Factory Integration Technology Working Group (FITWG) ITRS Presentation

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

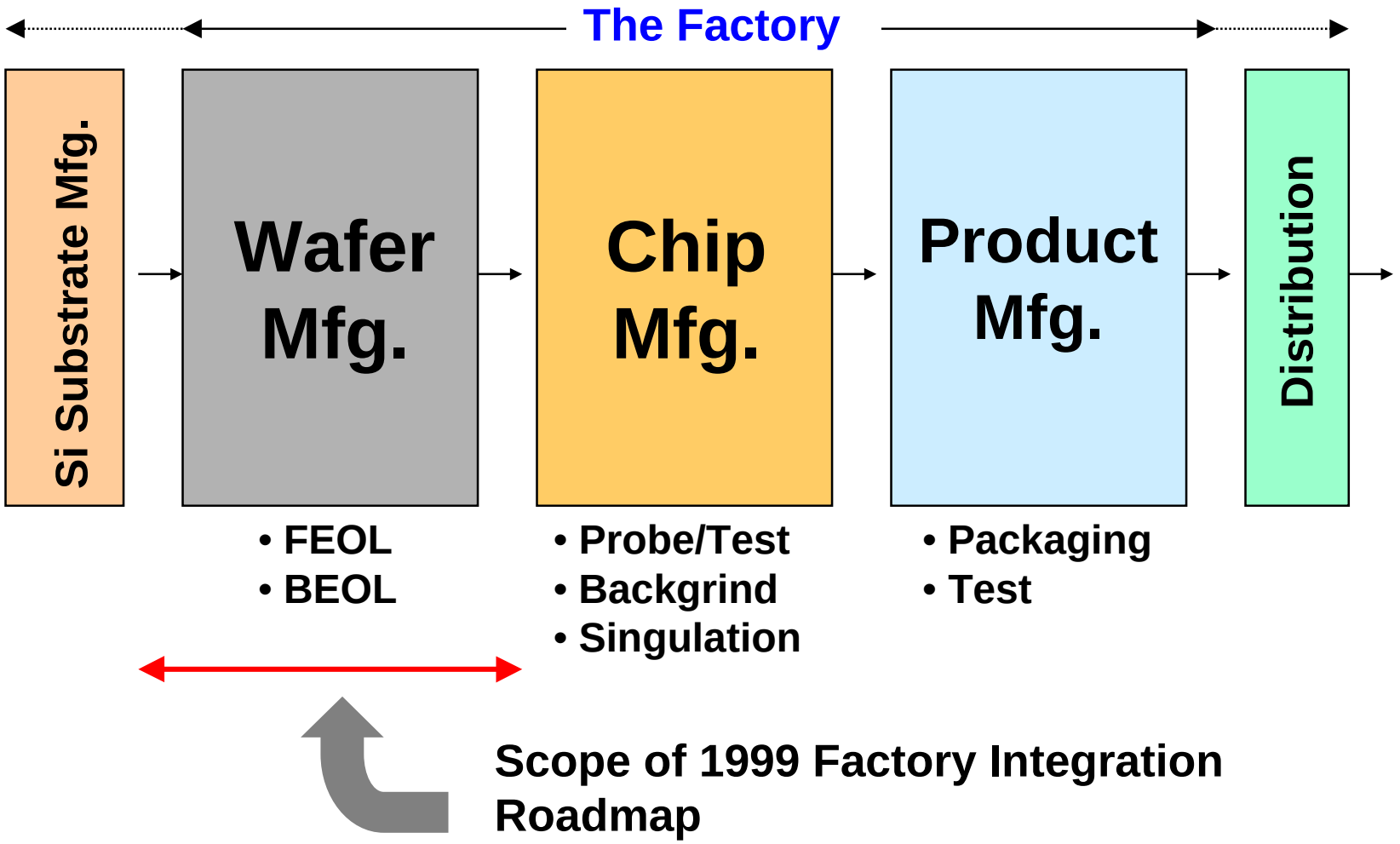
Factory Assumptions

- 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

Cleanroom Ceiling interface stds

Cleanroom
- Environment:
- Temp, humidity
- Ceiling height
- Max weight, size
- Others ..

Cleanroom design
- bay/chase
- ball-room
- other

Overhead Hoist Transport MHS (OHT)

Facilities systems

Factory systems

Maintenance & spares

Process Equipment

Wafer & Carrier

Metrology Equipment

Interbay MHS

Lot ID

Stocker

Operator productivity

Ground based Intrabay Vehicle

Ground based Intrabay Vehicle

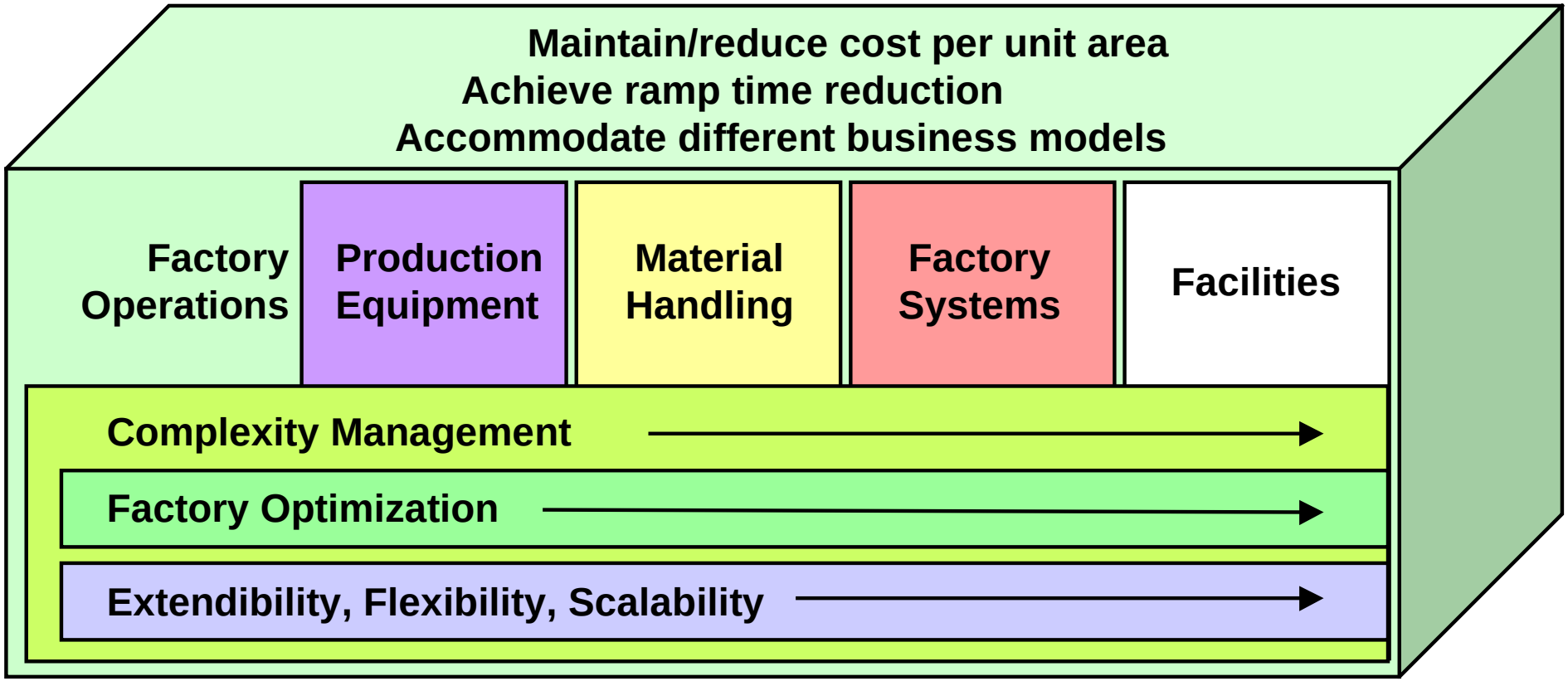
Operator and Maintenance technicians

Factory Operations

Factory Operations **Production Equipment** **Facilities**

Material Handling **Factory Systems**

Factory Integration Challenges & Technology Thrusts



Factory Integration Challenges & Technology Thrusts

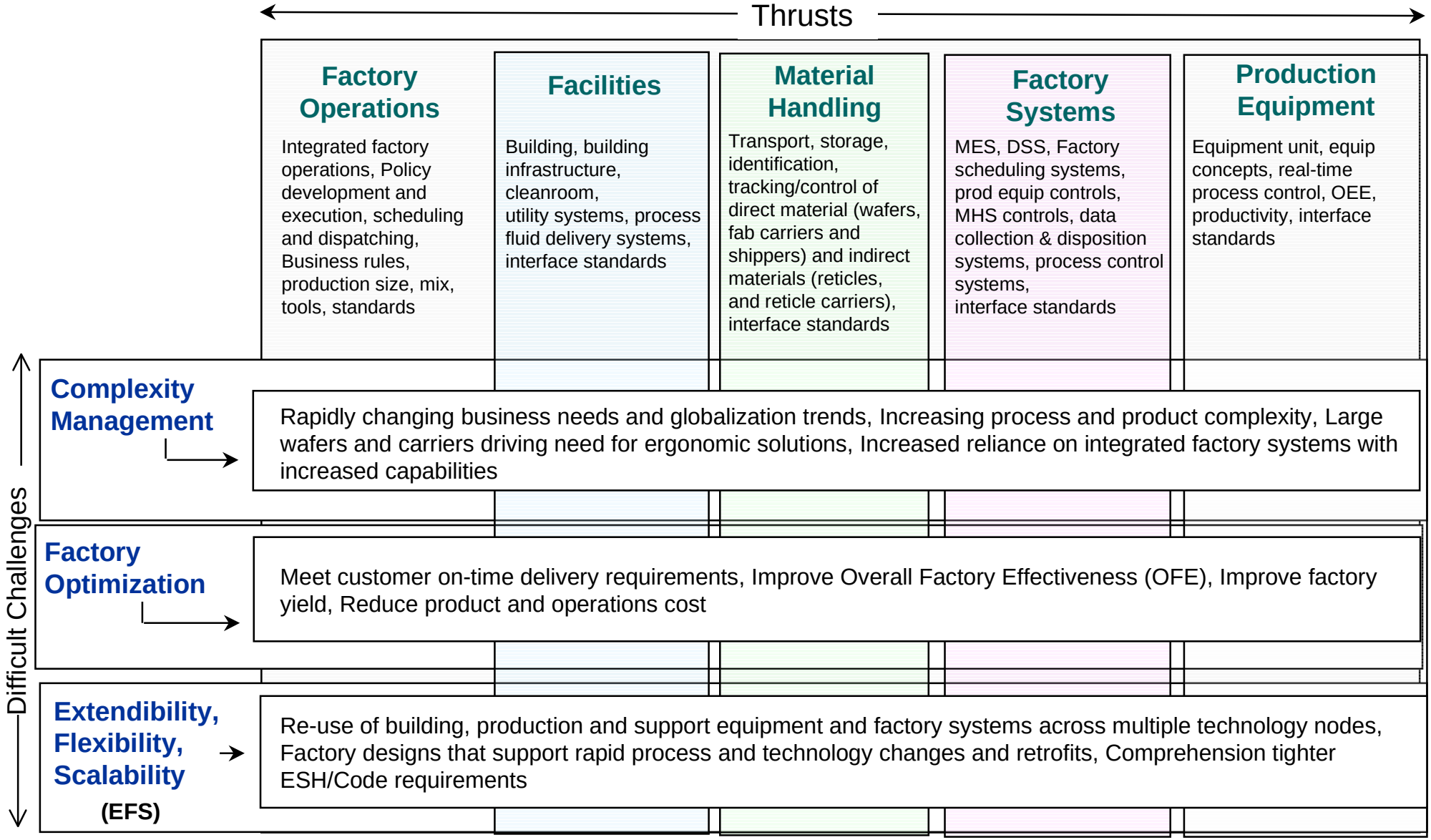


Table 51 Factory Integration Difficult Challenges

Difficult Challenges	*Summary of Issues*
Complexity Management	Rapidly changing business needs and globalization trends • Increasing rate of new product and technology introductions • Globally disparate factories run as single "virtual factory" • Need to meet regulations in different geographical areas Increasing process and product complexity • Explosive growth of data collection/analysis requirements • Increasing number of processing steps • Multiple lots in a carrier Larger wafers and carriers driving ergonomic solutions • Increasing expectations for material handling automation systems Increased reliance on factory systems • Multiple system interdependencies • Co-existence of new factory systems with existing (legacy) systems
Factory Optimization	Meet customer ontime delivery • Balanced throughput and cycle time • Reduce time to ramp factories, products, and processes Improve Overall Factory Effectiveness (OFE) • Improve all Factory Integration thrust areas Improve factory yield • Control production equipment and factory processes to reduce parametric variation Reduce product and operation cost • Minimize waste and scrap and reduce the number of nonproduct wafers Satisfy all local, state and federal regulations.
Extendibility, Flexibility, and Scalability	Reuse of building, production and support equipment, and factory systems • Across multiple technology nodes • Across a wafer size conversion Factory designs that support rapid process and technology changes and retrofits • Understand up-front costs to incorporate EFS • Determine which EFS features to include and not to include • Minimize downtime to on-going operations Comprehension tighter ESH/Code requirements Comprehension increase purity requirements for process and materials

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 • 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 • 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 • 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 • 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 • 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 • 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 • 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 • 廃棄物とスクラップの最小化及び非生産ウェハ（ＮＰＷ）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 • 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 • 汎用性、拡張性に結びつく先行投資への考え方 • 汎用性、拡張性の対する可否判断 • 生産ラインの中断時間の最小限化 より厳しくなるＥＳＨ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

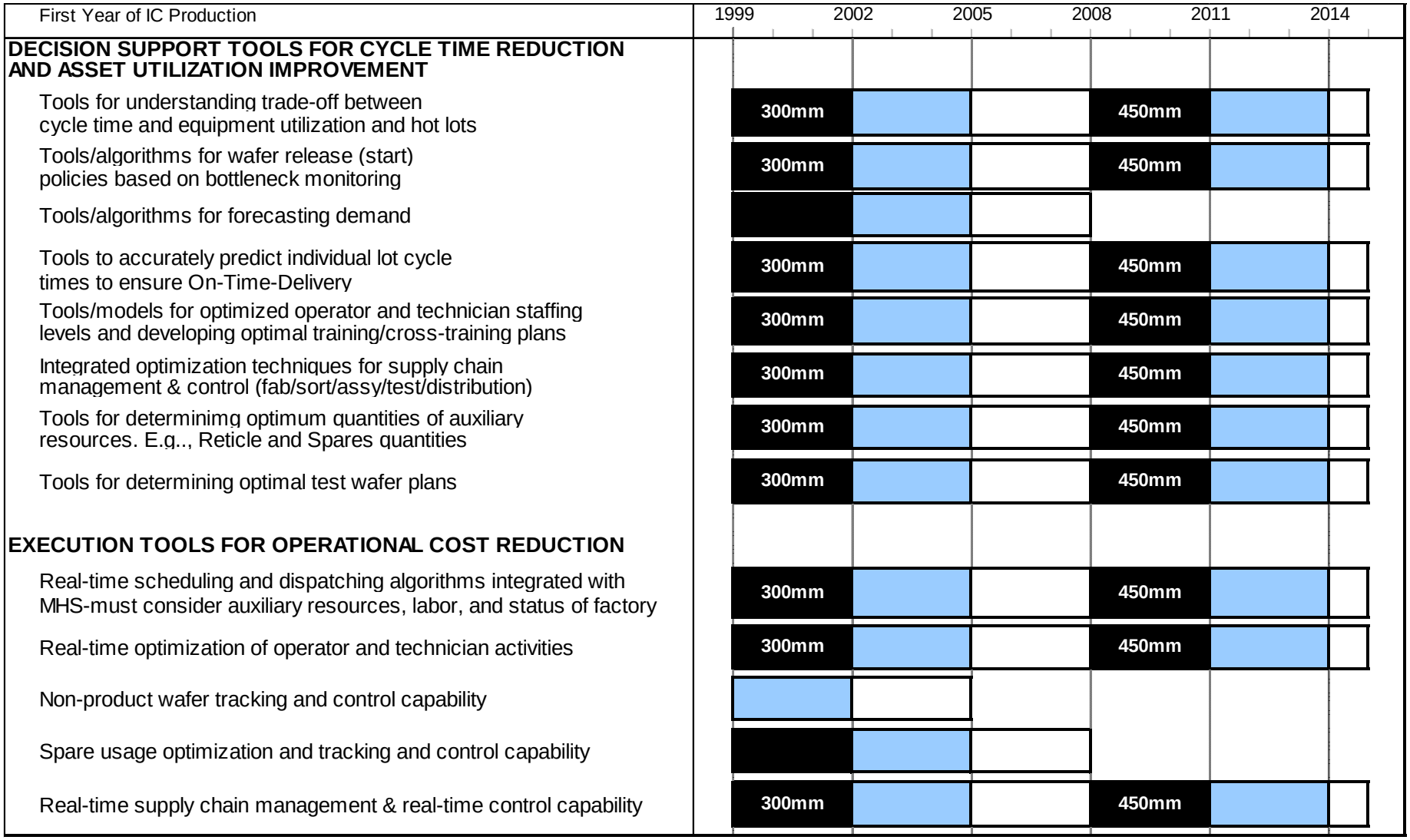
Table 52 The Technology Requirements metrics tables

Year *Technology Node* *Wafer Diameter*	*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*
High Volume/Low Mix Factory requirements						
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**
High Volume/High Mix Factory requirements						
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**
Common Requirements across both factory types						
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



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.

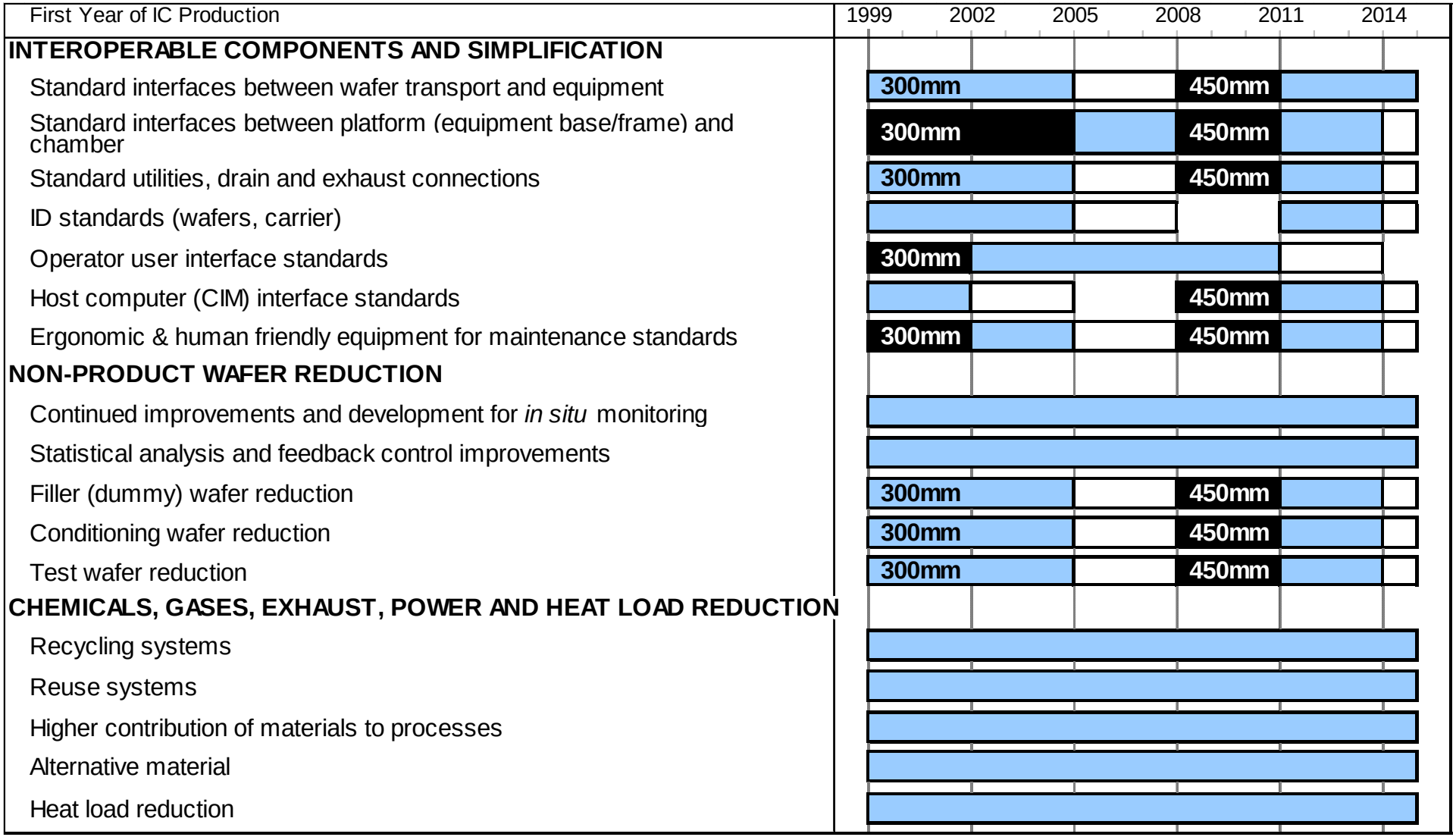
Production Equipment

Table 53 The Technology Requirements metrics tables

Year *Technology Node* *Wafer Diameter*	*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

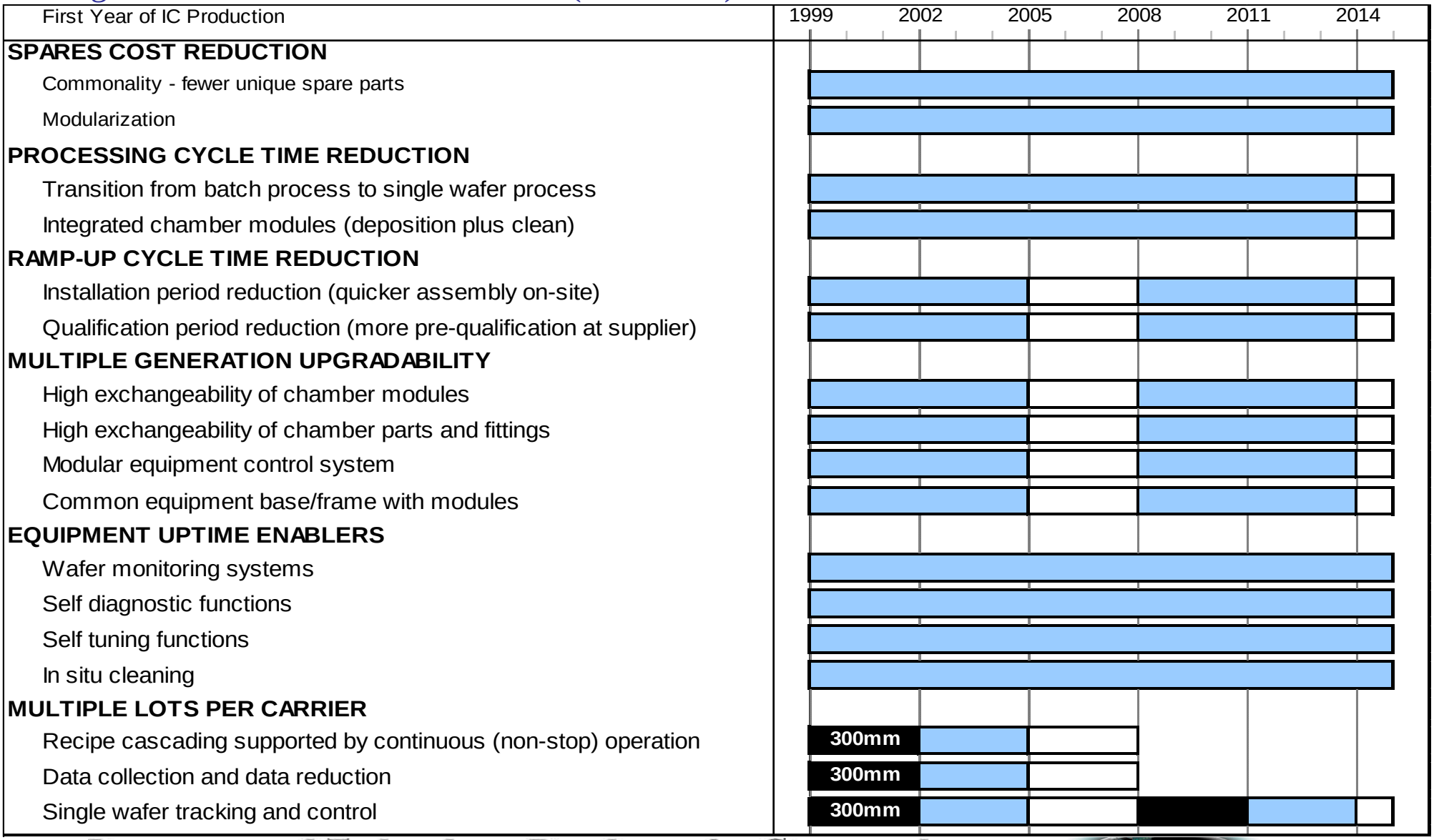
Production Equipment

Figure 39 The Potential Solutions



Production Equipment

Figure 39 The Potential Solutions (Continued)



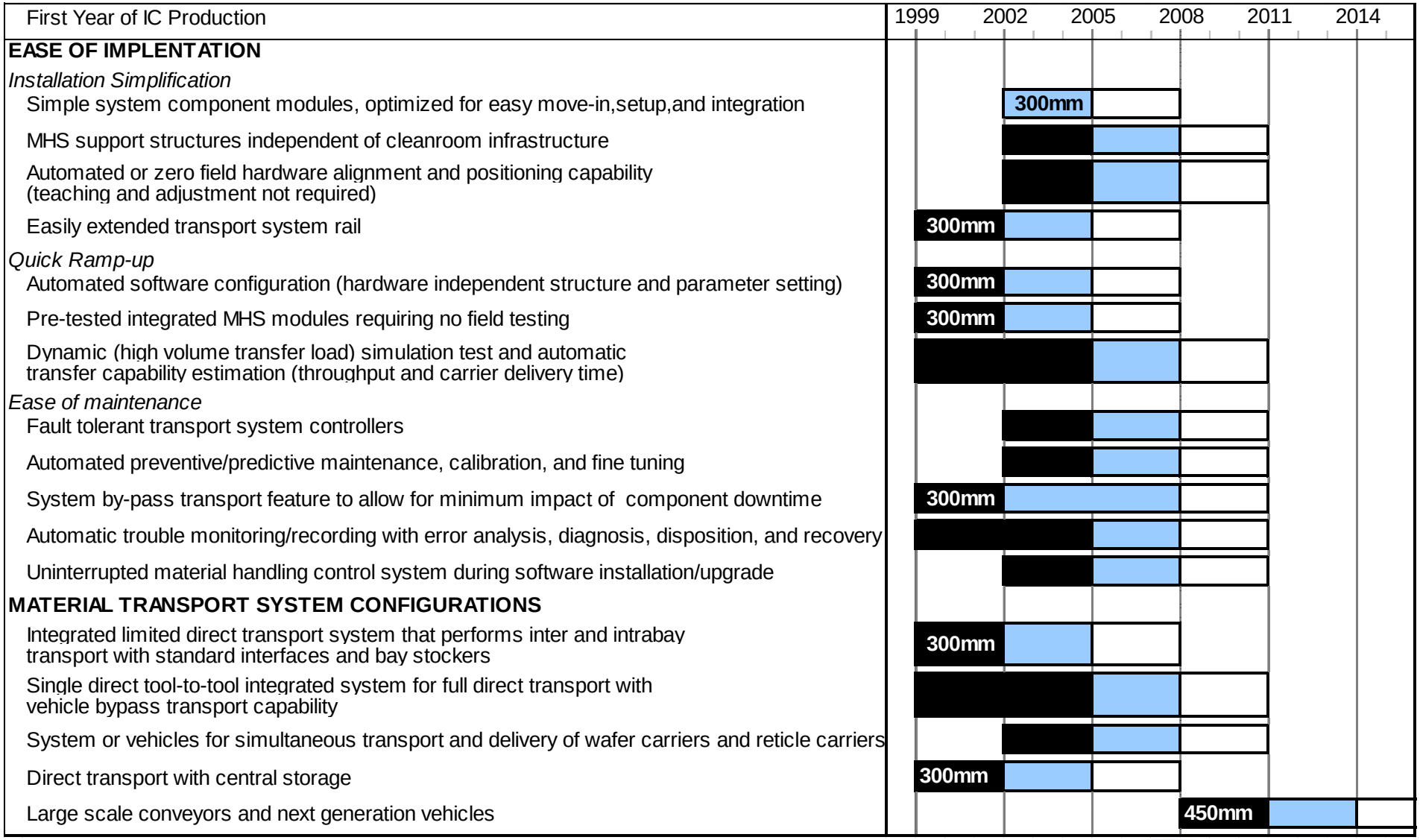
Material Handling Systems

Table 54 The Technology Requirements metrics tables

Year *Technology Node* *Wafer Diameter*	*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*
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**

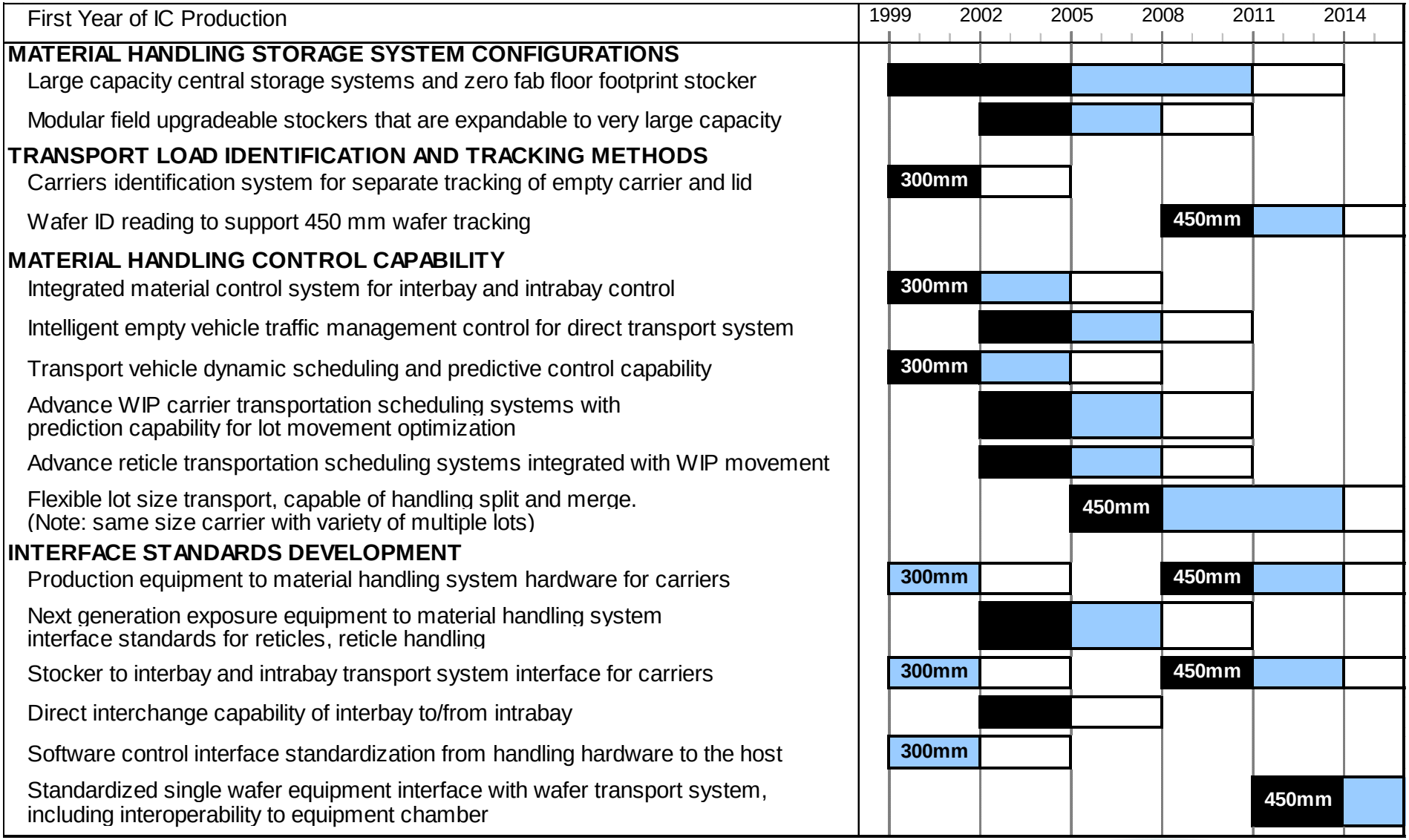
Material Handling Systems

Figure 40 The Potential Solutions

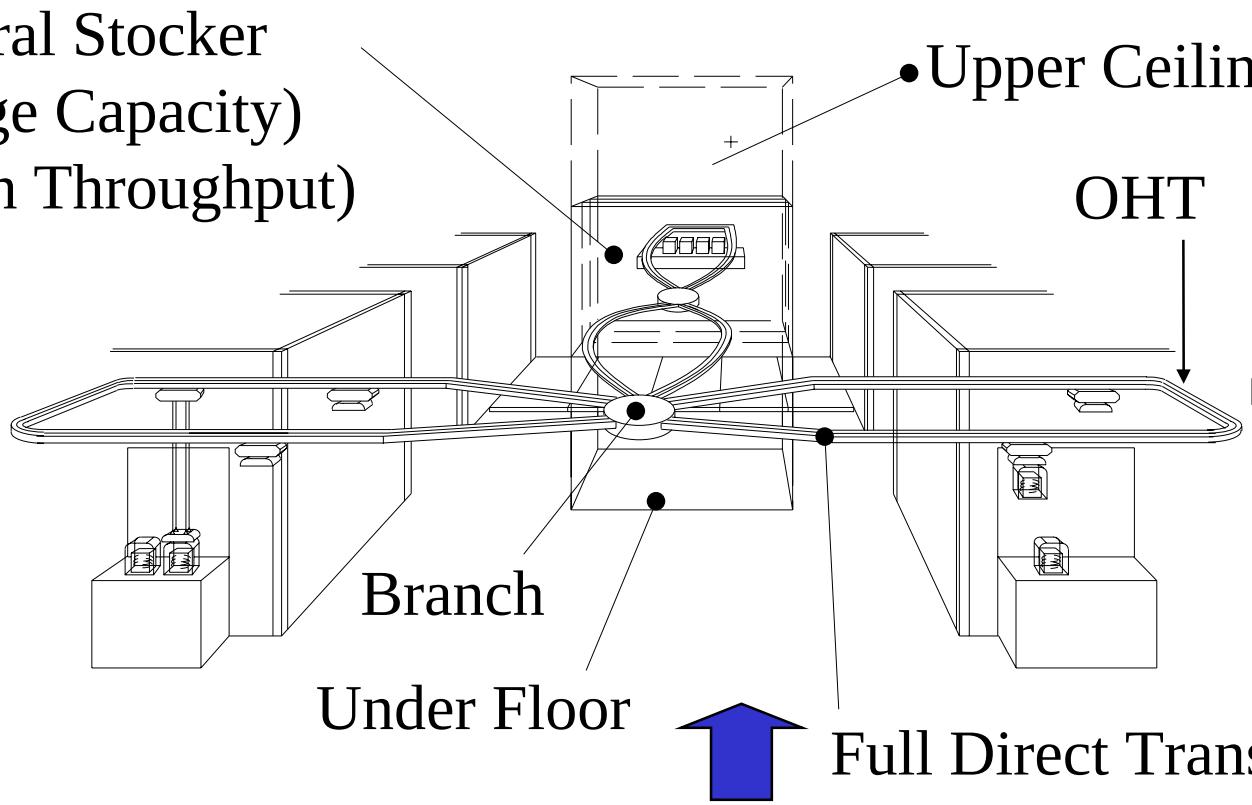


Material Handling Systems

Figure 40 The Potential Solutions (Continued)



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

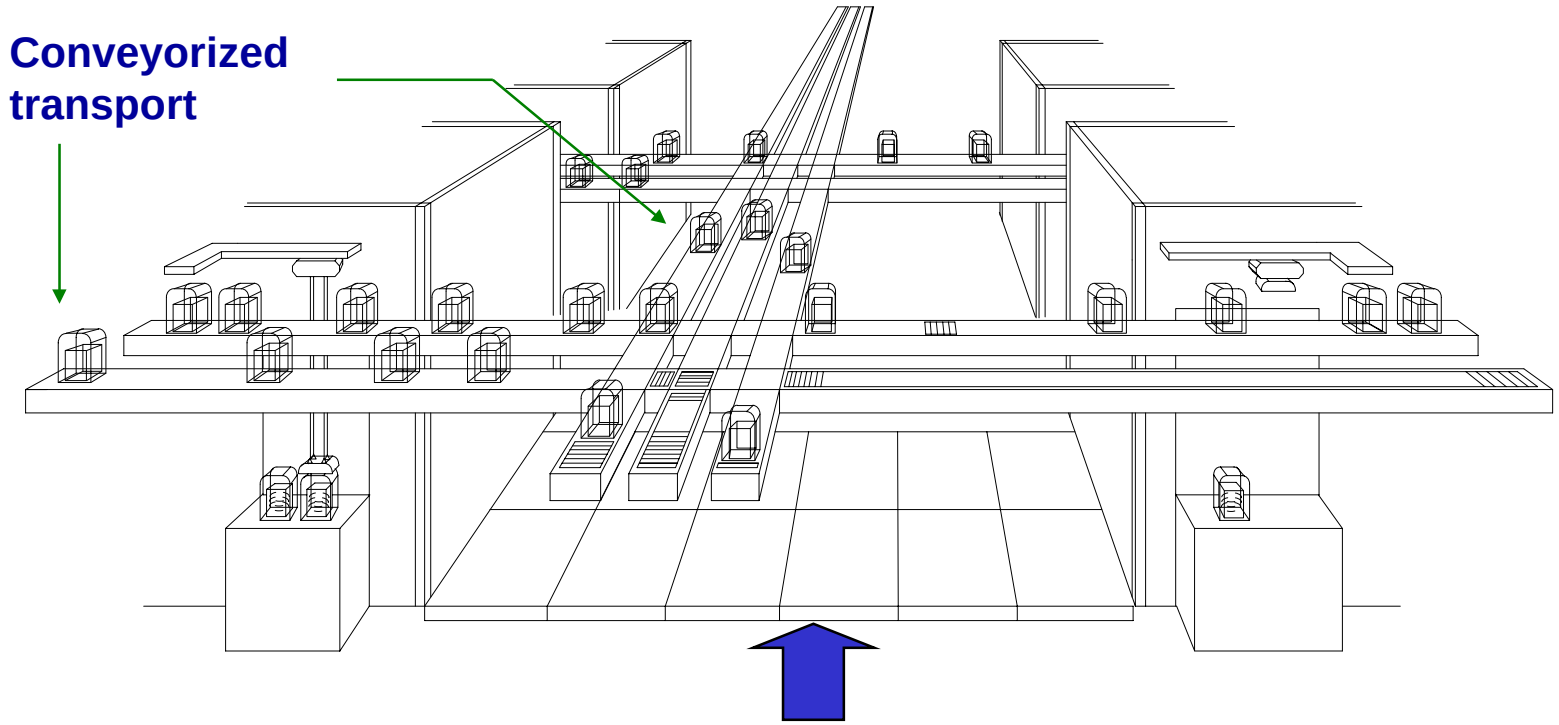


However, current OHT systems cannot meet the longer-term throughput

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

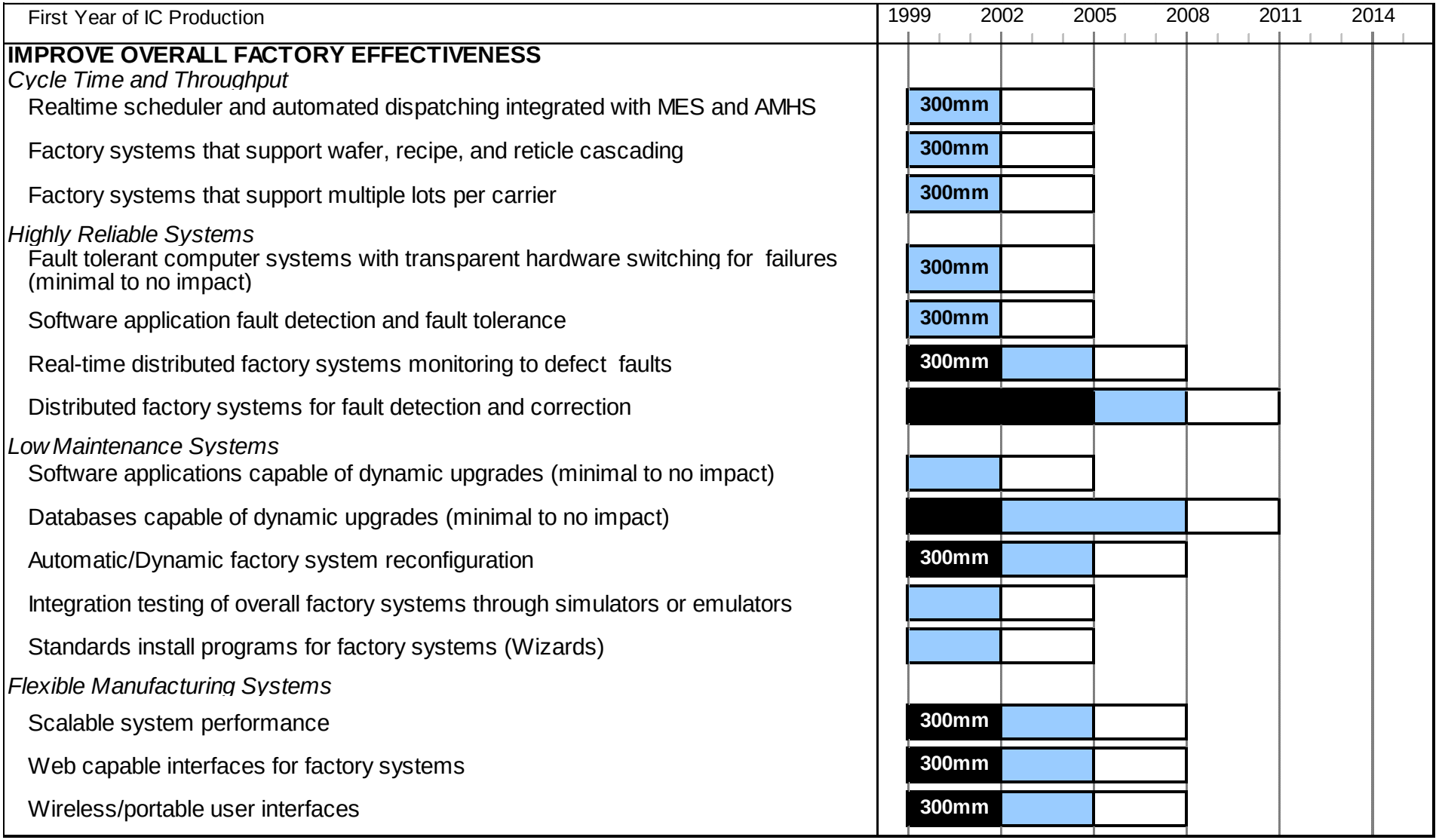
Factory Systems

Table 55 The Technology Requirements metrics tables

Year *Technology Node* *Wafer Diameter*	*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* *15 nm* *450 mm*
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

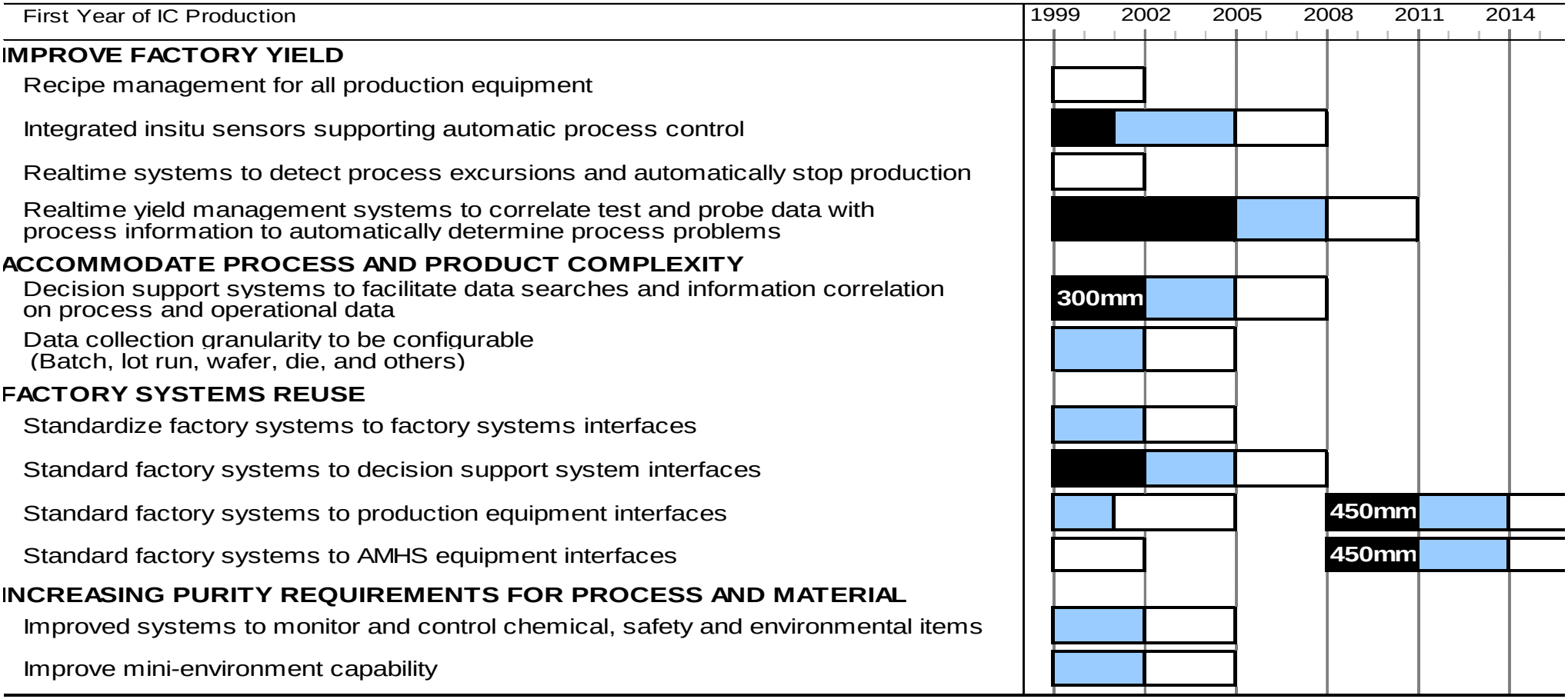
Factory Systems

Figure 41 The Potential Solutions



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

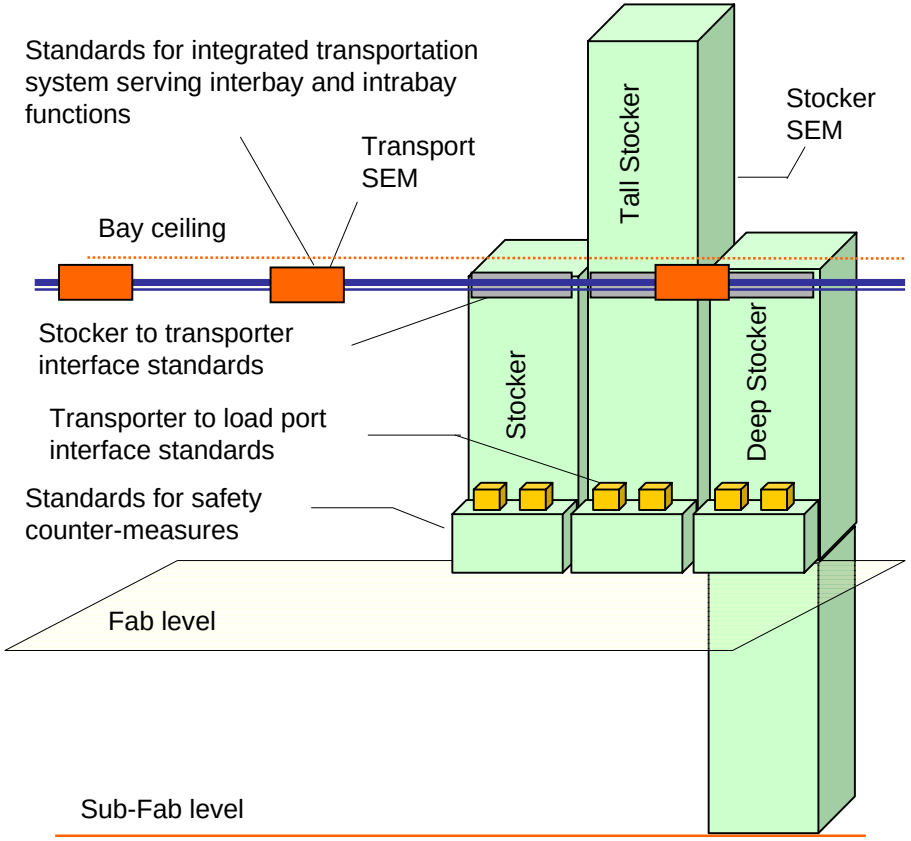
Factory Interface Standards

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

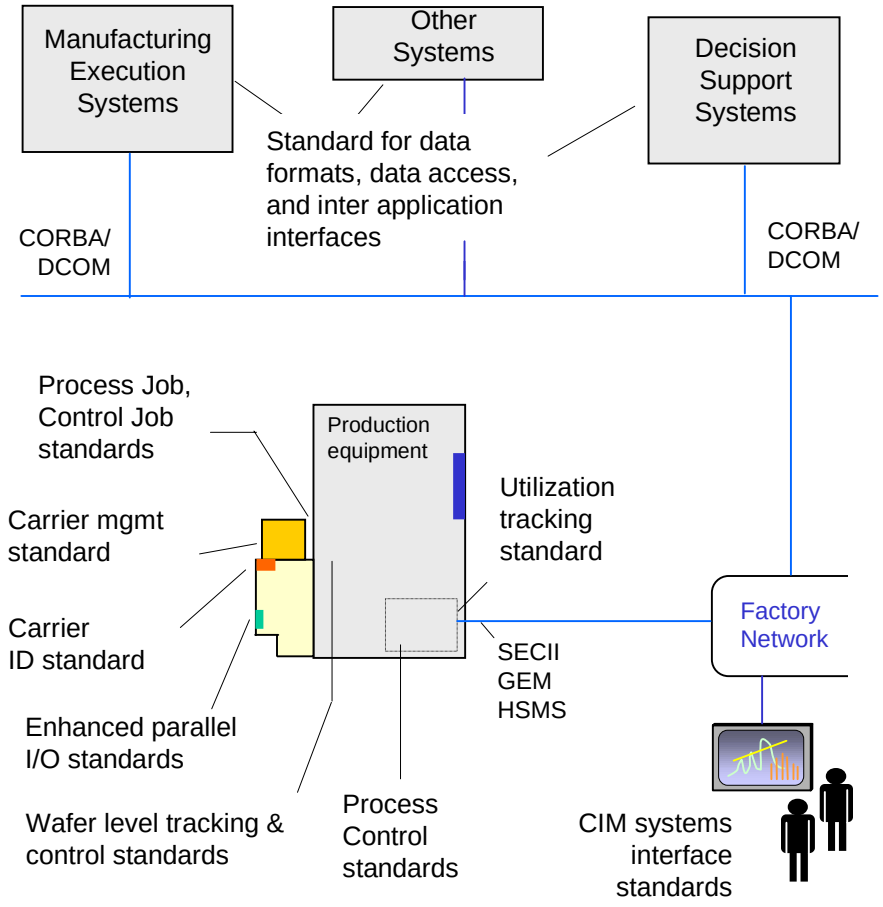
Standards are a Key Part of Potential Solutions

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