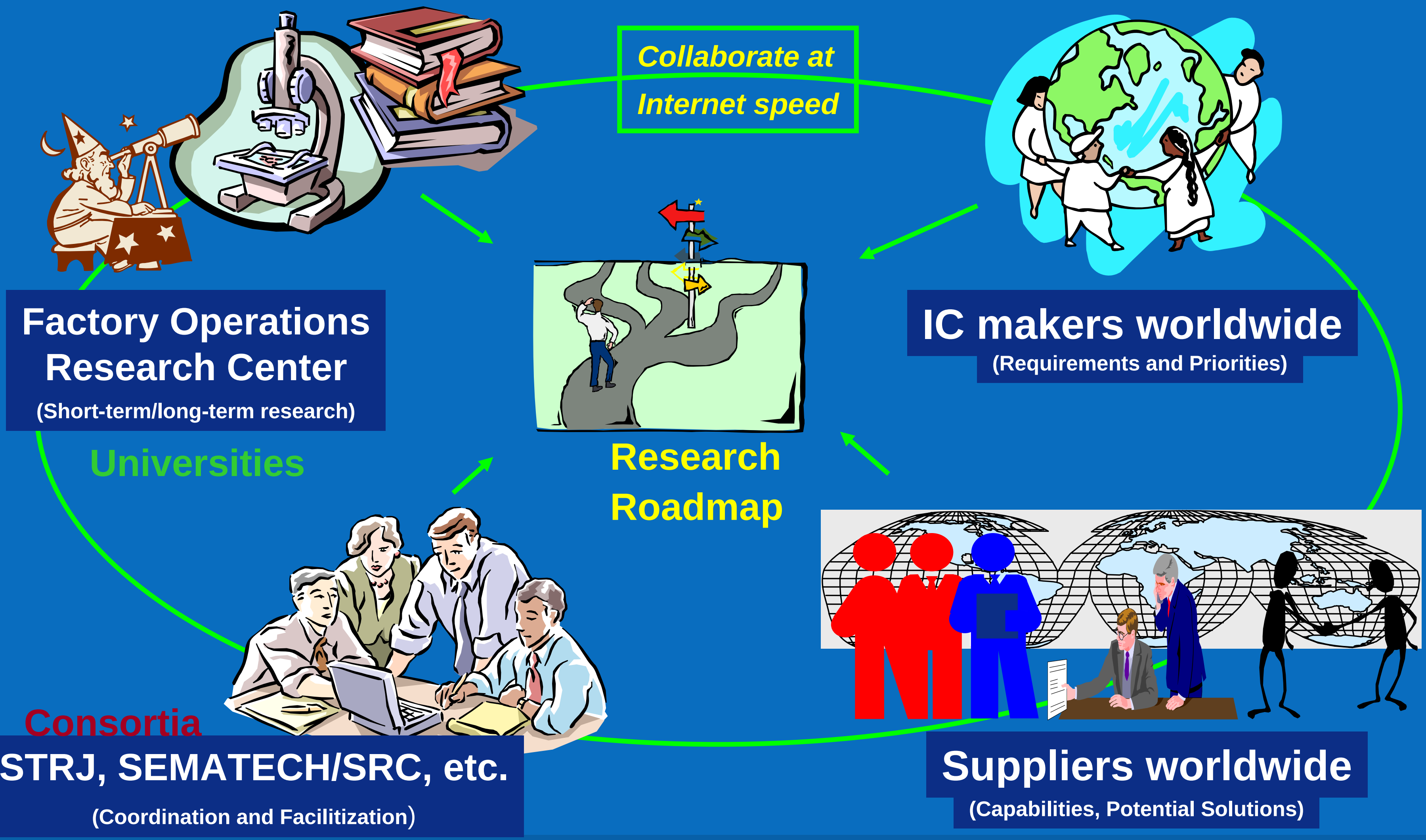
Why do research in High Vol Mfg?

- Moore's Law enabling significant technology development
- Manufacturing methods, techniques and innovation must keep pace with our technology roadmap
- Leveraging Universities for Manufacturing research allows us to explore fundamental and innovative concepts and theories

Developing Manufacturing Research Roadmap



Research collaboration models



A single engagement model does not fit all scenarios

Research Methods

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Seeking Improvement with a new Technology

1) Engage members of the Research community to identify

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•Technologies people using outside of Intel that we should be exploring?
• Current state of research on the technologies
•Informed estimates about the future of the technologies

2) Engage members of the Intel HVM organization to identify

• Targets of opportunity for application of the technologies
  - it may address a widely recognized problem
  - it may dramatically impact something not considered to be a problem

Applying a known technology to a problem

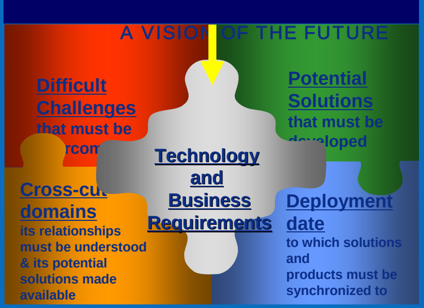
3) Engage members of the Intel HVM organization to identify

•The target problem, boundary conditions, assumptions, timing, etc

4) Engage members of the Research community to identify

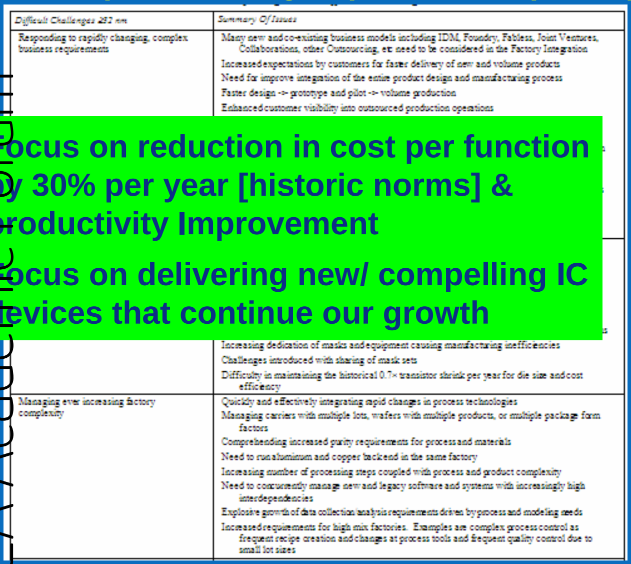
•The world-class experts on the problem you have specified
• The appropriate research arrangement with the experts

ITRS FI 15 year roadmap



International Technology Roadmap for Semiconductor (ITRS) Factory Integration (FI) evaluates industry's difficult challenges and technology requirements to formulate potential solutions to meet these needs

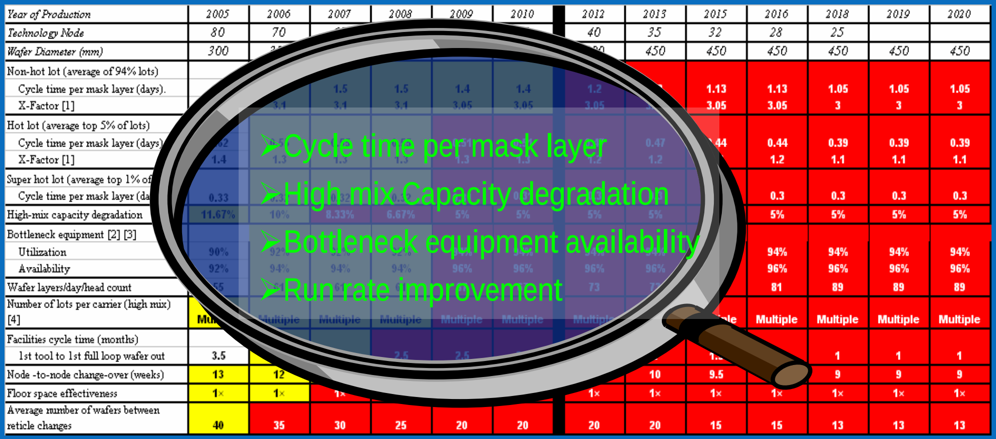
Develop FI challenges (world wide participation)



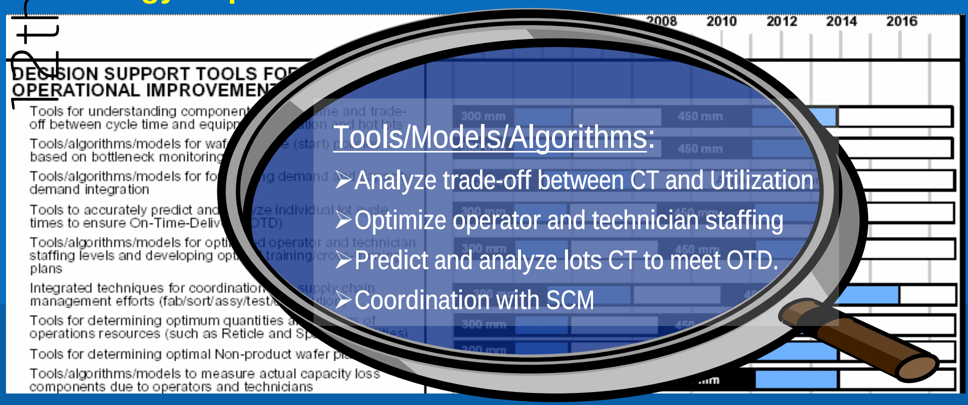
Focus on reduction in cost per function by 30% per year [historic norms] & productivity Improvement

Focus on delivering new/ compelling IC devices that continue our growth

Develop FI technology requirement tables based on challenges



Develop FI potential solution tables based on technology requirements



Provide direction for the semiconductor

Drive direction for industry research, pre-competitive standards and industry enabling capabilities

Learn from each other (ex. High Mix production, requirements)

Influence Supplier Roadmap (common industry requirements, drive potential solutions, set time table for solutions)

Influence other IC Maker Direction (reduce re-invention, pool resources, increase reuse for cost reduction (standards))

Understand our competitive position in the industry and where we need to drive changes

Show Industry Leadership & Recruit students

Source: International Technology Roadmap for Semiconductors

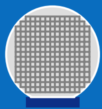
Some Projected Attributes of a 300mm ≤ 45nm Fab

Data standards and Systems for Rapid Mask Set Creation

Equipment & Systems designed for High Mix operation

Very Fast Cycle time Fabs for Hot & Normal lots

Wafer Data Standard For Packaging

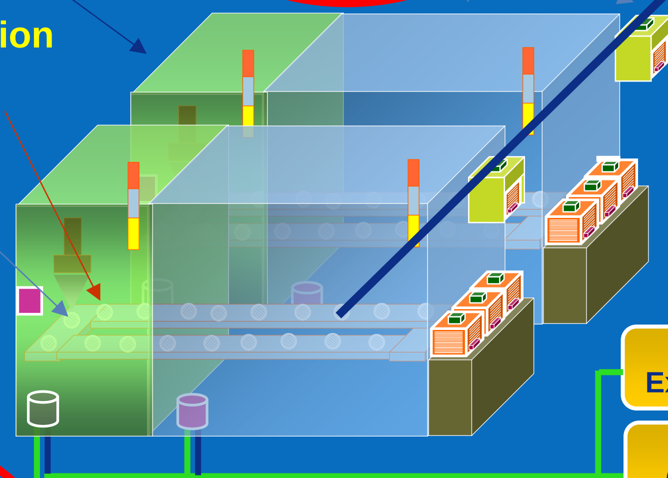


100% Direct Tool Delivery AMHS

Aggressive NPW Reduction & Efficient Spares Mgmt

Full Wafer Level Tracking & Recipe/Parameter Changes

Systems Scaled for > 50k wspm



Ubiquitous APC; Rapid Process Matching & New Product Qualification

Equipment Engineering Capabilities

Equipment & Process Data

APC | FDC | SPC | Recipes

Yield | PCS | E-Diag | EPT

Manufacturing Execution Systems

Equipment Control Systems

Factory Scheduler And Material Control

SECS Control Line

Partner, Customer Or Supplier

Pervasive E-Diagnostics

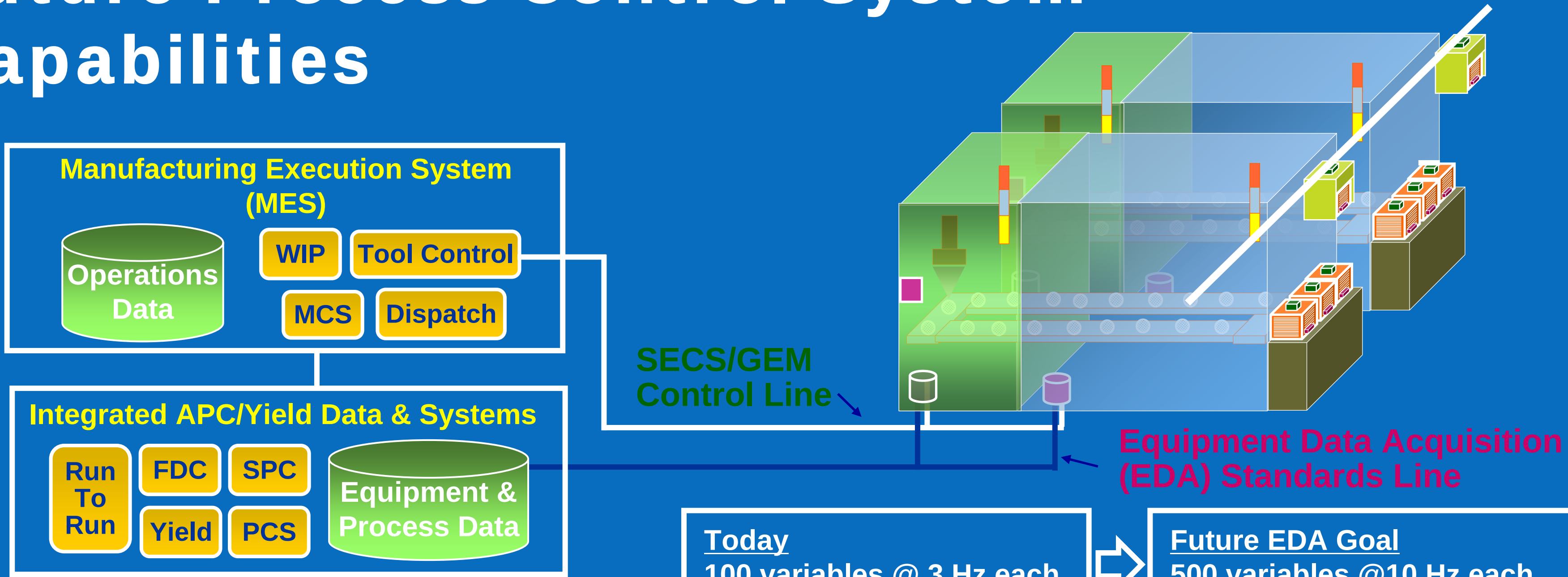
Equipment Data Acquisition (EDA) Standards to get Rich Equipment Data

Standard, Detailed Equipment Performance Tracking (EPT) Data

Offline tools to test schedule rules and rapidly put in Mfg

Source: International Technology Roadmap for Semiconductors

Future Process Control System Capabilities



Today
100 variables @ 3 Hz each
= 300 values per sec

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Future EDA Goal
500 variables @10 Hz each
= 10,000 values per sec

Automation Capabilities

1. Data Sharable between APC applications
2. High data transfer rates
3. Single point configurations
4. Integrated yield, process control, and operational systems
5. Rapid application development (run to run algorithms, etc.)

Equipment Capabilities

1. Standardized data and connectivity
2. Fast sensor sampling & data transfer rates
3. Host ability to stop processing as needed
4. Graceful recovery when a fault occurs
5. Ability to change parameters and values between wafers
6. Wafer tracking all points within the tool

Source: International Technology Roadmap for Semiconductors

Factory Integration Requirement Drivers

Cycle Time Reduction & Operational flexibility	**Cycle Time/Operational Flexibility:** Multiple lots per carrier and/or fewer wafers per carrier. Get new products to customer much faster.
More good wafers out per tool	**Output per tool must increase:** Find breakthrough solutions that result in significant increases in good wafer out and increased OEE (eg: APC, e-Diag)
Highly automated factory	**The 300mm factory is much more automated and must be designed to transport hot-lots and hand-carry's.**
Reduce Time to Money	**Reduce time to $$$/Cycle-time reduction:** What are stretch goals for cycle time from ground-breaking to first full loop wafer out. How to achieve quicker shrink?
Factory size is becoming an issue	**Increased floor space effectiveness:** Don't want each new generation to drive big increase in cleanroom size, esp. since fab is segregated Cu/non-Cu and new metal layers added at each node.

Source: ITRS

Source: International Technology Roadmap for Semiconductors

FI Technology Requirements

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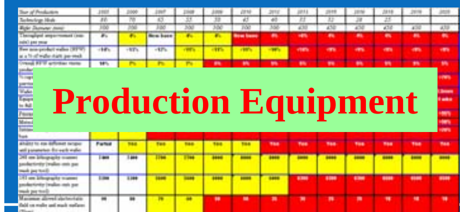
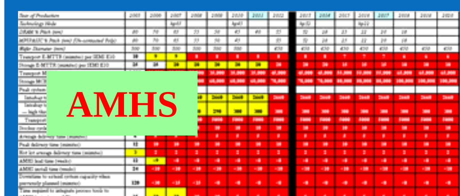
FI Sub section	Key objectives
	**Speed & Flexibility** 1) Reduce mfg cycle times, 2) Improve Equipment Utilization, 3) Reduce Losses from High Mix
	**Productivity & Cost** 1) NPW reduction, 2) Reliability Improvement, 3) Run rate (throughput) improvement
	**Efficiency and Speed** 1) Increase throughput for Traditional and Unified Transport, 2) Reduce Average Delivery times, 3) Improve Reliability
	**Reliability and Efficiency** 1) Increase Reliability, 2) Increase Factory Throughput, 3) Reduce Mask Shop Cycle Time, 4) Reduce Costs
	**Extendibility and Cost** 1) Factory Extendibility, 2) AMC, 3) Rapid Install/Qualification, 4) Reduce Costs

Solution exists | Solution being developed | Solution required

Source: ITRS

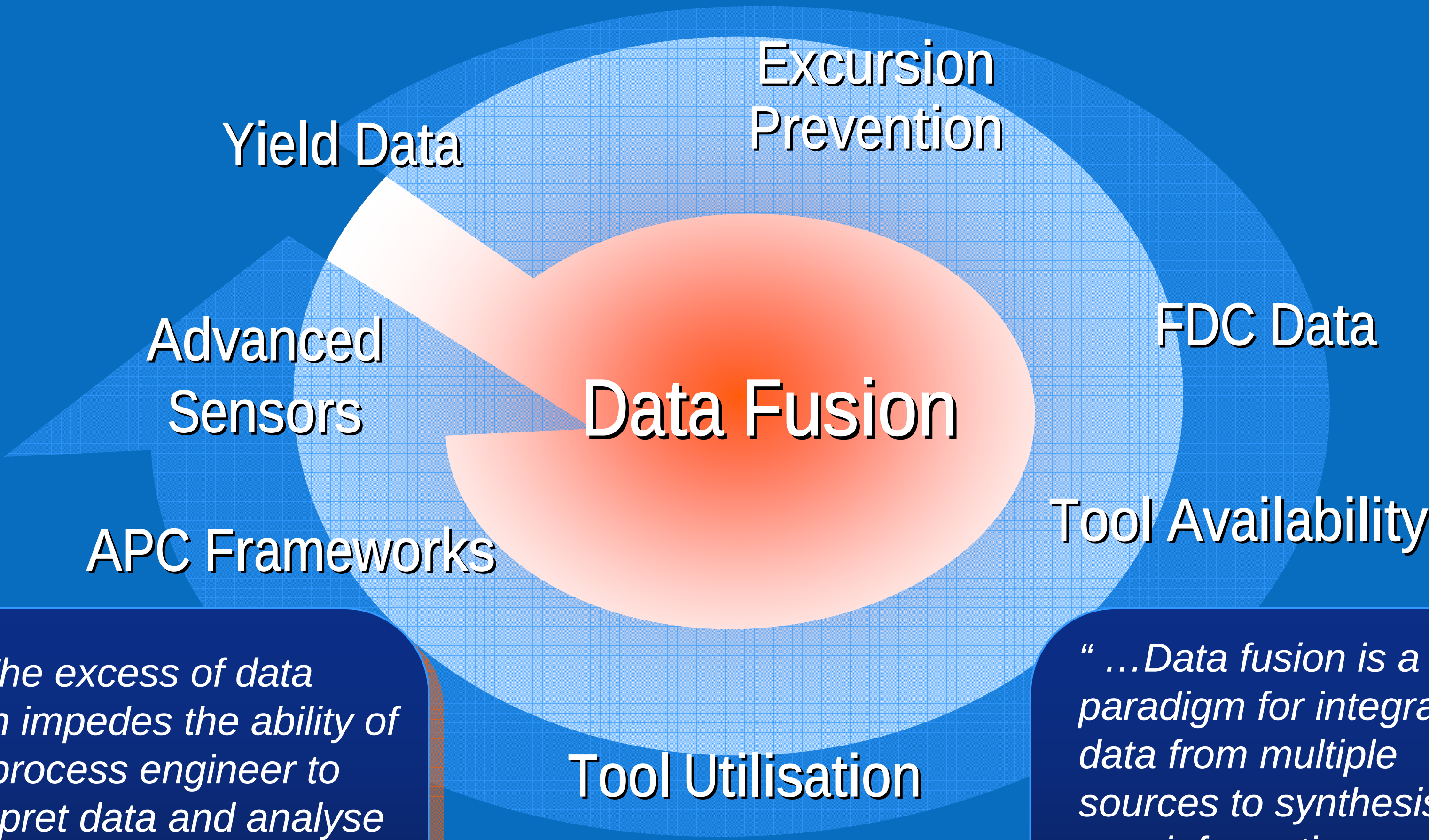
Data Convergence Vision

The correct data needed by the user to make an informed decision are available at any

time both in-situ and remotely

"Data is pre-processed at each level based on job role requirements using in-line intelligence to ensure an optimised decision making process"

Building the Data Ecosystem

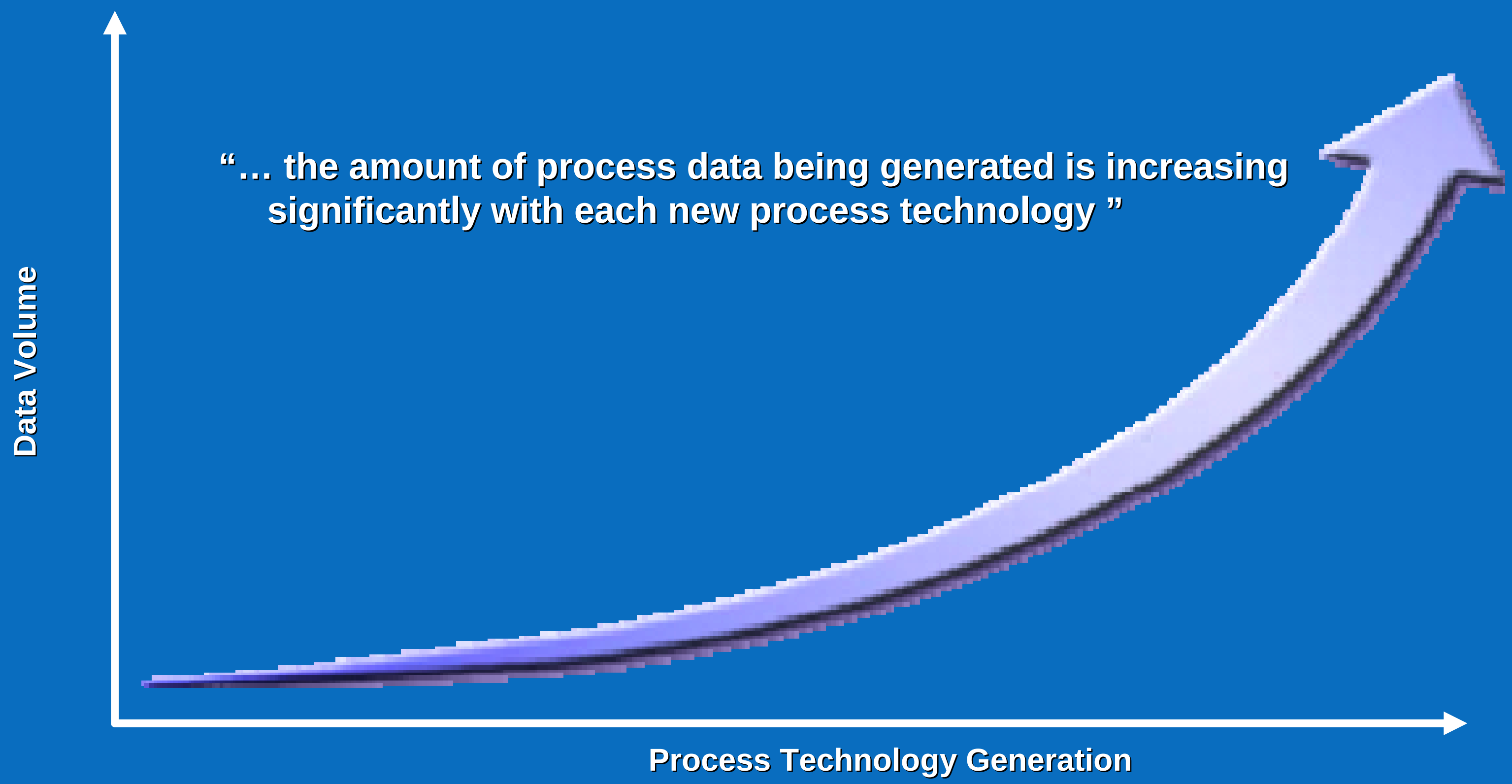


"…The excess of data often impedes the ability of the process engineer to interpret data and analyse the data. This problem requires the development of new data mining applications…"

" …Data fusion is a paradigm for integrating data from multiple sources to synthesise new information such that the whole is greater than the sum of its parts…" [1]

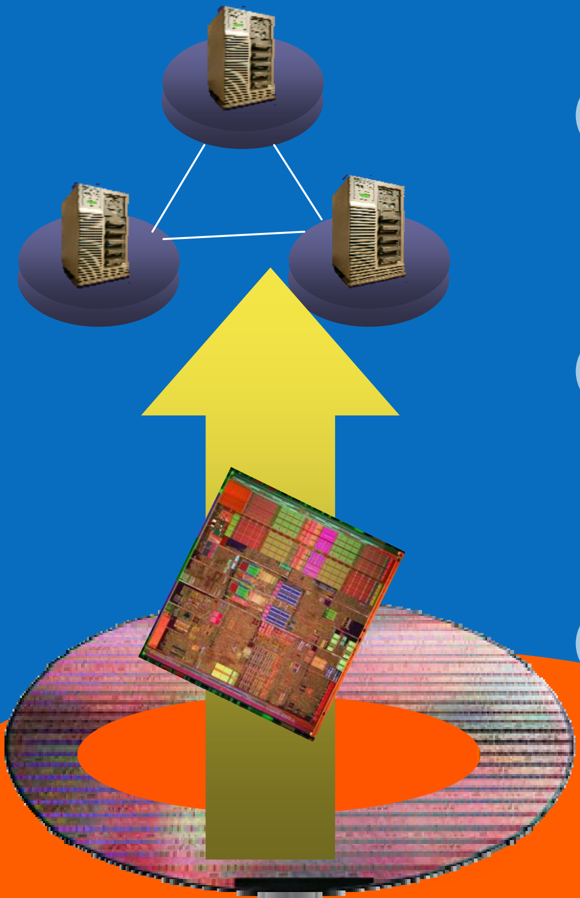
[1] *'Lyengar et al 'Foundations of Data Fusion for Automation' IEEE Instrumentation & Measurement Magazine Dec. 2003*

The Data Explosion



Faced with an explosion in the amount of data being generated the standard approach will no longer work.

Development Focus



Applications & Human interfaces

Business processes And methodologies

Data & Information Systems

Information & Technology services

Highly integrated data environments of both structure and unstructured data sets based on standard data formats and data exchange protocols. Increased speed and quality of decision making. Proactive decision making rather than reactive.

Areas of Focus

Production Equipment

– Process and Metrology equipment
– Mainframe and process chambers
– Wafer Handling Robots, Load Ports
– Internal software & computers

Factory Operations

– Policies & procedures used to plan, monitor and control production
– Direct factory labor

Factory Information & Control

– Data and Control systems required to run the factory
– Equipment and Process Control Systems
– WIP Tracking and Decision support Systems
– Plan, Schedule, Dispatch Systems
– Computers, databases, software outside equipment

List of Potential Research Areas

3D (Multiple-floor) L/O

Real-time event-driven scheduling

Lot streaming (single wafer processing)

Queuing theory application for CT estimation (CT modeling)

CT reduction:

a) **Variability impact and elimination**
b) **WIP bubble forecasting and recovery**
c) **Design For Manufacturability (DFM) and TPT-Yield trade-offs**

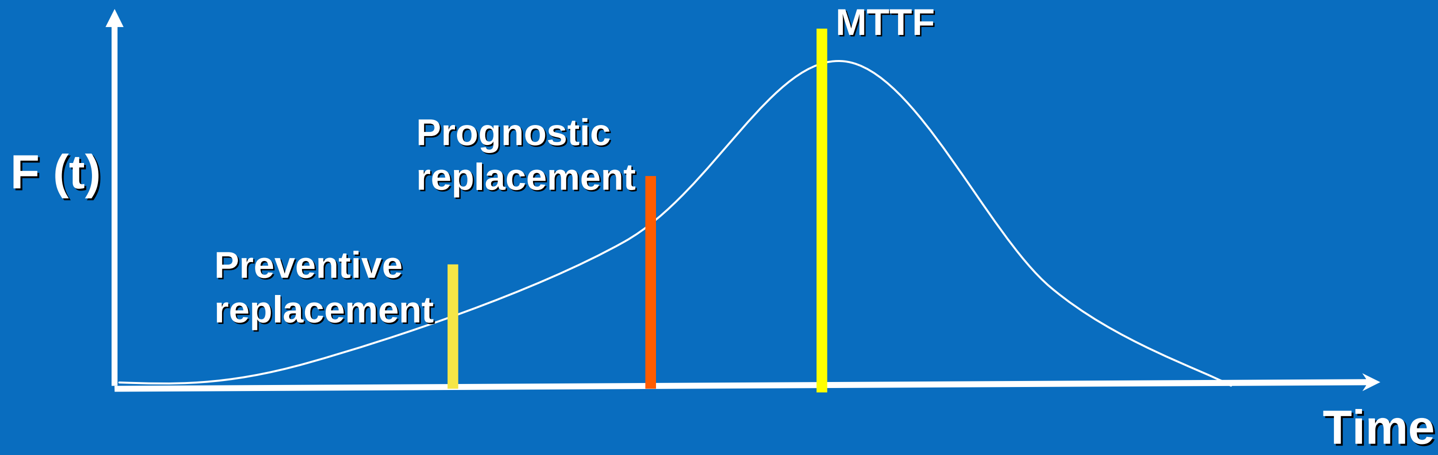
Demand/Data Flow Technology (DFT) implementation

Capacity Planning/Modeling: the impact of multiple constraints

Automated tool-L/O **planning**

Iceberg model – Predictive Maintenance

Predictive maintenance - opportunity



Eliminate equipment variability by moving unscheduled events to scheduled.

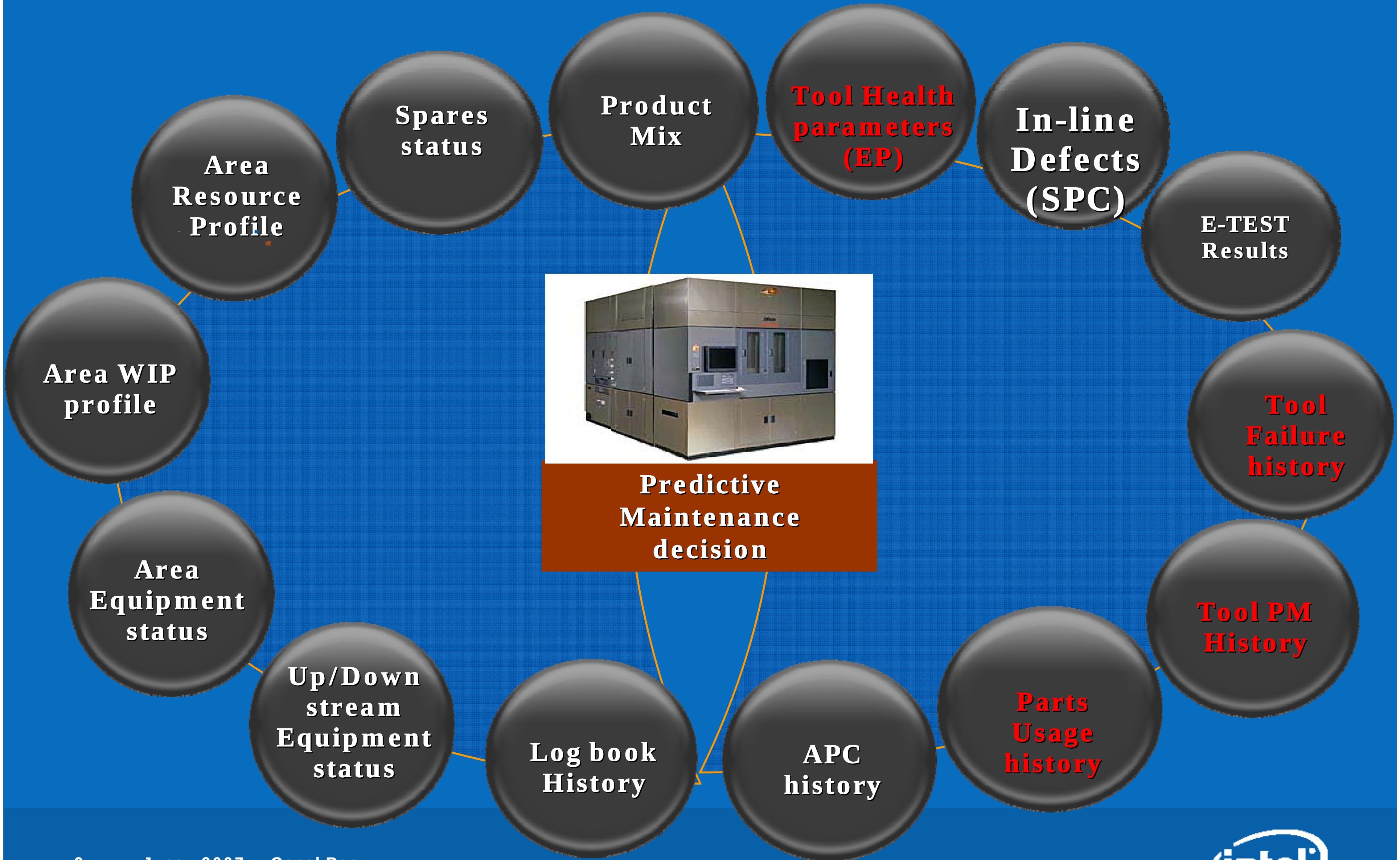
Increased availability by extending time between PM cycles.

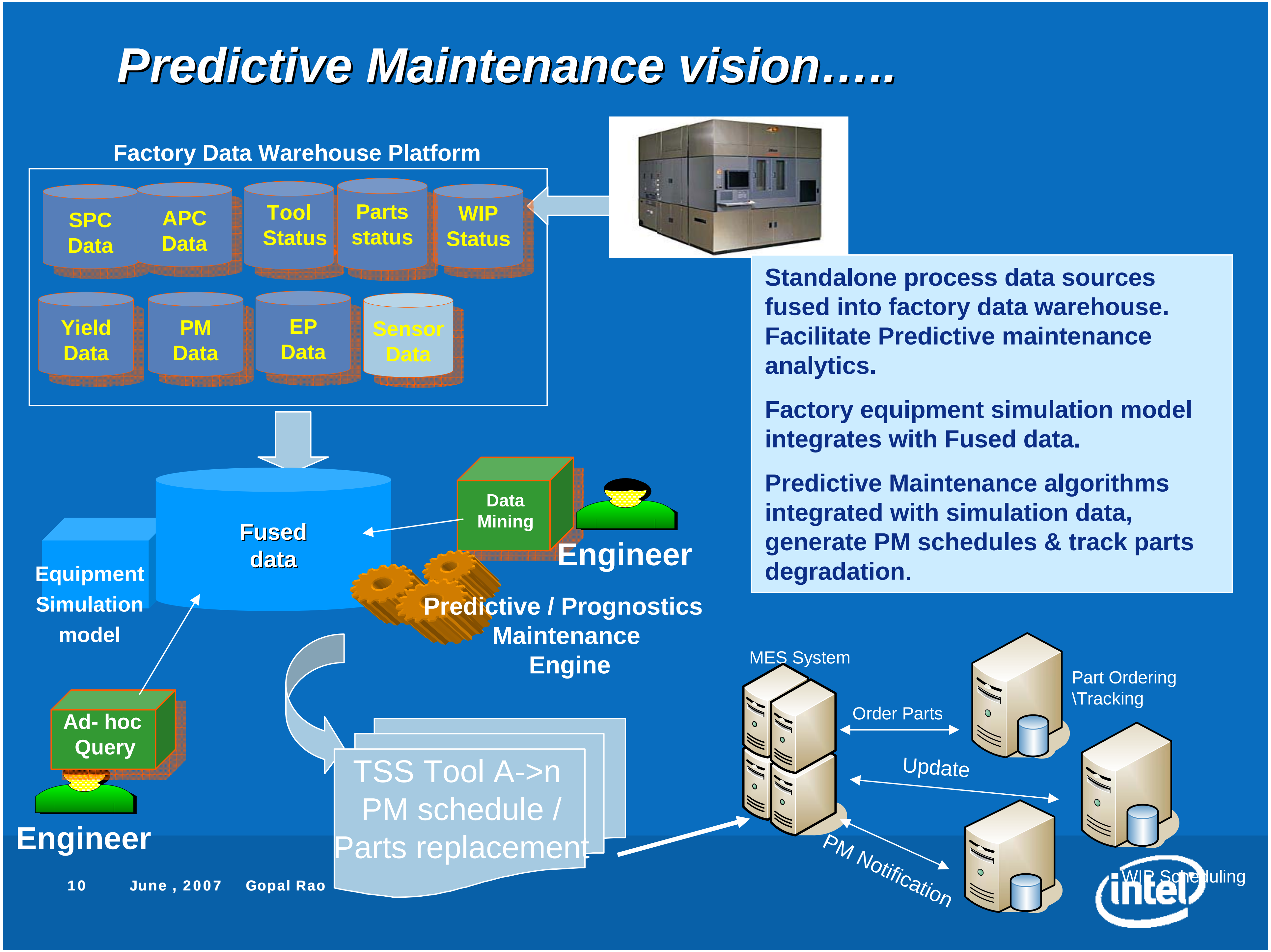
Perform maintenance JIT, better resource balancing.

Reduced parts replacement = $$.

Caution: Need to ensure no Yield impact or CT.

Predictive Maintenance decision parameters




Predictive Maintenance vision…..
Factory Data Warehouse Platform
SPC Data
APC Data
Tool Status
Parts status
WIP Status
Yield Data
PM Data
EP Data
Sensor Data
Standalone process data sources fused into factory data warehouse. Facilitate Predictive maintenance analytics.
Factory equipment simulation model integrates with Fused data.
Predictive Maintenance algorithms integrated with simulation data, generate PM schedules & track parts degradation.
Fused data
Data Mining
Engineer
Equipment Simulation model
Predictive / Prognostics Maintenance Engine
Ad- hoc Query
Engineer
TSS Tool A->n PM schedule / Parts replacement
MES System
Order Parts
Part Ordering \Tracking
Update
PM Notification
WIP Scheduling
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Summary

We have four unique production advantages:

- Technology Pipeline
- Scale
- Agility
- Operational Excellence

We're extending Moore's Law with industry-leading technology

We are enhancing our Manufacturing capabilities through innovation and integration of our core production advantages