

Factory Integration Technology Working Group (FITWG) ITRS Presentation

International Technology Roadmap for Semiconductors
Tokyo, Japan; November 1999



Objectives of Presentation

- Final Report of ITRS`99 FITWG activities
- Get feedback and suggestions

Agenda

- Factory Assumptions
- Factory Needs
- Difficult Challenges and Thrusts
- Technology Requirements Tables
- Potential Solutions
- Cross Cut Issues
- Summary

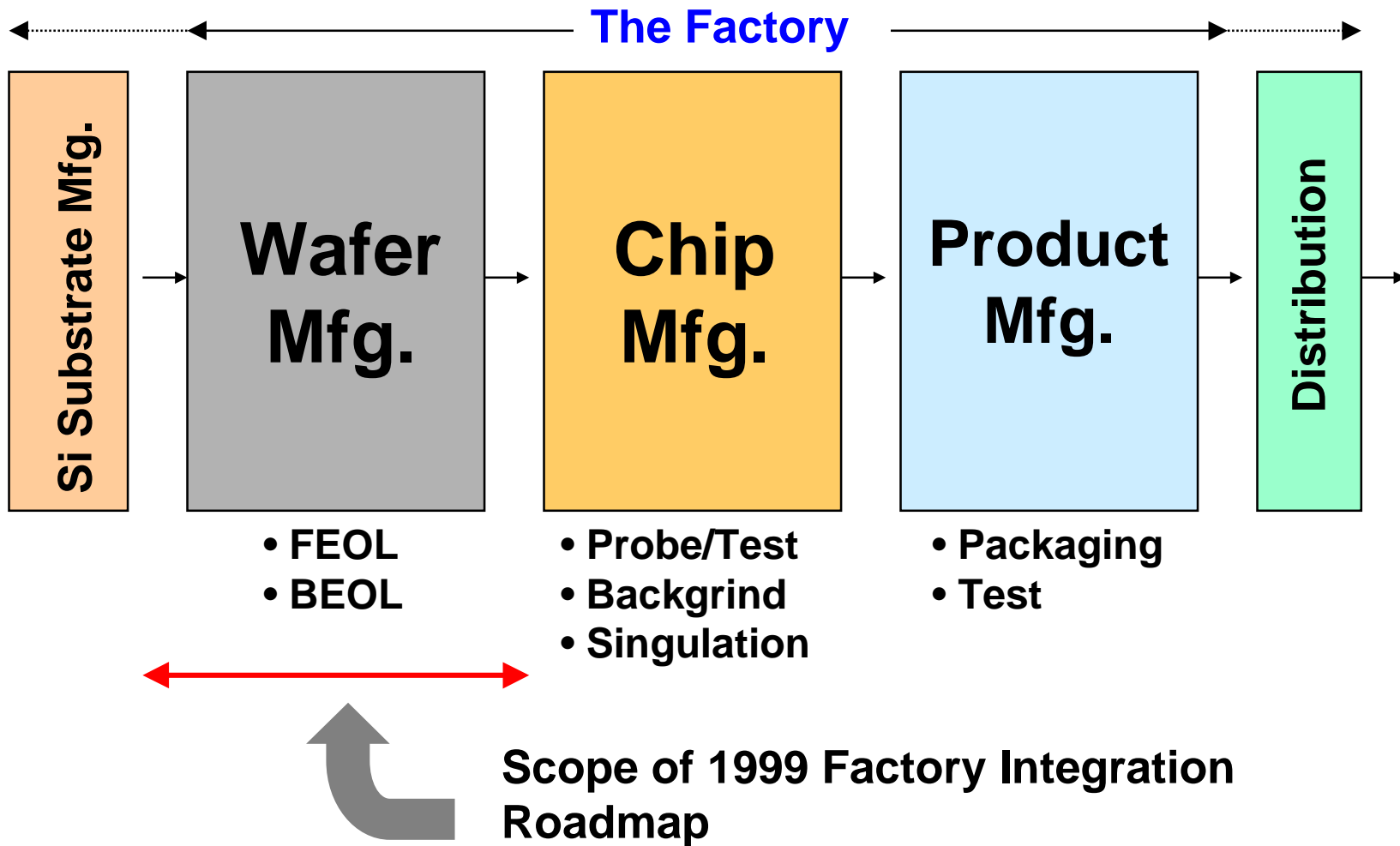
Factory Assumptions

- Any slowdown in Moore's law (cost/function/year), caused by approaching technology barriers, *cannot be compensated* by improved manufacturing efficiencies, but, Manufacturing must *increase* its contribution to cost reduction
- The Roadmap is driven by high-volume/high-mix and by high-volume/low-mix factories
- Batch processing in Furnace & Wet production equipment will continue
- Multiple lots per carrier are required
- Increased automation will significantly alter the way we plan, design, build, layout, operate, staff and manage the factory

Factory Needs

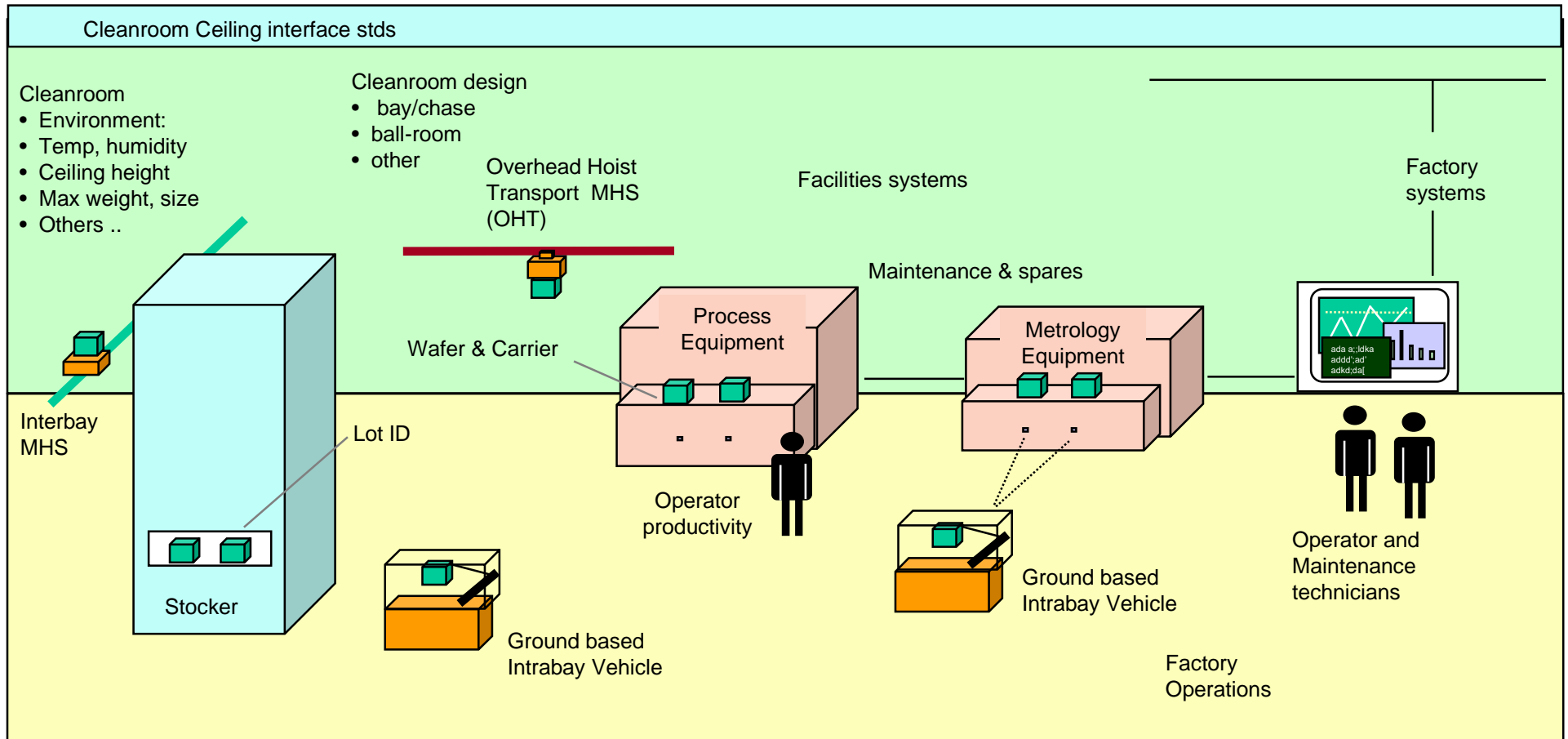
- ◆ The factory is driven by the following cost & productivity needs irrespective of technology nodes:
 - ① Reduce factory capital and operating costs per function
 - ② Improve factory optimization capability for different business models (high-volume/high-product mix and high-volume/low-product mix)
 - ③ Increase factory life via extendibility, flexibility, and scalability
 - ④ Increase equipment reliability and availability
 - ⑤ Reduce ramp time for both new and retrofit factories
- ◆ These needs influence difficult challenges and potential solutions for Factory Integration

Factory Scope



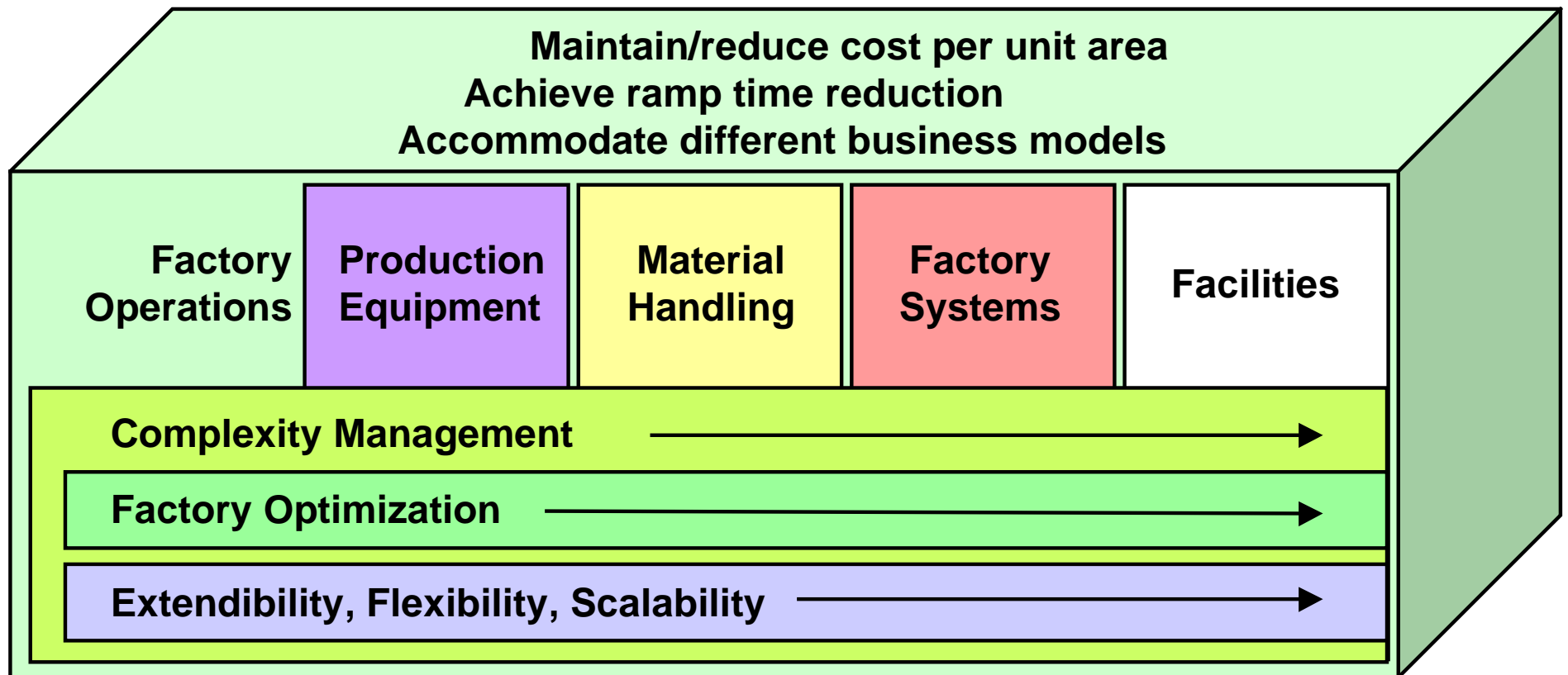
Factory Integration Scope

Supply Chain



Factory Operations **Production Equipment** **Facilities**
Material Handling **Factory Systems**

Factory Integration Challenges & Technology Thrusts



Factory Integration Challenges & Technology Thrusts

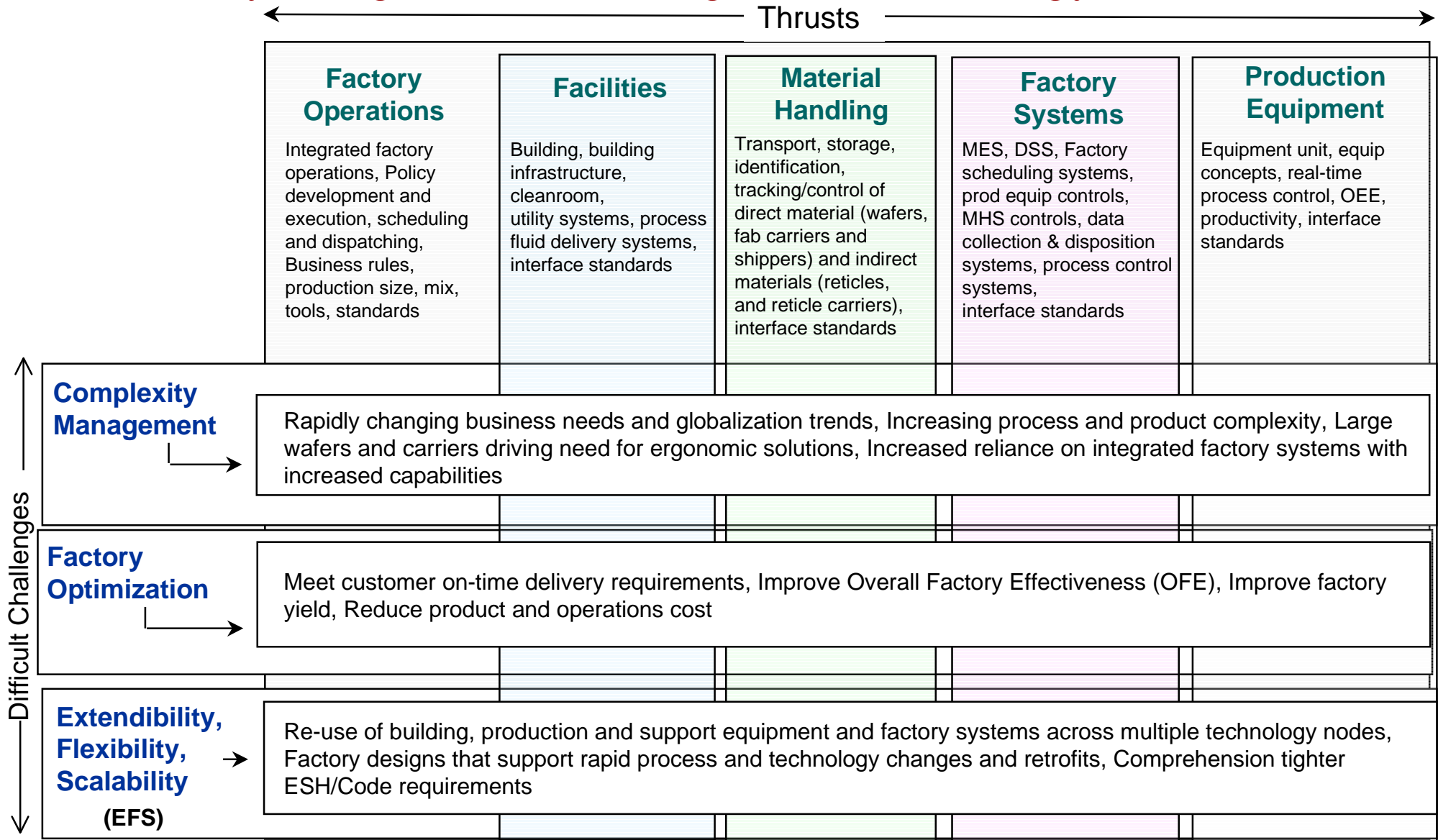


Table 51 Factory Integration Difficult Challenges

<i>DIFFICULT CHALLENGES</i>	<i>SUMMARY OF ISSUES</i>
Complexity Management	<p>Rapidly changing business needs and globalization trends</p> <ul style="list-style-type: none"> • Increasing rate of new product and technology introductions • Globally disparate factories run as single “virtual factory” • Need to meet regulations in different geographical areas <p>Increasing process and product complexity</p> <ul style="list-style-type: none"> • Explosive growth of data collection/analysis requirements • Increasing number of processing steps • Multiple lots in a carrier <p>Larger wafers and carriers driving ergonomic solutions</p> <ul style="list-style-type: none"> • Increasing expectations for material handling automation systems <p>Increased reliance on factory systems</p> <ul style="list-style-type: none"> • Multiple system interdependencies • Co-existence of new factory systems with existing (legacy) systems
Factory Optimization	<p>Meet customer ontime delivery</p> <ul style="list-style-type: none"> • Balanced throughput and cycle time • Reduce time to ramp factories, products, and processes <p>Improve Overall Factory Effectiveness (OFE)</p> <ul style="list-style-type: none"> • Improve all Factory Integration thrust areas <p>Improve factory yield</p> <ul style="list-style-type: none"> • Control production equipment and factory processes to reduce parametric variation <p>Reduce product and operation cost</p> <ul style="list-style-type: none"> • Minimize waste and scrap and reduce the number of nonproduct wafers <p>Satisfy all local, state and federal regulations.</p>
Extendibility, Flexibility, and Scalability	<p>Reuse of building, production and support equipment, and factory systems</p> <ul style="list-style-type: none"> • Across multiple technology nodes • Across a wafer size conversion <p>Factory designs that support rapid process and technology changes and retrofits</p> <ul style="list-style-type: none"> • Understand up-front costs to incorporate EFS • Determine which EFS features to include and not to include • Minimize downtime to on-going operations <p>Comprehension tighter ESH/Code requirements</p> <p>Comprehension increase purity requirements for process and materials</p>

Table 51 ファクトリーインテグレーションの挑戦課題

挑戦課題	課題内容
複雑なマネージメント	ビジネスニーズとグローバルなトレンドの急速な変化 <ul style="list-style-type: none"> • 新製品及び新技術導入比率の増大 • バーチャルファクトリー • 異なる地域における規制の整合の必要性 プロセスと製品の複雑さの増大 <ul style="list-style-type: none"> • データ集積／解析要求の急増 • プロセスステップの増加 • 混載ロットへの対応 大口径ウェハ及びキャリア運用への人間工学的な解決策 <ul style="list-style-type: none"> • 自動搬送システムへの期待の増大 工場システムへの依存度の増大 <ul style="list-style-type: none"> • 多様なシステムの相互依存性 • 既存システムと新規工場システムの共存
工場の最適化	顧客への納期確保 <ul style="list-style-type: none"> • 工期とスループットのバランス • 工場、製品、プロセスの立上げ時間短縮 工場全体の有用性（OFE）の改善 <ul style="list-style-type: none"> • 全ての工場に組み込まれる技術項目の改善 工場歩留りの改善 <ul style="list-style-type: none"> • 変動要素削減の為の製造装置と工場システムの制御 製造及び運用コストの削減 <ul style="list-style-type: none"> • 廃棄物とスクラップの最小化及び非生産ウェハ（N P W）数量の削減 全ての地域的基準への準拠
拡張性、汎用性、スケーラビリティ	建家、製造／付帯装置及び工場システムの再利用 <ul style="list-style-type: none"> • 多世代の技術ノードにまたがる再利用 • ウェハ径の変化にまたがる再利用 急速なプロセス及び技術変化に対応した工場デザイン <ul style="list-style-type: none"> • 汎用性、拡張性に結びつく先行投資への考え方 • 汎用性、拡張性に対する可否判断 • 生産ラインの中断時間の最小限化 より厳しくなるE S Hへの要求 プロセス及び材料に対する精度要求の増大

Contents of Factory Integration Section

Technology Requirements

Factory Operations
Production Equipment
Material Handling Systems
Factory Systems
Facilities



Potential Solutions

Factory Operations
Production Equipment
Material Handling Systems
Factory Systems
Facilities

Backup Section

Action Items for

- Researchers
- National Labs
- IC Makers
- Suppliers
- Other participants

The Technology Requirements & Potential Solutions metrics

- It shows general trend and framework agreed by FITWG members.
- It still requires further research and consideration. (Especially, Facility Requirements will be discussed in next phase.)

Factory Operations

Table 52 The Technology Requirements metrics tables

<i>Year</i>	1999	2002	2005	2008	2011	2014
<i>Technology Node</i>	180 nm	130 nm	100 nm	70 nm	50 nm	35 nm
<i>Wafer Diameter</i>	200 mm	300 mm	300 mm	300 mm	300 mm	450 mm
<i>High Volume/Low Mix Factory requirements</i>						
Factory cycle time per mask layer (non-hot lot) [1]	1.75 days	1.5 days	1.4 days	1.3 days	1.2 days	1.1 days
Factory cycle time per mask layer (hot lot)	1.2 days	1.0 day	1.0 day	1.0 day	1.0 day	1.0 day
Number of lots per carrier	One lot	One lot	One lot	One lot	One lot	One lot
<i>High Volume/High Mix Factory requirements</i>						
Factory cycle time per mask layer (non-hot lot) [2,3]	1.8 days	1.6 days	1.4 days	1.3 days	1.2 days	1.1 days
Factory cycle time per mask layer (hot lot) [2,3]	0.9 days	0.85 days	0.8 days	0.75 days	0.7 days	0.65 days
Number of lots per carrier	Single lot [4]	Multiple lots	Multiple lots	Multiple lots	Multiple lots	Multiple lots
<i>Common Requirements across both factory types</i>						
Groundbreaking to first full loop wafer out	< 18 months	< 16 months	< 14 months	< 12 months	< 11 months	< 10 months
Total number of operators and technicians in the factory	N	0.9×N	0.8×N	0.7×N	0.6×N	0.5×N
Product/ process change-over time	12 weeks	10 weeks	8 weeks	6 weeks	5 weeks	4 weeks

Solutions Exist

Solutions Being Pursued

No Known Solutions



Factory Operations

Figure 38 The Potential Solutions

First Year of IC Production	1999	2002	2005	2008	2011	2014
DECISION SUPPORT TOOLS FOR CYCLE TIME REDUCTION AND ASSET UTILIZATION IMPROVEMENT						
Tools for understanding trade-off between cycle time and equipment utilization and hot lots	300mm			450mm		
Tools/algorithms for wafer release (start) policies based on bottleneck monitoring	300mm			450mm		
Tools/algorithms for forecasting demand						
Tools to accurately predict individual lot cycle times to ensure On-Time-Delivery	300mm			450mm		
Tools/models for optimized operator and technician staffing levels and developing optimal training/cross-training plans	300mm			450mm		
Integrated optimization techniques for supply chain management & control (fab/sort/assy/test/distribution)	300mm			450mm		
Tools for determining optimum quantities of auxiliary resources. E.g., Reticle and Spares quantities	300mm			450mm		
Tools for determining optimal test wafer plans	300mm			450mm		
EXECUTION TOOLS FOR OPERATIONAL COST REDUCTION						
Real-time scheduling and dispatching algorithms integrated with MHS-must consider auxiliary resources, labor, and status of factory	300mm			450mm		
Real-time optimization of operator and technician activities	300mm			450mm		
Non-product wafer tracking and control capability						
Spare usage optimization and tracking and control capability						
Real-time supply chain management & real-time control capability	300mm			450mm		

Research required

Development Underway

Qualification/Pre-Production

This legend indicates the time during which research, development, and qualification/pre-production should be taking place for this solution.

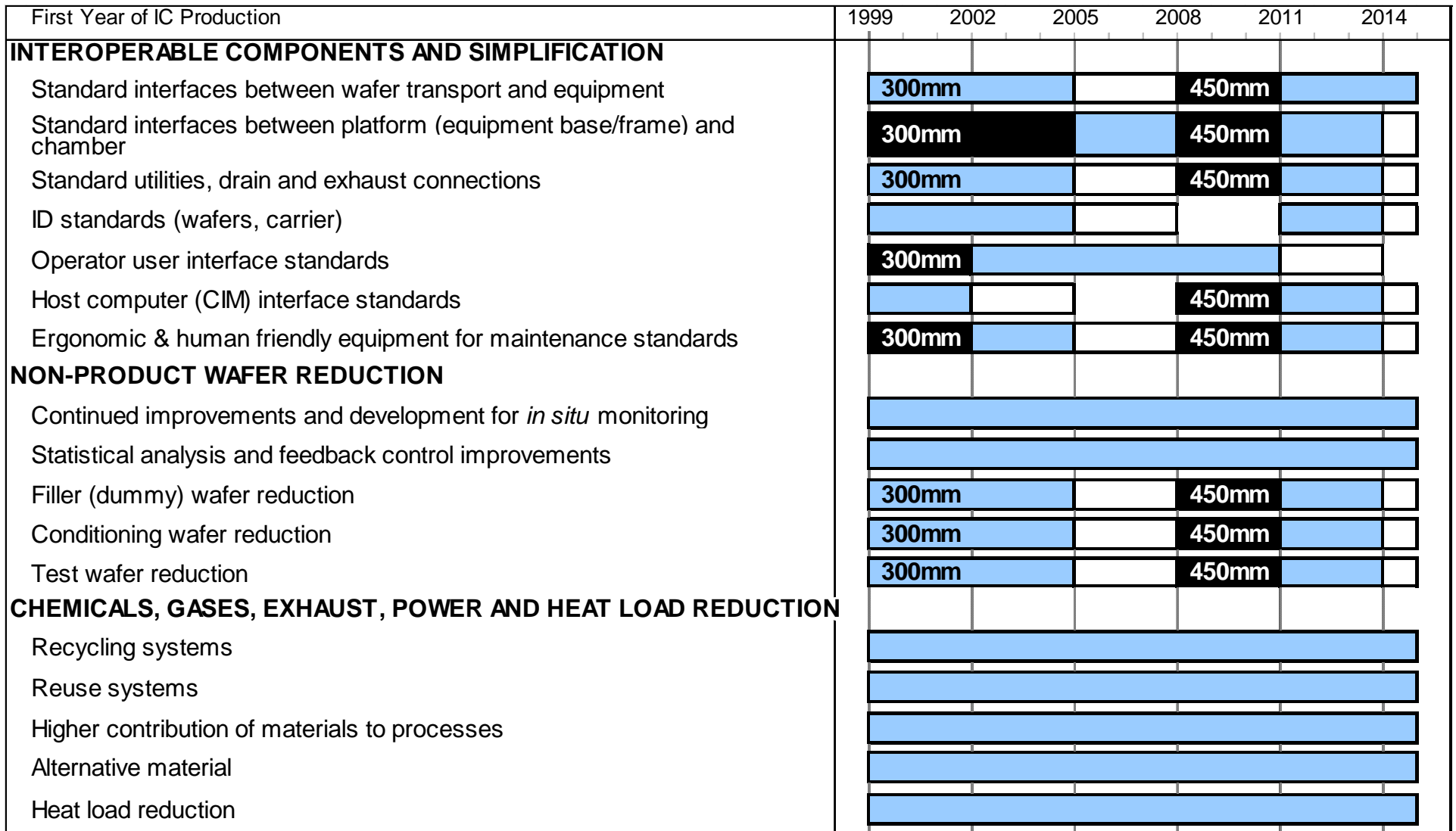
Production Equipment

Table 53 The Technology Requirements metrics tables

<i>Year</i> <i>Technology Node</i> <i>Wafer Diameter</i>	1999 180 nm 200 mm	2002 130 nm 300 mm	2005 100 nm 300 mm	2008 70 nm 300 mm	2011 50 nm 300 mm	2014 35 nm 450 mm
Relative capital cost [1]		< 1.3 × 200 mm [2]	< 98% of previous node	<98% of previous node	<98% of previous node	< 1.3×300 mm
Relative consumables, exhaust, emissions, and utilities		< 1.0 × 200mm	10% less than previous node	10% less than previous node	10% less than previous node	10% less than previous node
Bottleneck production equipment OEE [3] (SEMI E79)	75%	87%	89%	91%	92%	92%
Average production equipment OEE [3] (SEMI E79)	55%	65%	71%	78%	80%	82%
Relative equipment footprint		< 1.0×200 mm	<98% of previous node	<98% of previous node	<98% of previous node	<1.0×of 300 mm
Relative maintenance and spares cost		< 1.0×200 mm	<98% of previous node	<98% of previous node	<98% of previous node	< 120% of previous node
Overall factory non-product wafer usage (per wafer start)		< 16% of production	< 12% of production	< 11% of production	< 10% of production	< 9% of production
% Capital equipment reused from one process node to next	> 70%	> 0%	> 80%	> 80%	> 80%	>20%
Wafer edge exclusion [4]	3 mm	2 mm	1 mm	1 mm	1 mm	1 mm
Production equipment lead time (months from order to full throughput capability) [5]	< 9 months	< 8 months	< 7 months	< 6 months	< 5 months	<5 months
Production equipment installation, including hook-up and qualification cost as a % of capital cost	< 6%	< 0.95× of cost of previous node	< 0.95× of cost of previous node	< 0.95× of cost of previous node	< 0.95× of cost of previous node	< 0.95× of cost of previous node
Process equipment availability [6] (SEMI E10)	> 85%	> 90%	> 93%	> 95%	> 95%	> 95%
Metrology equipment availability [6] (SEMI E10)	> 90%	>95%	>95%	>98%	>98%	>98%
Number of process recipes per carrier	Single	Multiple	Multiple	Multiple	Multiple	Multiple

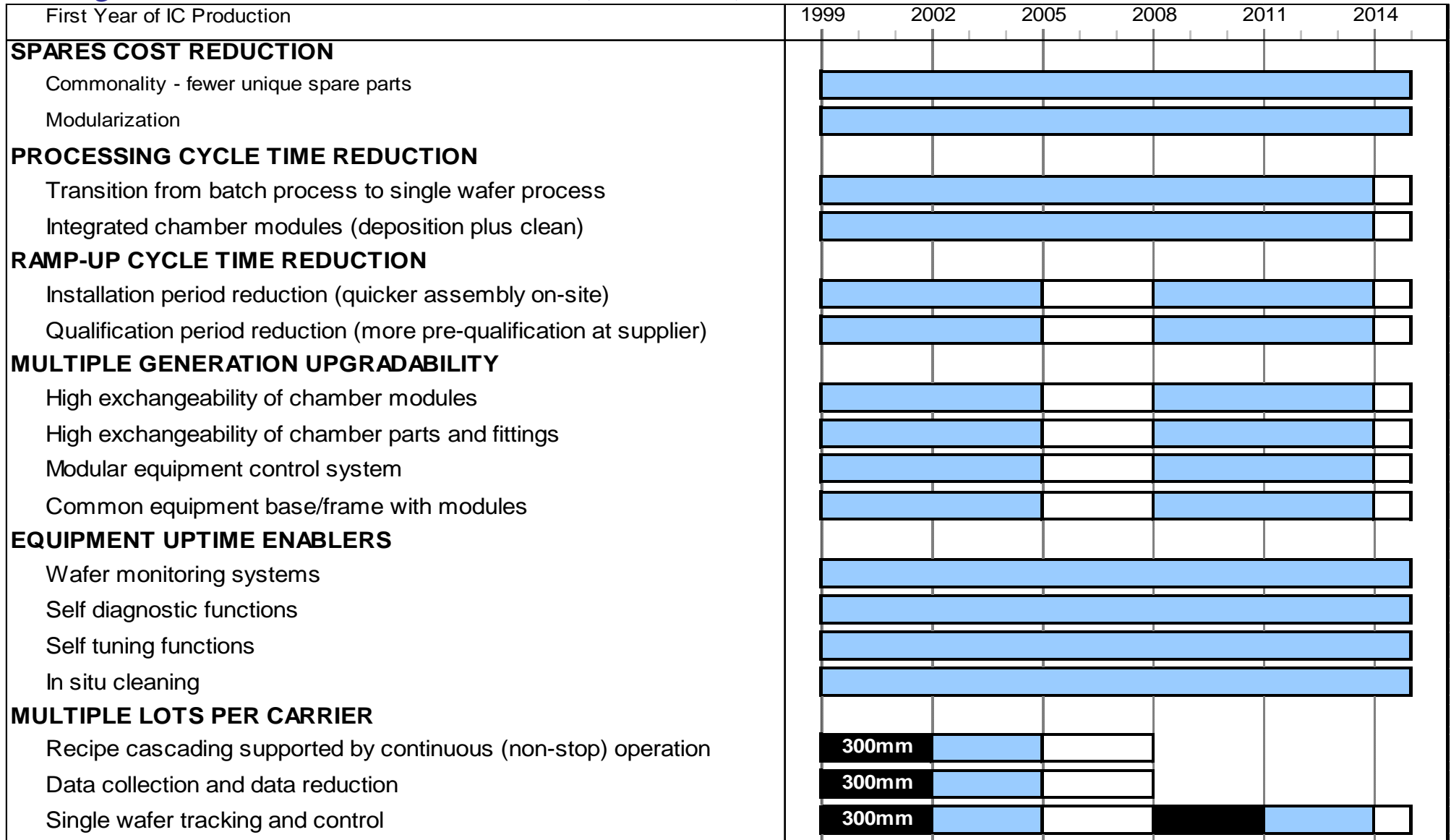
Production Equipment

Figure 39 The Potential Solutions



Production Equipment

Figure 39 The Potential Solutions (Continued)



Material Handling Systems

Table 54 The Technology Requirements metrics tables

<i>Year</i> <i>Technology Node</i> <i>Wafer Diameter</i>	<i>1999</i> <i>180 nm</i> <i>200 mm</i>	<i>2002</i> <i>130 nm</i> <i>300 mm</i>	<i>2005</i> <i>100 nm</i> <i>300 mm</i>	<i>2008</i> <i>70 nm</i> <i>300 mm</i>	<i>2011</i> <i>50 nm</i> <i>300 mm</i>	<i>2014</i> <i>35 nm</i> <i>450 mm</i>
Material handling total capital cost as a % of total capital cost	< 5%	< 3% [1]	< 2% [2]	< 2%	< 2%	< 3%
Transport system types within a factory	Interbay and intrabay	Interbay and intrabay	Some inter/intrabay and some direct (one integrated system)	One integrated system	One integrated system	One integrated system
MTTR (minutes) (SEMI E10)	30	20	15	15	12	10
Failures per 24 hour day over total system (SEMI E10)	<1	<1	<0.5	<0.5	<0.5	<0.5
System throughput						
Interbay transport (moves/hour)	1000	1200	1500	2000	2200	2500
Intrabay transport (moves/hour)	150	170	200	n/a	n/a	n/a
Stocker (moves/hour)	200	240	300	360	360	360
Stocker cycle time (seconds)	18	15	12	10	10	10
Factory wide carrier delivery time (in minutes)	Average=10 Maximum=20	Average=10 Maximum=20	Average=8 Maximum=15	Average=5 Maximum=15	Average=5 Maximum=15	Average=5 Maximum=10

Material Handling Systems

Figure 40 The Potential Solutions

First Year of IC Production	1999	2002	2005	2008	2011	2014
EASE OF IMPLEMENTATION						
<i>Installation Simplification</i>						
Simple system component modules, optimized for easy move-in, setup, and integration		300mm				
MHS support structures independent of cleanroom infrastructure						
Automated or zero field hardware alignment and positioning capability (teaching and adjustment not required)						
Easily extended transport system rail	300mm					
<i>Quick Ramp-up</i>						
Automated software configuration (hardware independent structure and parameter setting)		300mm				
Pre-tested integrated MHS modules requiring no field testing		300mm				
Dynamic (high volume transfer load) simulation test and automatic transfer capability estimation (throughput and carrier delivery time)						
<i>Ease of maintenance</i>						
Fault tolerant transport system controllers						
Automated preventive/predictive maintenance, calibration, and fine tuning						
System by-pass transport feature to allow for minimum impact of component downtime		300mm				
Automatic trouble monitoring/recording with error analysis, diagnosis, disposition, and recovery						
Uninterrupted material handling control system during software installation/upgrade						
MATERIAL TRANSPORT SYSTEM CONFIGURATIONS						
Integrated limited direct transport system that performs inter and intrabay transport with standard interfaces and bay stockers		300mm				
Single direct tool-to-tool integrated system for full direct transport with vehicle bypass transport capability						
System or vehicles for simultaneous transport and delivery of wafer carriers and reticle carriers						
Direct transport with central storage	300mm					
Large scale conveyors and next generation vehicles					450mm	

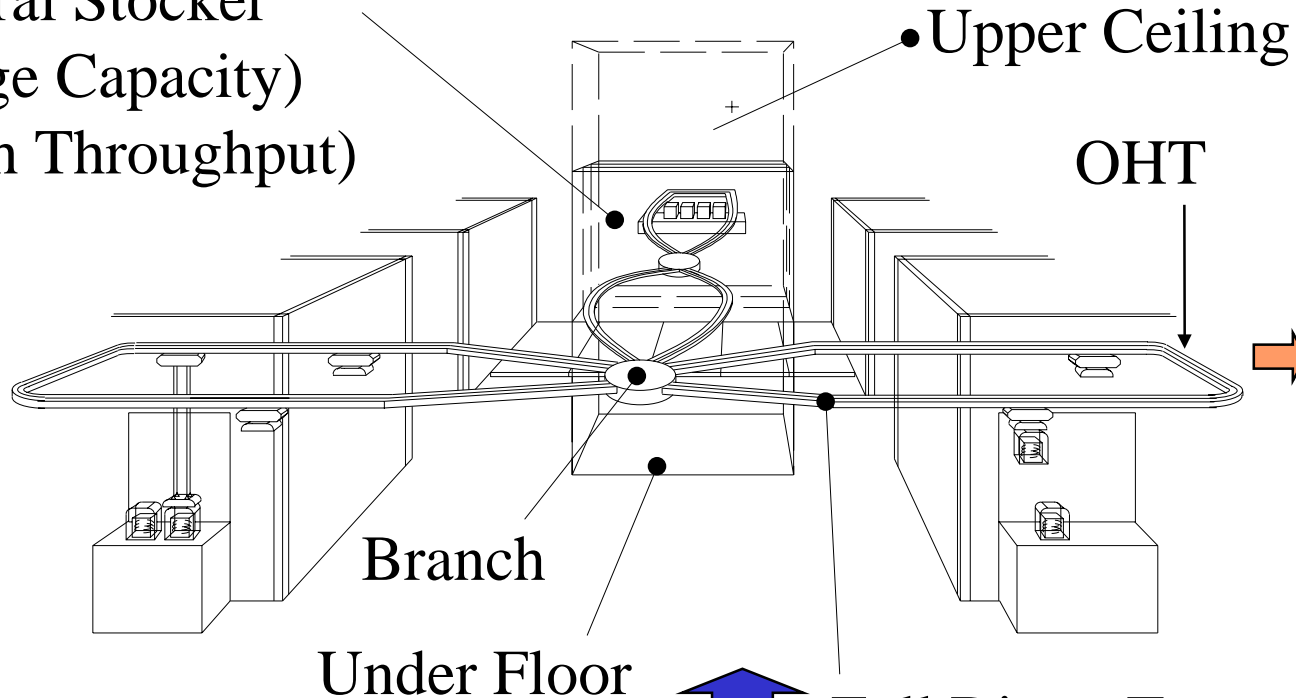
Material Handling Systems

Figure 40 The Potential Solutions (Continued)

First Year of IC Production	1999	2002	2005	2008	2011	2014
MATERIAL HANDLING STORAGE SYSTEM CONFIGURATIONS						
Large capacity central storage systems and zero fab floor footprint stocker						
Modular field upgradeable stockers that are expandable to very large capacity						
TRANSPORT LOAD IDENTIFICATION AND TRACKING METHODS						
Carriers identification system for separate tracking of empty carrier and lid						
Wafer ID reading to support 450 mm wafer tracking						
MATERIAL HANDLING CONTROL CAPABILITY						
Integrated material control system for interbay and intrabay control						
Intelligent empty vehicle traffic management control for direct transport system						
Transport vehicle dynamic scheduling and predictive control capability						
Advance WIP carrier transportation scheduling systems with prediction capability for lot movement optimization						
Advance reticle transportation scheduling systems integrated with WIP movement						
Flexible lot size transport, capable of handling split and merge. (Note: same size carrier with variety of multiple lots)						
INTERFACE STANDARDS DEVELOPMENT						
Production equipment to material handling system hardware for carriers						
Next generation exposure equipment to material handling system interface standards for reticles, reticle handling						
Stocker to interbay and intrabay transport system interface for carriers						
Direct interchange capability of interbay to/from intrabay						
Software control interface standardization from handling hardware to the host						
Standardized single wafer equipment interface with wafer transport system, including interoperability to equipment chamber						

Material Handling: A Concept for Integrated [Interbay & Intrabay] Transport

Central Stocker
(Large Capacity)
(High Throughput)



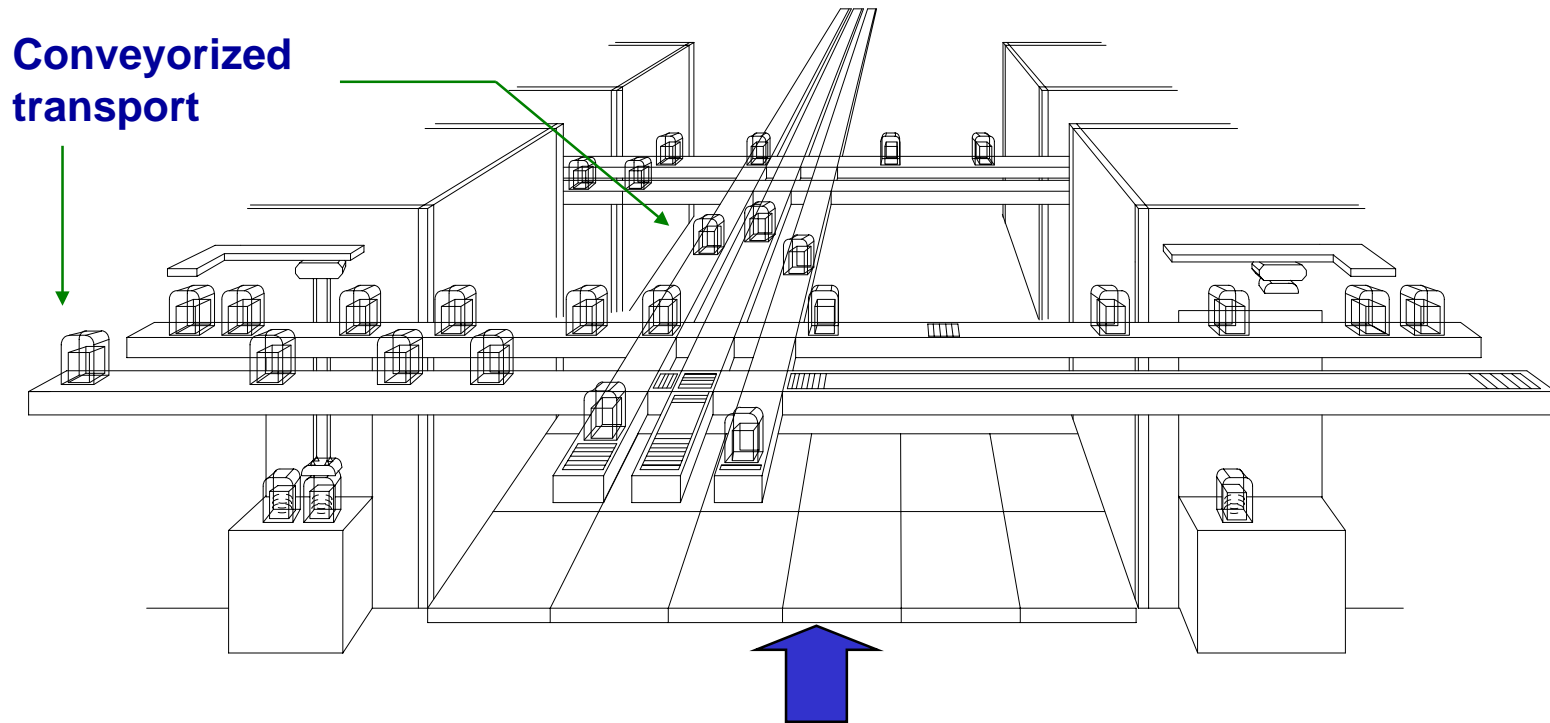
However, current OHT systems cannot meet the longer-term throughput

Under Floor Full Direct Transport

Material Handling:

	1999	2002	2005	2008	2011	2014
# of Transport Systems types within a factory	Interbay & Intrabay systems	Interbay & Intrabay systems	One integrated system	One integrated system	One integrated system	One integrated system

Material Handling: Another Concept for Integrated [Interbay & Intrabay] Transport



Material Handling:

	1999	2002	2005	2008	2011	2014
# of Transport Systems types within a factory	Interbay & Intrabay systems	Interbay & Intrabay systems	One integrated system	One integrated system	One integrated system	One integrated system

Factory Systems

Table 55 The Technology Requirements metrics tables

<i>Year</i> <i>Technology Node</i> <i>Wafer Diameter</i>	<i>1999</i> <i>180 nm</i> <i>200 mm</i>	<i>2002</i> <i>130 nm</i> <i>300 mm</i>	<i>2005</i> <i>100 nm</i> <i>300 mm</i>	<i>2008</i> <i>70 nm</i> <i>300 mm</i>	<i>2011</i> <i>50 nm</i> <i>300 mm</i>	<i>2014</i> <i>15 nm</i> <i>450 mm</i>
Factory systems cost including integration (% of capital)	< 3%	< 3%	< 2%	< 2%	< 2%	< 3%
MTBF for mission critical applications (months)	> 6	> 6	> 9	> 9	> 12	> 24
Mean Time to Recover for mission critical applications (minutes)	90	45	30	15	5	0
Factory system reuse	> 80%	> 80% of previous node	> 80% of previous node	> 80% of previous node	> 80% of previous node	> 80% of previous node
% of equipment to factory systems interface standards defined [2]	75% 300 mm	100% 300 mm	100% 300 mm	100% 300 mm	80% 450 mm	100% 450 mm
% conformance: equipment to factory systems interface standards [2]	100% 200 mm	100% 300 mm	100% 300 mm	100% 300 mm	100% 300 mm	100% 450 mm
% of factory systems to factory systems interface standards defined [2]	15% 300 mm	100% 300 mm	100% 300 mm	100% 300 mm	80% 450 mm	100% 450 mm
% Conformance: factory systems to factory systems interface standards [2]	0%	75% 300 mm	100% 300 mm	100% 300 mm	100% 300 mm	100% 450 mm
Time to install/upgrade a mission critical application in a working factory (minutes)	< 60	< 30	< 15	0	0	0
Time to install/upgrade a mission critical database in a working factory (hours)	6-24	6-24	2	2	< 1	< 1
Number of process recipes per carrier	Single	Multiple	Multiple	Multiple	Multiple	Multiple

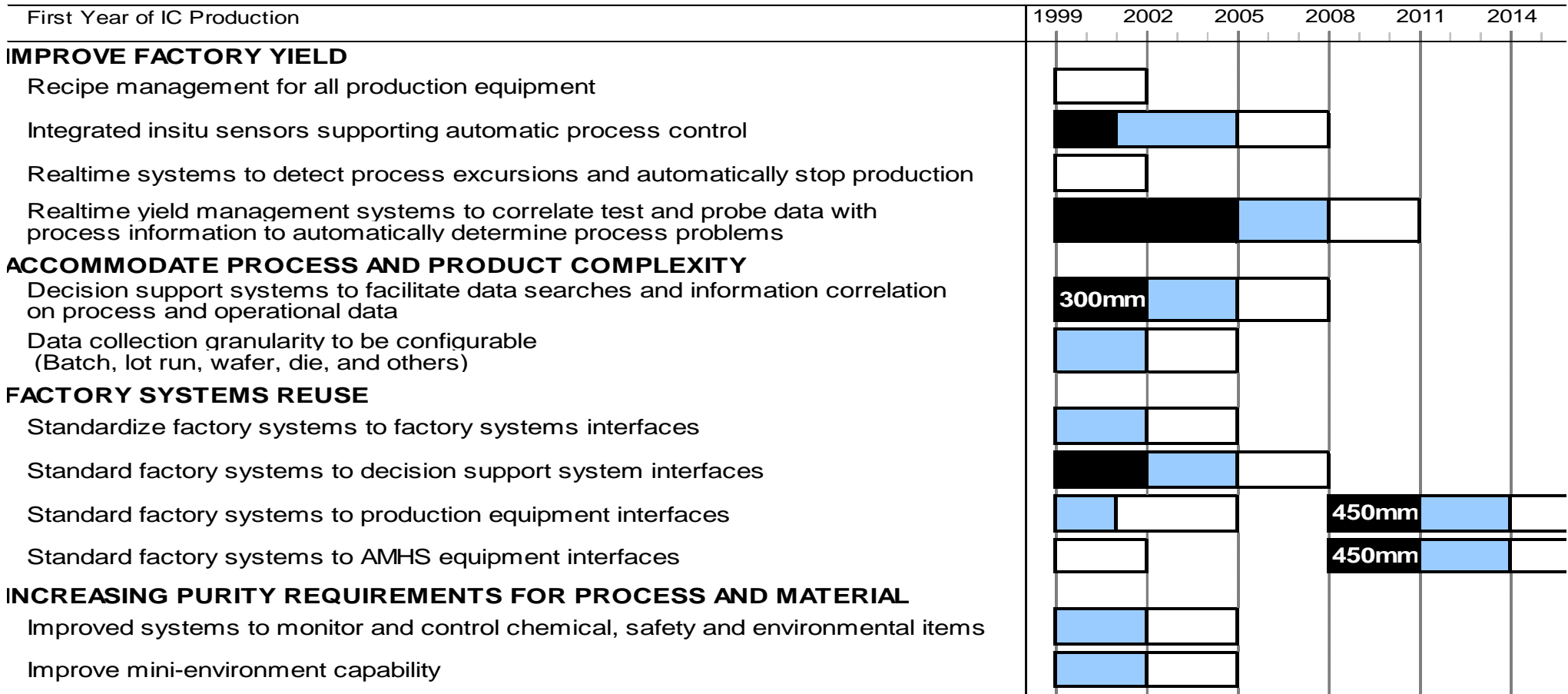
Factory Systems

Figure 41 The Potential Solutions

First Year of IC Production	1999	2002	2005	2008	2011	2014
IMPROVE OVERALL FACTORY EFFECTIVENESS						
<i>Cycle Time and Throughput</i>						
Realtime scheduler and automated dispatching integrated with MES and AMHS	300mm					
Factory systems that support wafer, recipe, and reticle cascading	300mm					
Factory systems that support multiple lots per carrier	300mm					
<i>Highly Reliable Systems</i>						
Fault tolerant computer systems with transparent hardware switching for failures (minimal to no impact)	300mm					
Software application fault detection and fault tolerance	300mm					
Real-time distributed factory systems monitoring to detect faults	300mm					
Distributed factory systems for fault detection and correction						
<i>Low Maintenance Systems</i>						
Software applications capable of dynamic upgrades (minimal to no impact)						
Databases capable of dynamic upgrades (minimal to no impact)						
Automatic/Dynamic factory system reconfiguration	300mm					
Integration testing of overall factory systems through simulators or emulators						
Standards install programs for factory systems (Wizards)						
<i>Flexible Manufacturing Systems</i>						
Scalable system performance	300mm					
Web capable interfaces for factory systems	300mm					
Wireless/portable user interfaces	300mm					

Factory Systems

Figure 41 The Potential Solutions (Continued)



Cross Cut Issues

Environmental Safety and Health

- Minimize water use & environmentally toxic effluents

Defect Reduction

- Lower NPW use through improved defect reduction model

Modeling and Simulation

- Improve yield by coupling APC with equip/process models

Metrology

- Integrate metrology & factory communication systems

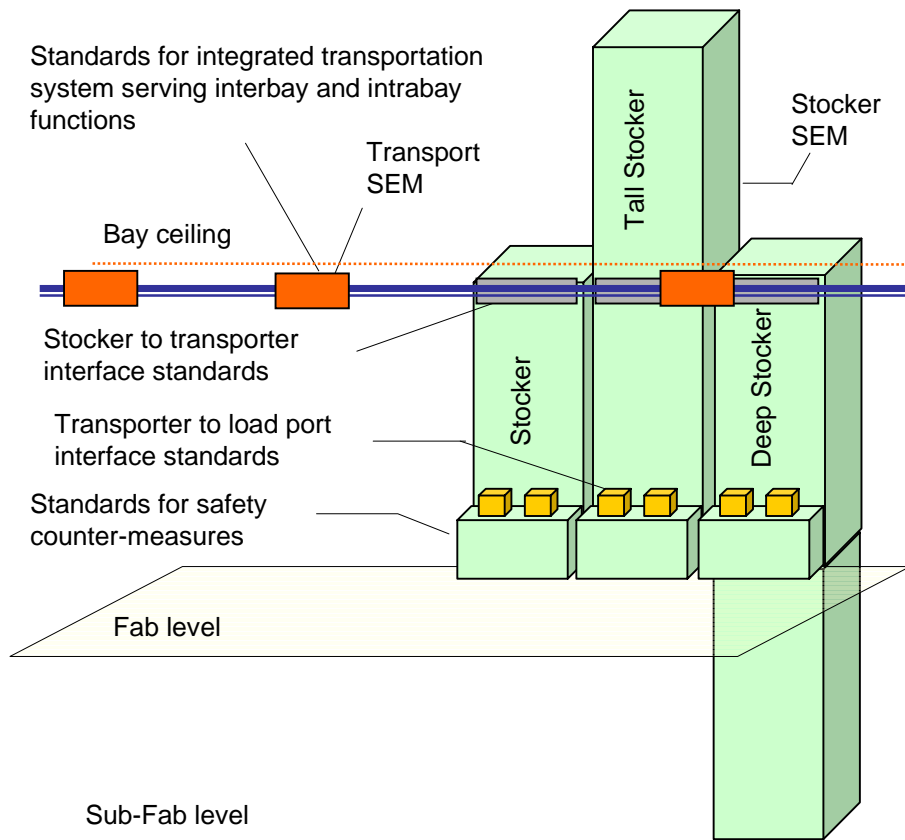
Factory Interface Standards

- Improve complexity management by standardizing interfaces within factory hardware and software systems

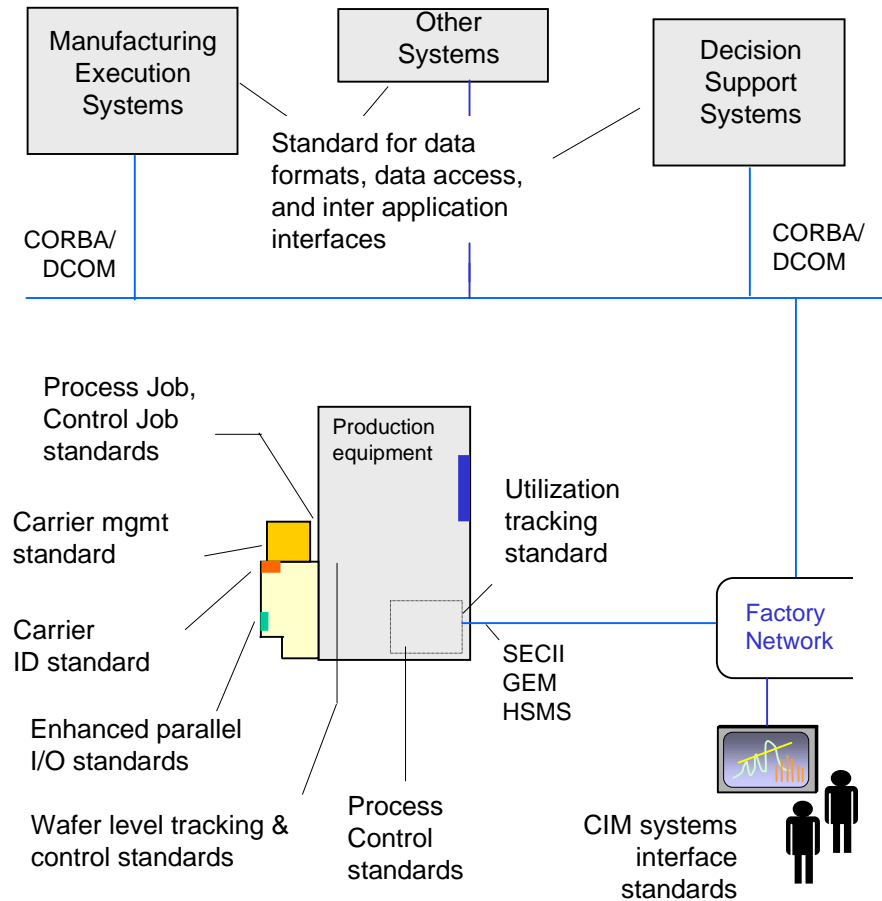
Standards are a Key Part of Potential Solutions

300mm example

Material Handling Systems



Factory Systems



Summary

- Excellent international cooperation by IC Makers, Suppliers, Universities and Research labs has resulted in successful completion of a comprehensive factory roadmap
- We believe this roadmap provides meaningful Action Plans to achieve productivity goals
 - there is lots of work ahead for everybody
- We invite and encourage you all to participate in FITWG activities during 2000 to convert these plans to reality