International Technology Roadmap for Semiconductors

2000 Update

Factory Integration

TABLE OF CONTENTS

FACTORY INTEGRATION

SUMMARY

For the 2000 FI ITRS, the key focus was to 1) update status based on actual 300mm implementations, 2) address issues with equipment reliability and 3) to expand the scope of the chapter through the cross cut section into the Assembly/Test arena.

DIFFICULT CHALLENGES:

No changes to the difficult challenges text, tables, or figures. Key challenges remain the same from 1999:

1. Reduce factory capital and operating costs per function
2. Improve factory optimization 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

TECHNICAL REQUIREMENTS:

1. Updated dates in the tables to match revised ORTC technology node timelines.
2. Updated table colors to match ORTC guidelines. Also, tables were updated to reflect progress on 300mm in production equipment, AMHS, factory systems, facilities, and factory operations.
3. No changes to the technical requirements values.

POTENTIAL SOLUTIONS:

1. Updated dates in the tables to match revised ORTC technology node timelines
2. Key issue for both 200mm and 300mm equipment is the added remote diagnostic capability as a potential solution to help resolve the large gap between equipment availability requirements and actual factory performance.

CROSS CUT:

1. Environmental, Health, and Safety: We updated the section to include reflect the impact of copper processing and 300mm factory conversions.

Assembly/Test Equipment: We added a section on Assembly/Test to focus on material handling and equipment communication cost reduction. For material handling, potential solutions for cost reduction include standards for carriers, media, and equipment load/unload interfaces. For assembly/test equipment, potential solutions for cost reduction include equipment communications standards to the MES using proven semiconductor industry and mainstream computing standards.

2000 UPDATE										
YEAR OF PRODUCTION *TECHNOLOGY NODE* ***(1999 ITRS)***	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
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2000 UPDATE TABLES

*Table 52 Factory Operations Technology Requirements***

YEAR *TECHNOLOGY NODE* *WAFER DIAMETER*	*1999* *180 nm* *200 mm*	*2001* *130 nm* *300 mm*	*2004* *90 nm* *300 mm*	*2008* *60 nm* *300 mm*	*2011* *40 nm* *300 mm*	*2014* *30 nm* *450 mm*
High Volume/Low Mix Factory Requirements						
Factory cycle time per mask layer (non-hot lot) [1, 2]	**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]	**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**	**< 11.5 months**	**< 11 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**

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Notes for Table 52 for Factory Operations Requirements

[1] Assume number of hot lots in the factory is less than 3 % of all lots

[2] Average number of wafers per hot lot ranges between 5 and 10

[3] Assume number of hot lots in the factory is less than 10 % of all lots

[4] Assumes variable number of wafers per lot

Explanation of items

Item	*Explanation*
Factory cycle time per mask layer	*A key metric of time to money. For example, if a process has 20 masking layers, and cycle time per mask layer is 1.5, then total factory (fabrication+sort) cycle time is 20×1.5 = 30 days.*

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Year of Production *Technology Node* ***(1999 ITRS)***	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
Year of Production *Technology Node* ***(Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

Number of lots per carrier	*Number of lots in each carrier that needs to be tracked, monitored, and processed at each production equipment. It is also a measure of the extent of "recipe cascading" needed to enable production equipment to run in a continuous (non-stop) mode between lots in the same carrier and between sequential carriers.*
Groundbreaking to first full loop wafer out	*A key metric of new factory ramp-up time. This is the time elapsed in months from groundbreaking start to first full loop wafer out.*
Total number of operators and technicians in the factory	*It is expected the number of factory operators will decrease over time on a relative basis.*
Process/product changeover time	*The time in weeks for a new product or process to be implemented in a working factory (production equipment carry-in to first lot out). About 80% of the current equipment is reused and 20% is new. Furnace and wet process equipment are not replaced.*

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*Table 53 Production Equipment Technology Requirements***

YEAR *TECHNOLOGY NODE* *WAFER DIAMETER*	*1999* *180 nm* *200 mm*	*2001* *130 nm* *300 mm*	*2004* *90 nm* *300 mm*	*2008* *60 nm* *300 mm*	*2011* *40 nm* *300 mm*	*2014* *30 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, gases, chemicals, exhaust, emissions, and utilities		**<1.0×200 mm**	**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) [6]	**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) [7]	**> 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**

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[6] SEMI. E79-0299 – *Standard for Definition and Measurement of Equipment Productivity.*

[7] SEMI. E10-0699E – *Standard for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM).*

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Notes for Table 53 for Production Equipment Requirements

[1] Moore's law requires 29% cost reduction per function per year. Lithography improvements contribute 15 to 20 % cost reduction per year. A significant part of the remainder must be made up by improvements in factory productivity through better operational efficiency, lower costs and cycle time reductions. This is very important for production equipment since it is the largest component of factory cost.

[2] See References for a discussion of the basis for the 1.3 ratio. [8],[9].

[3] Reused from 1998 Roadmap. [10]

[4] Relevant to basic equipment processing capability only.

[5] This line is intended to drive increasingly better awareness of supply chain management.

[6] Equipment availability includes all components. Examples: process chambers, load ports, wafer handling systems, embedded controllers, mini-environment.

Explanation of Items

Item	*Explanation*
Relative capital cost	*For 130 nm node, it is the ratio of (300 mm equipment capital cost/300 mm throughput in wafers per hour) divided by (200 mm equipment capital cost/200 mm throughput in wafers per hour). For the 100 nm node and beyond capital cost is 98% of previous node assuming the same throughput.*
Relative consumables, exhaust, emissions, and utilities	*For the 130 nm node, relative consumables is a ratio of (300 mm consumables/300 mm throughput in wafers per hour) divided by (200 mm consumables/200 mm throughput in wafers per hour). The same methodology applies for gases, chemicals, exhaust, emissions, and utilities. For the 100 nm node and beyond consumables is 90% of previous node assuming the same throughput. Global warming and general ESH initiatives may force additional tightening of this requirement.*
Bottleneck production equipment OEE	*Overall equipment effectiveness of the bottleneck production equipment. Typically, the bottleneck is the most expensive machine group in the factory. (Refer to SEMI E79 for OEE definition.)*
Average production equipment OEE	*Overall equipment effectiveness of the average production equipment. Typically, the bottleneck is the most expensive machine group in the factory. (Refer to SEMI E79 for OEE definition.)*
Relative equipment footprint	*For the 130 nm node, it is ratio of (300 mm equipment footprint/300 mm throughput in wafers per hour) divided by (200 mm equipment footprint/200 mm throughput in wafers per hour). For the 100 nm node and beyond, footprint is 98% of previous node assuming the same throughput. [Refer to SEMI E72.* [11] *The footprint used here infers to the cost footprint in the SEMI standard.]*
Relative maintenance and spares cost	*For the 130 nm node, it is ratio of (300 mm maintenance and spares cost/300 mm throughput in wafers per hour) divided by (200 mm maintenance and spares cost/200 mm throughput in wafers per hour). For the 100 nm node and beyond it is 98% of previous node assuming the same throughput.*
Overall factory non-product wafer usage (per wafer start)	*Ratio of total non-production wafer consumption divided by total production wafer started for the same period. Typical nonproduct wafers include test wafers, monitor wafers, calibration wafers, dummy wafers.*

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[8] SEMATECH. *I300I Factory Guidelines: Version 4.1*. 97063311E-ENG. Austin, TX: SEMATECH. July 15, 1999.

[9] Daniel Seligson, "The Economics of 300 mm Processing," *Semiconductor International*, vol. 21, number 1, January 1998, pages 52-58.

[10] Semiconductor Industry Association. "National Technology Roadmap for Semiconductors: 1998 Update." Austin, TX:SEMATECH, 1999.

[11] SEMI. E72-0699 – *Provisional Specification and Guide for 300 mm Equipment Footprint, Height, and Weight.*

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YEAR OF PRODUCTION TECHNOLOGY NODE **(PROPOSED NODE YEARS ARE NOW 2007/65NM; 2010/45NM; 2013/33NM; 2016/23NM) (SC. 2.0)**	*1999 180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 NM]**	2011 **[40 NM]**	2014 **[30 NM]**

% Capital equipment reused from one process node to next	*% of capital (production) equipment quantity that is reused from node N to N+1. Example: if X number of production equipment of node N can be reused for node N+1 and the total number of production equipment for node N+1 is Y, then equipment reuse % is defined as X/Y .*
Wafer edge exclusion	*Dimension in millimeters measured from wafer edge that is not used for printing saleable chips.*
Production equipment lead time (months from order to full throughput in factory)	*Time elapsed between when a purchase order has been placed for a production equipment until the time the equipment has been installed in the factory and qualified to run wafers at the quoted throughput (wafers per hour).*
Production equipment installation, hookup and qualification cost as a % of capital cost	*Ratio of (installation cost + hook-up cost + qualification cost) divided by the capital cost of the production equipment, expressed as a percentage.*
Process equipment availability	*Availability is 100% minus (scheduled downtime % + unscheduled downtime %) of the production equipment. Scheduled downtime and unscheduled downtimes are defined in SEMI E10.*
Metrology equipment availability	*Metrology equipment availability as defined by SEMI E10. This is 100% minus (scheduled downtime % + unscheduled downtime %) of the metrology equipment.*
Number of process recipes per carrier	*Indicates a requirement on all single wafer processing equipment to incorporate the ability to automatically change recipe and process parameters between any two wafers in a carrier and to do so in a continuous manner without interruption or manual intervention.*

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*Table 54 Material Handling Systems Technology Requirements***

Year *Technology Node* *Wafer Diameter*	*1999* *180 nm* *200 mm*	*2001* *130 nm* *300 mm*	*2004* *90 nm* *300 mm*	*2008* *60 nm* *300 mm*	*2011* *40 nm* *300 mm*	*2014* *30 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**

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Notes for Table 54 for Material Handling Requirements

[1] Year 2002—High throughput transportation
[2] Year 2005—Direct transportation and fewer stockers

Explanation of Items

Item	*Explanation*
Material handling total capital cost as a % of total capital cost	*Ratio of total capital cost of material (wafer and reticle, inter and intrabay) handling hardware divided by the total capital cost for production equipment and the building, expressed a percentage. For example, if the material handling cost is $30M, and the factory (capital equipment and building cost) is $1000M, then this ratio is 30/1000 = 3%.*
Transport system types within a factory	*Transport system types used in a factory for handling wafer carriers. Typically, today these are interbay and intrabay transport systems. In the future, there is a need to have one system that performs both the interbay and the intrabay transport functions. This does not mean one system from one supplier. This system maybe composed of interoperable sub-systems from multiple (best of breed) suppliers.*
MTTR	*Mean Time To Repair, in minutes, for the fully-integrated system. This means the mean unscheduled downtime (defined by SEMI E10) while repairing any system component.*
Failures per 24 hour day (over total system)	*Number of system component failures allowed throughout the system in a 24 hour day (or period). (Refer to SEMI E10 for more details on failure definition.)*
System throughput	*Number of material handling moves per hour by the sub-system. A move is defined as a carrier move from either a stocker storage bin to a production equipment load port or a carrier move from a production equipment to a stocker storage bin or a carrier move from Stocker X storage bin to Stocker Y storage bin or a carrier move from one stocker port/storage bin to the another storage bin/port of the same stocker.*
Stocker cycle time	*Time required, in seconds, for the stocker internal robot to travel to a carrier at a port or storage bin, pickup the carrier, and deliver it to another port or storage bin within the same stocker.*
Factory-wide carrier delivery time	*Time required, in minutes, to transport a carrier from one production equipment to any other production equipment in the factory. The time begins at the request for carrier movement and ends when the carrier arrives at the load port of the receiving equipment. Maximum delivery time is considered the peak performance capability defined as the average plus two standard deviations.*

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*Table 55 Factory Systems Technology Requirements [1]***

Year *Technology Node* *Wafer Diameter*	*1999* *180 nm* *200 mm*	*2001* *130 nm* *300 mm*	*2004* *90 nm* *300 mm*	*2008* *60 nm* *300 mm*	*2011* *40 nm* *300 mm*	*2014* *30 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)	**< 24**	**< 24**	**2**	**2**	**< 1**	**< 1**
Number of process recipes per carrier	**Single**	**Multiple**	**Multiple**	**Multiple**	**Multiple**	**Multiple**

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Notes for Table 55 for Factory Systems Requirements

[1] Supply chain management standardization and conformance needs to be addressed in future editions of this roadmap.

[2] Standardization for 450 mm must occur five years prior to high volume production (one year for Global Joint Guidelines (GJG) , two years for standards, and two years for development and validation). [12, 13]

Explanation of Items

Item	*Explanation*

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[12] International 300 mm Initiative and Japan 300 mm Semiconductor Technology Conference (J300). "Global Joint Guidance for 300 mm Semiconductor Factories, version 1." July 1997.

[13] SEMATECH. *CIM Global Joint Guidance for 300 mm Semiconductor Factories: Release Four*. 98063534C-ENG. Austin, TX:SEMATECH, declassed, July 30, 1999.

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2000 Update										
Year of Production Technology Node ***(1999 ITRS)***	*1999 180 nm*	*2000*	*2001*	*2002 130 nm*	*2003*	*2004*	*2005 100 nm*	*2008 70 nm*	*2011 50 nm*	*2014 35 nm*
Year of Production Technology Node ***(Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999 180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

Factory systems cost including integration	*Percentage of overall factory cost spent on factory systems. Initial investment for factory only. Does not include software maintenance and yearly operating costs. Includes computer hardware, software application development, software license, network, and integration.*
MTBF for mission critical applications	*Mean Time Between Failure (MTBF) for mission critical application (unscheduled) downtime. Mission critical applications within the factory systems are those that are required to keep the entire wafer factory operational (documented in the supplemental material). MTBF is measured in months and on a per installation basis.*
Mean time to recover for mission critical applications	*Mean time to recover a mission critical application following an unscheduled downtime. Mission critical applications within the factory system are those that are required to keep the entire wafer factory operational. Mean time to recover is measured in minutes per incident.*
Factory system reuse	*Percentage of factory systems (both computer hardware and software) that is reused from process technology node to process technology node measured in cost.*
% of equipment to factory systems interface standards defined	*Percentage of equipment embedded controller to factory systems interfaces that have defined industry standards for each technology node as required by the Roadmap.*
% conformance: equipment to factory systems interface standards	*Percentage of equipment that comply with industry standard interfaces to factory systems for each technology node as required by the Roadmap.*
% of factory systems to factory systems interface standards defined	*Percentage of factory systems to factory systems interfaces that have defined industry standards for each technology node as required by the Roadmap.*
% conformance: factory systems to factory systems interface standards	*Percentage of factory systems that comply with industry standard interfaces to factory systems for each technology node as required by the Roadmap.*
Time to install/upgrade a mission critical application in a working factory (minutes)	*Down time, in minutes, to install or upgrade a mission critical application while the factory is in production. This includes the time to upgrade hardware, software, and database portions of an overall factory application. Note that database upgrades assume no change to the database schema nor updates to the database contents itself. These scenarios are covered in the metric below, "Time to install/upgrade a mission critical database in a working factory (hours)."* *Frequency of required upgrades should be <1 per year. More frequent upgrades at user request.*
Time to install/upgrade a mission critical database in a working factory (hours)	*Down time, in hours, to install or upgrade a mission critical database while the factory is in production. This includes the time to upgrade and reconfigure the database portions of an overall factory application.* *Frequency of required upgrades should be <1 per year. More frequent upgrades at user request.*
Number of process recipes per carrier	*Indicates a requirement on factory systems to incorporate the ability to automatically change recipe and process parameters between any two wafers in a carrier on production equipment and to do so in a continuous manner without interruption or manual intervention. Also includes the ability to track and control multiple lots per carrier.*

*** In response to the observed acceleration of the Technology Nodes (TN) represented by DRAM half-pitch, the IRC proposes a new TN called Scenario 2 (SC. 2.0) for the year 2001 Renewal. However, due to the lack of time the subsequent contents of this Table are not updated to reflect the new TN.*

All modifications of the items and/or numericals modified from the 1999 ITRS are based on the TN of ITRS 1999 and are highlighted in bold blue text.

2000 UPDATE										
YEAR OF PRODUCTION *TECHNOLOGY NODE* ***(1999 ITRS)***	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
YEAR OF PRODUCTION *TECHNOLOGY NODE* ***(PROPOSED NODE YEARS ARE NOW 2007/65NM; 2010/45NM; 2013/33NM; 2016/23NM) (SC. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 NM]**	2011 **[40 NM]**	2014 **[30 NM]**

*Table 56 Facilities Technology Requirements***

YEAR *TECHNOLOGY NODE* *WAFER DIAMETER*	*1999* *180 nm* *200 mm*	*2001* *130 nm* *300 mm*	*2004* *90 nm* *300 mm*	*2008* *60 nm* *300 mm*	*2011* *40 nm* *300 mm*	*2014* *30 nm* *450 mm*
Factory construction cost per cleanroom area ($/m^2) [1]	**1999 factory costs**	**95% of previous node**	**95% of previous node**	**95% of previous node**	**95% of previous node**	**95% of previous node**
Factory construction time (months)	**12**	**11**	**10**	**10**	**10**	**9.5**
Facilities services reliability (%)	**99 %**	**99.5%**	**99.9%**	**99.9%**	**99.9%**	**99.9%**
Cleanroom cleanliness class [2]	**ISO Class 3–5 (Class 1–100)**	**ISO Class 3–5 (Class 1–100)**	**ISO Class 5–6 (Class 100–1000)**	**ISO Class 5–6 (Class 100–1000)**	**ISO Class 5–6 (Class 100–1000)**	**ISO Class 5–6 (Class 100–1000)**

Solutions Exist ☐ *Solutions Being Pursued* 🟨 *No Known Solutions* 🟥

Notes for Table 56 for Facilities Requirements

[1] In this table, the 1999 cost entries represents the current required levels for the 1999 180 nm technology node.

[2] It is generally believed that achieving ISO Class 6 (Class 1000) results in significant cost savings in facilities and building systems However, the industry must comprehend the ability of production equipment to operate in this environment.

Performance requirements enabling facilities to prevent defects and maintain process critical fluids and materials purity requirements are discussed in the Defect Reduction Chapter.

Performance requirements affecting facilities involving natural resources conservation are discussed in the ESH chapter and involving gases, chemicals, exhaust, emissions, and utilities usage are discussed in the Process Equipment section of this chapter.

Performance requirements affecting facilities involving production equipment installation are discussed in the Process Equipment sections of this chapter.

Explanation of Items

Item	*Explanation*
Factory construction cost per cleanroom area ($/m^2)	*Factory construction cost includes all site work, design, construction and construction management costs for the construction of a semiconductor factory. This includes construction of the factory building shell, office space, factory cleanroom, support spaces, central utility pad or building, mechanical systems, ultrapure water systems, wastewater treatment systems, bulk gas and chemical systems, life-safety systems, control systems, and electrical systems. This excludes costs for land, production equipment, and gas/chemical distribution systems typically included in production equipment installation.*
Factory construction time (months)	*Factory construction time is defined by the formula as the period in months from first concrete pour to the time the first piece of production equipment is ready for qualification. The term "first concrete pour" is equivalent to the term "groundbreaking" used in Table 52 for Factory Operations Technology Requirements.*
Facilities services reliability (%)	*Facilities services reliability is defined as [(total hours/year of operation)-(total hours/year of utility interruption) (outage or out of specification)] divided by [(total hours/year of operation)]. Facilities Services include all utilities for which the facilities organization is responsible (such as power, water, fuel, house gases and wastewater). Interruptions include both utility outages and out-of-specification conditions. Utility performance specifications are established by process engineering typically using industry standards for the device size geometries being produced.*
Cleanroom class	*Cleanliness class of wafer factory cleanroom as defined by ISO 14644-1 (and Fed Std. 209E).* [14]

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[14] Federal Standard 209E (FED-STD-209E). *Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones.*

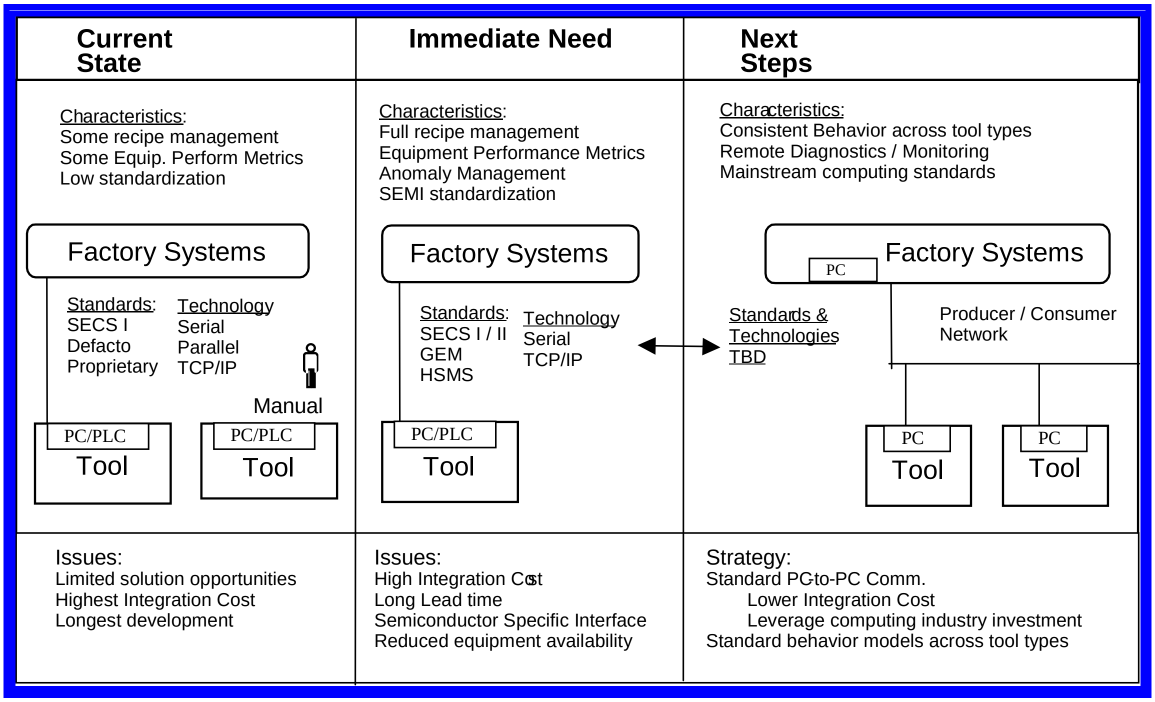
*** In response to the observed acceleration of the Technology Nodes (TN) represented by DRAM half-pitch, the IRC proposes a new TN called Scenario 2 (SC. 2.0) for the year 2001 Renewal. However, due to the lack of time the subsequent contents of this Table are not updated to reflect the new TN.*

All modifications of the items and/or numericals modified from the 1999 ITRS are based on the TN of ITRS 1999 and are highlighted in bold blue text.

2000 Update										
Year of Production *Technology Node* ***(1999 ITRS)***	*1999* *180 nm*	*2000*	*2001*	*2002* *130 nm*	*2003*	*2004*	*2005* *100 nm*	*2008* *70 nm*	*2011* *50 nm*	*2014* *35 nm*
Year of Production *Technology Node* ***(Proposed node years are now 2007/65nm; 2010/45nm; 2013/33nm; 2016/23nm) (Sc. 2.0)***	*1999* *180 nm*	*2000*	*2001* ***130 nm***	*2002*	*2003*	*2004* ***90nm***	*2005*	2008 **[60 nm]**	2011 **[40 nm]**	2014 **[30 nm]**

*New Figure 43 Assembly, Packaging, and Test Potential Solutions***

KEY ISSUES	***POTENTIAL SOLUTIONS***
Material Handling Costs	***Carrier standards*** ***Media standards*** ***Production equipment load/unload interface standards***
Equipment Communication Costs	***Adherence to existing proven standards*** ***Improved Equipment<-->Host communications standards*** ***Standard behavioral Models across equipment types*** ***Tester <-> Prober/Handler interface standards***



*** In response to the observed acceleration of the Technology Nodes (TN) represented by DRAM half-pitch, the IRC proposes a new TN called Scenario 2 (SC. 2.0) for the year 2001 Renewal. However, due to the lack of time the subsequent contents of this Table are not updated to reflect the new TN.*

All modifications of the items and/or numericals modified from the 1999 ITRS are based on the TN of ITRS 1999 and are highlighted in bold blue text.