INTERNATIONAL
TECHNOLOGY ROADMAP
FOR
SEMICONDUCTORS

2004 UPDATE

Factory Integration

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FACTORY INTEGRATION

2004 UPDATE HIGHLIGHTS

The International Technology Roadmap for Semiconductors (ITRS) is a 15 year roadmap that analyzes the industry's difficult challenges and technology requirements and then formulates potential solutions to meet these needs. The pace of technology is governed by the desire to stay on Moore's law, reduce cost per function by 30% per year [historic norms], and deliver new and compelling IC devices that continue our industry's growth.

While most of the ITRS focuses on process technology, the objective of the Factory Integration chapter is to ensure that our factories fully integrate physical and data elements of the factories to enable the development and high volume running of these process technologies so that the right products are made in the right volumes on schedule, while meeting cost targets. Historically, cost per function has been reduced through a technology advances such as device feature size reductions, yield improvement to near 100% and wafer size increases (i.e. 300mm wafers). It is expected that improvements in manufacturing productivity will play an even greater future role in reducing time to money and getting the most out of the factory investment. The need for future break-through technologies and capabilities that radically improve semiconductor factory design and manufacturing has never been greater. The scope of factory integration covers operations, AMHS, information systems, facilities and equipment in the fab area.

The focus for the FI team this year is to review difficult challenges, update technology requirements table, potential solutions table and to identify key focus areas to work on. For year 2004, the difficult challenges remained the same and most of the technology requirements and potential solutions table were unchanged except for small changes. However, the team identified the following 9 focus areas including AMC, 450mm wafer transition, etc.:

2004 ITRS FI focus areas:

- Airborne Molecular Contamination (AMC) Implications at < 45nm process technologies (Now →2006)
- Implications of Relaxed Fab Facility Cleanliness (Now →)
- Litho EUV: Design for Manufacturability (2006 →2010?)
- Fab Point of Use vs. Bulk Systems (Now →)
- Rapid Equipment Install and Qualification (Now →)
- Integrated Metrology Guidelines (Now →)
- Wafer and Unit Traceability from Fab through Packaging (Now →)
- "Proactive Visual" manufacturing (Now →)
- 450mm Wafer Size Transition (2005 →2012)

The team is currently working on selecting top 3-4 focus areas in order to put together sub-teams to define the impact of these focus areas on FI and also on other cross-cut ITRS chapters.

Link to the 2003 ITRS Factory Integration chapter

WORKING GROUP TABLES

Table 84a Factory Integration Difficult Challenges—Near-term

Difficult Challenges ≥45 nm/Through 2009	*Summary of Issues*
Responding to Rapidly Changing, Complex Business Requirements	Many new and co-existing business models including IDM, Foundry, Joint Ventures, Collaborations, other Outsourcing, etc Increased expectations by customers for faster delivery of new and volume products Need for improve integration of the entire product design and manufacturing process Faster design -> prototype and prototype -> volume production Enhanced customer visibility into outsourced production operations Reduced time to ramp factories, products, and processes to stay competitive within the rapidly changing business environment Building 30+ mask layer System on a Chip (SoC) with long cycle times where needs are rapidly changing Rapid and frequent factory plan changes driven by changing business needs Ability to model factory performance so that output can be optimized Ability to constantly adjust equipment loading to keep the factory profitable Need to run globally disparate factories as single “virtual factory”
Achieving Growth Targets while Margins are Declining	Implications of rising wafer, packaging, and other materials cost on meeting cost targets Meeting high factory yield much faster at startup Addressing increased complexity while keeping costs in check Reducing complexity and waste across the supply chain Inefficiencies introduced by non-product wafers (NPW) competing for resources with production wafers High cost and cycle time of mask sets for manufacturers impacting affordability of new product designs Increasing dedication of masks and equipment causing manufacturing inefficiencies Challenges introduced with sharing of mask sets Difficulty maintaining the historical 0.7× transistor shrink per year for die size and cost efficiency
Managing Ever Increasing Factory Complexity	Quickly and effectively integrating rapid changes in process technologies Managing carriers with multiple lots, wafers with multiple products, or multiple package form factors Comprehending increased purity requirements for process and materials Need to run aluminum and copper back end in the same factory Increasing number of processing steps coupled with process and product complexity Need to concurrently manage new and legacy software systems and systems with increasingly high interdependencies Explosive growth of data collection/analysis requirements driven by process and modeling needs Increased requirements for wafer level tracking and die level tracking
Meeting Factory and Equipment Reliability, Capability or Productivity Requirements per the Roadmap	Process equipment not meeting availability, run rate, and utilization targets out of the box Stand alone and integrated reliability for equipment and systems to keep factories operating Increased impacts that single points of failure have on a highly integrated and complex factory Quality issues with production equipment embedded controllers Lack of good data to measure equipment and factory effectiveness for optimization and improvement programs Factory capacity planning and supply chain management systems are not continuously base lined with actual factory data creating errors Lack of migration paths which inhibit movement from old inefficient systems to new highly productive systems

Table 84b Factory Integration Difficult Challenges—Long-term

Difficult Challenges ≥45 nm/Through 2009	*Summary of Issues*
Meeting the Flexibility, Extendibility, and Scalability Needs of a Cost-effective, Leading-edge Factory	Need to quickly convert factories to new process technologies while reusing equipment, facilities, and skills Minimizing downtime to on-going operations while converting factories to new technologies Scalability implications to meet large 300 mm factory needs [50K WSPM] Continued need to improve both throughput and cycle time Reuse of building, production and support equipment, and factory information and control systems across multiple technology nodes Understanding up-front costs to incorporate EFS Ability to convert 200 mm facilities to 300 mm wafer size Comprehending increased purity requirements for process and materials Accelerating the pace of standardization to meet industry needs
Meeting Process Requirements at 65 nm and 45 nm Nodes Running Production Volumes	Small process windows and tight process targets at 65 nm and 45 nm nodes in many modules make process control increasingly difficult Complexity of integrating next generation lithography equipment into the factory Overall development and volume production timelines continuing to shrink Device and process complexity make the ability to trace functional problems to specific process areas more difficult Difficulty in running different process parameters for each wafer while maintaining control windows and cycle time goals Reducing the impacts of parametric variation
Increasing Global Restrictions on Environmental Issues	Need to meet regulations in different geographical areas Need to meet technology restrictions in some countries while still meeting business needs Comprehending tighter ESH/Code requirements Lead free and other chemical and materials restrictions New material introduction
Difficult Challenges <45 nm/2010 Through 2018	*Summary of Issues*
Post-conventional CMOS Manufacturing Uncertainty	Uncertainty of novel device types replacing conventional CMOS and the impact of their manufacturing requirements will have on factory design Timing uncertainty to identify new devices, create process technologies, and design factories in time for a low risk industry transition Potential difficulty in maintaining an equivalent 0.7× transistor shrink per year for given die size and cost efficiency Need to run CMOS and post CMOS processes in the same factory
Emerging Factory Paradigm and Next Wafer Size Change	Uncertainty about the next wafer size [450 mm] and the conversion timing [See Backup material as a link in the electronic chapter at http://public.itrs.net.] Traditional strategies to scale wafers and carriers for the next wafer size conversion may not work with [450 mm] 25 wafer carriers and drive significant production equipment and material handling changes Uncertainty concerning how to reuse buildings, equipment, and systems to enable the next wafer size conversion [to 450 mm] at an affordable cost

Table 85a Factory Operations Technology Requirements—Near-term

Year of Production	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Technology Node		*hp90*			*hp65*		
DRAM ½ Pitch (nm)	*100*	*90*	*80*	*70*	*65*	*55*	*50*
MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	*107*	*90*	*80*	*70*	*65*	*55*	*50*
Wafer Diameter (mm)	*300*	*300*	*300*	*300*	*300*	*300*	*300*
Non-hot lot (average of 94% lots) Cycle time per mask layer (days). X-Factor [1]	**1.6** **3.2**	**1.6** **3.2**	**1.6** **3.2**	**1.5** **3.1**	**1.5** **3.1**	**1.5** **3.1**	**1.4** **3.05**
Hot lot (average top 5% of lots) Cycle time per mask layer (days) X-Factor [1]	**0.62** **1.4**	**0.62** **1.4**	**0.62** **1.4**	**0.55** **1.3**	**0.55** **1.3**	**0.55** **1.3**	**0.51** **1.3**
Super hot lot (average top 1% of lots) Cycle time per mask layer (days)	**0.33**	**0.33**	**0.33**	**0.32**	**0.32**	**0.32**	**0.31**
High-mix capacity degradation	**15%**	**13.33%**	**11.67%**	**10%**	**8.33%**	**6.67%**	**5%**
Bottleneck equipment [2] [3] Utilization Availability	**90%** **92%**	**90%** **92%**	**90%** **92%**	**92%** **94%**	**92%** **94%**	**92%** **94%**	**94%** **96%**
Wafer layers/day/head count	**55**	**55**	**55**	**61**	**61**	**61**	**67**
Number of lots per carrier (high mix) [4]	**Multiple**	**Multiple**	**Multiple**	**Multiple**	**Multiple**	**Multiple**	**Multiple**
Facilities cycle time (months) 1st tool to 1st full loop wafer out	**4**	**3.5**	**3.5**	**3**	**3**	**2.5**	**2.5**
Node -to-node change-over (weeks)	**13**	**13**	**13**	**12**	**12**	**12**	**11**
Floor space effectiveness	**1×**	**1×**	**1×**	**1×**	**1×**	**1×**	**1×**
Average number of wafers between reticle changes	**50**	**45**	**40**	**35**	**30**	**25**	**20**

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Notes for Tables 85a and 85b:

[1] X-factor is shown for continuous improvement. Actual X-Factor values will depend heavily on raw process time for a given process technology or generation.

[2] A bottleneck tool usually refers to a lithography tool

[3] Utilization and Availability are shown for continuous improvement

[4] High mix is defined as the followings:

- *Running > three technology generation concurrently in the same Fab*
- *Running > ten process flows within the same technology generation*
- *Running > 50 products concurrently through the Fab*
- *Many of small lots of 1–10 wafers in size*
- *Running an average of < 50 wafers between Reticle changes for each lithography expose equipment*
- *Lot starts are based on customer orders. There is a daily variation in the number of lots you start with different products and process flows*
- *At least five large volume products (product flows) with no one product having >50% of production volume*

Table 85b Factory Operations Technology Requirements—Long-term UPDATED

	Year of Production	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Technology Node	hp45			hp32			hp22		
	DRAM ½ Pitch (nm)	45	40	35	32	28	25	22	20	18
	MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	45	40	35	32	28	25	22	20	18
	Wafer Diameter (mm)	300		450	450		450	450		450
	Non-hot lot (average of 94% lots)									
WAS	Cycle time per mask layer (days).	1.4	-	1.2	1.2	-	1.13	1.13	-	1.05
IS	Cycle time per mask layer (days).	1.4	1.2	1.2	1.2	1.2	1.13	1.13	1.13	1.05
WAS	X-Factor [1]	3.05	-	3.05	3.05	-	3.05	3.05	-	3
IS	X-Factor [1]	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3
	Hot lot (average top 5% of lots)									
WAS	Cycle time per mask layer (days)	0.51	-	0.47	0.47	-	0.44	0.44	-	0.39
IS	Cycle time per mask layer (days)	0.51	0.47	0.47	0.47	0.47	0.44	0.44	0.44	0.39
WAS	X-Factor [1]	1.3	-	1.2	1.2	-	1.2	1.2	-	1.1
IS	X-Factor [1]	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1
	Super hot lot (average top 1% of lots)									
WAS	Cycle time per mask layer (days)	0.31	-	0.3	0.3	-	0.3	0.3	-	0.3
IS	Cycle time per mask layer (days)	0.31	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
WAS	High-mix capacity degradation	5%	-	5%	5%	-	5%	5%	-	5%
IS	High-mix capacity degradation	5%	5%	5%	5%	5%	5%	5%	5%	5%
	Bottleneck equipment [2] [3]									
WAS	Utilization	94%	-	94%	94%	-	94%	94%	-	94%
IS	Utilization	94%	94%	94%	94%	94%	94%	94%	94%	94%
WAS	Availability	96%	-	96%	96%	-	96%	96%	-	96%
IS	Availability	96%	96%	96%	96%	96%	96%	96%	96%	96%
WAS	Wafer layers/day/head count	67	-	73	73	-	81	81	-	89
IS	Wafer layers/day/head count	67	73	73	73	73	81	81	81	89
WAS	Number of lots per carrier (high mix) [4]	Multiple	-	Multiple	Multiple	-	Multiple	Multiple	-	Multiple
IS	Number of lots per carrier (high mix) [4]	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Table 85b Factory Operations Technology Requirements—Long-term UPDATED (continued)

	Year of Production	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
	Technology Node	*hp45*			*hp32*			*hp22*		
	DRAM ½ Pitch (nm)	*45*	*40*	*35*	*32*	*28*	*25*	*22*	*20*	*18*
	Facilities cycle time (months)									
WAS	1st tool to 1st full loop wafer out	**2.5**	**-**	**2**	**2**	**-**	**1.5**	**1.5**	**-**	**1**
IS	2nd tool to 1st full loop wafer out	**2.5**	**2**	**2**	**2**	**2**	**1.5**	**1.5**	**1.5**	**1**
WAS	Node -to-node change-over (weeks)	**11**	**-**	**10**	**10**	**-**	**9.5**	**9.5**	**-**	**9**
IS	Node -to-node change-over (weeks)	**11**	**10**	**10**	**10**	**10**	**9.5**	**9.5**	**9.5**	**9**
WAS	Floor space effectiveness	**1×**	**-**	**1×**	**1×**	**-**	**1×**	**1×**	**-**	**1×**
IS	Floor space effectiveness	**1×**	**1×**	**1×**	**1×**	**1×**	**1×**	**1×**	**1×**	**1×**
WAS	Average number of wafers between reticle changes	**20**	**-**	**20**	**20**	**-**	**15**	**15**	**-**	**13**
IS	Average number of wafers between reticle changes	**20**	**20**	**20**	**20**	**21**	**15**	**15**	**16**	**13**

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Explanation of Items for Factory Operations Requirements

Item	*Explanation*
Factory cycle time per mask layer (non-hot lot)	*Measure of total time to process a wafer lot per mask layer. Assume 25 wafers per lot. For example, if a process has 20 masking layers, and cycle time per mask layer is 1.5, then total factory (fabrication) cycle time is 20 × 1.5 = 30 days. A key metric of time to money.*
Factory cycle time per mask layer (hot lot)	*Same definition as of above. Factories typically prioritize these lots over non-hot lots. As a result, the cycle time for hot lots are < 50% of non-hot lots. Assume 25 wafers per lot. New product introduction lots can be processed as hot lots*
Factory cycle time per mask layer (super-hot lot)	*Assume ~ five wafers per lot. Factories typically prioritize these lots over conventional lots, hold tools downstream to rapidly move them through the process flow and reduce sampling rates. As a result, the cycle time for super hot lots are shorter than hot lots.*
X-factor [1]	*X-factor is the total cycle time (queue time + hold time + raw process time + travel time) divided by the raw process time (RPT). Raw process time for a lot at a tool is the time it takes to process a lot on the tool. Generally this time will be from when the tool starts to process the lot (and thus cannot be moved to another tool for processing) until the lot is finished and can be moved to the next operation. Raw process time for a technology is the sum of the raw process times for each of the tools in the processes in the technology plus the total travel time. Raw process time is not shown in the technology table since X factor and cycle time per mask layers are shown.* *The relationship is: cycle time = raw process time × X-factor* *Assume current cycle time is 1.6 days/mask level and the X-factor for normal lots is 3.2 at 80% utilization. Thus RPT for normal lots = 1.6/3.2 = 0.5* *Assume same RPT for normal and hot lots. X-factor for hot lots is determined by "last-in-first-out" priority*

Explanation of Items for Factory Operations Requirements (continued)

Item	*Explanation*
High-mix capacity degradation	*The penalty paid by factory operations in terms of lost capacity due to high mix (measured in %). This capacity loss is caused by reduced batch sizes, increased set ups, etc. This is the average for all tool sets in the line. Degradation increases from 5% (low mix, 25 wafers/FOUP, change recipe/setup every ten lots, single product on a wafer) to maximum. Of 15% (high-mix, <25 wafers/FOUP, change recipe/setup for every FOUP, multiple product in a lot). This metric impact the utilization of effective capacity, which is best, defined as being (1–(Idle No WIP)).* *Idle No WIP is the fraction of a tool's capacity that is idle when the tool is up and there is no WIP either waiting to be run on the tool or in transit to the tool. In some cases, No operator can also contribute to utilization of effective capacity.*
Bottleneck equipment utilization and availability [2] [3]	*Availability is defined in SEMI E10[1] as "the probability that the equipment will be in a condition to perform its intended function when required."* *Utilization is defined in SEMI E10 as "the percentage of time the equipment is performing its intended function during a specified time period." All based on 25-wafer lot. Availability includes setup, idle and processing time, utilization is considered as time directly adding value of constraint equipment (usually lithography tools) measured in % without sacrificing cycle time. Constraint equipment utilization (normally lithography) is the pulse of the Fab and usually determines the output capacity.*
Wafer layers/day/head count	*Measure of productivity that includes equipment output and direct labor staffing.* *Equation = total wafer processed per day in the factory × number of lithography mask layers/total number of direct labor employees per day.*
Number of lots per carrier (high mix) [4]	*The number of lots in each carrier that need to be tracked, monitored, and processed. For high-mix factories, the number of wafers can be <25 per lot and the production equipment must be able to run a different recipe and/or parameters for each wafer within the carrier. It also requires the factory information and control system to be able to track, monitor, and control the wafer at each point the factory and within the equipment. The factory information and control system must have the ability to drive the production equipment to run different recipes and/or parameters for each wafer. Multiple lots per carrier mean more than one product lot. High mix is at least five large volume products (product flows) with no one product has >50% of production volume.*
Time to 1st wafer out time (months) –1st tool move-in to 1st full loop wafer out	*A key metric of new factory ramp-up time. This is the time elapsed in months from first tool move-in to first full loop wafer out.*
Node-to-node change-over (weeks)	*The time in weeks for a new product or process to be implemented in a working factory (production equipment move-in to first lot out). About 80% of the current equipment is reused and 20% is new. Equipment already in place or available and may need to be qualified. Furnace and wet process equipment are not replaced. Not serial number 1 equipment*
Floor space effectiveness	*This is a measure of equipment installation density in the clean room, and drives the requirement for the smallest footprint and the fastest run rate for production equipment.* *Equation = (Number of processing steps in the Fab × WSPM/(floor space area × 30 days).* *For every major node, one additional metal layer is added, and assuming a 4% increased run-rate improvement each year (by reduced processing time per wafer), the best that can be mathematically achieved is getting the same output per square meters of clean room for each new node.*
Average number of wafers between reticle changes	*This is a measure of how efficiently high-product mix can be handled in the factory.* *As the metric indicates, it is the average number of wafers processed before a reticle is changed.*

FOUP—front opening unified pod

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[1] *SEMI E10-0699E: Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM).*

Table 86a Production Equipment Technology Requirements—Near-term UPDATED

	Year of Production	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*
	Technology Node		*hp90*			*hp65*			*hp45*
	DRAM ½ Pitch (nm)	*100*	*90*	*80*	*70*	*65*	*55*	*50*	*45*
	MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	*107*	*90*	*80*	*70*	*65*	*55*	*50*	*45*
	Wafer Diameter (mm)	*300*	*300*	*300*	*300*	*300*	*300*	*300*	*300*
WAS	Throughput improvement (run-rate) per year	**Base**	**Base**	**4%**	**New base**	**4%**	**4%**	**New base**	**+10 to 12%**
IS	Throughput improvement (run-rate) per year	**Base**	**Base**	**4%**	**4%**	**New base**	**4%**	**4%**	**+10 to 12%**
	New non-product wafers (NPW) as a % of wafer starts per week	**<16%**	**<15%**	**<14%**	**<13%**	**<12%**	**<11%**	**<11%**	**<11%**
	Overall NPW activities versus production wafers activities	**10%**	**10%**	**10%**	**7%**	**7%**	**7%**	**5%**	**5%**
	% capital equipment reused from previous node	**>90%**	**>90%**	**>90%**	**>90%**	**>90%**	**>90%**	**>90%**	**>90%**
WAS	Wafer edge exclusion	**3 mm**	**2mm**	**2mm**	**2mm**	**2mm**	**2mm**	**2mm**	**2mm**
IS	Wafer edge exclusion	**3 mm**	**2mm**	**2mm**	**1mm**	**1mm**	**1mm**	**1mm**	**1mm**
	Equipment lead time from setup to full throughput capable	**4 wks**	**4 wks**	**4 wks**	**4 wks**	**4 wks**	**4 wks**	**4 wks**	**4 wks**
WAS	Process availability (A80)	**>85%**	**>88%**	**>90%**	**>92%**	**>94%**	**>95%**	**>95%**	**>95%**
IS	Process availability (A80)	**>85%**	**>88%**	**92%**	**>92%**	**>94%**	**>95%**	**>95%**	**>95%**
WAS	Metrology availability (A80)	**>90%**	**92%**	**94%**	**>95%**	**95%**	**>96%**	**>97%**	**>98%**
IS	Metrology availability (A80)	**>90%**	**92%**	**96%**	**96%**	**96%**	**>96%**	**>97%**	**>98%**
WAS	Intrinsic setup time reduction year to year	**Base**	**10%**	**10%**	**10%**	**12%**	**12%**	**15%**	**15%**
IS	Intrinsic setup time reduction, vs. base	**Base**	**Base**	**6%**	**10%**	**12%**	**12%**	**15%**	**15%**
	Ability to run different recipes and parameters for each wafer	**Partial**	**Partial**	**Partial**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
	248 nm lithography scanner productivity (wafers outs per week per tool)	**7000**	**7400**	**7400**	**7400**	**7700**	**7700**	**8000**	**8000**
	193 nm lithography scanner productivity (wafers outs per week per tool)	**5000**	**5300**	**5300**	**5300**	**5600**	**5600**	**6000**	**6000**
	Maximum allowed electrostatic field on wafer and mask surfaces (V/cm)	**125**	**100**	**90**	**80**	**70**	**60**	**50**	**50**

Manufacturable solutions exist, and are being optimized	☐
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Table 86a Production Equipment Technology Requirements—Long-term UPDATED

	Year of Production	*2010*	***2011***	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
	Technology Node	*hp45*			*hp32*			*hp22*		
	DRAM ½ Pitch (nm)	*45*	***40***	*35*	*32*	*28*	*25*	*22*	*20*	*18*
	MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	*45*	***40***	*35*	*32*	*28*	*25*	*22*	*20*	*18*
	Wafer Diameter (mm)	*300*		*450*	*450*	*450*	*450*	*450*	*450*	*450*
WAS	Throughput improvement (run-rate) per year	**+10 to 12%**		**+10 to 12%**	**+10 to 12%**		**+10 to 12%**	**+10 to 12%**		**+10 to 12%**
IS	Throughput improvement (run-rate) per year	**+10 to 12%**	**+10 to 12%**	**+10 to 12%**	**+10 to 12%**	**+10 to 12%**	**+10 to 12%**	**+10 to 12%**	**+10 to 12%**	**+10 to 12%**
WAS	New non-product wafers (NPW) as a % of wafer starts per week	**<11%**		**<10%**	**<10%**		**<9%**	**<9%**		**<9%**
IS	New non-product wafers (NPW) as a % of wafer starts per week	**<11%**	**<10%**	**<10%**	**<10%**	**<10%**	**<9%**	**<9%**	**<9%**	**<9%**
WAS	Overall NPW activities versus production wafers activities	**5%**		**5%**	**5%**		**5%**	**5%**		**5%**
IS	Overall NPW activities versus production wafers activities	**5%**	**5%**	**5%**	**5%**	**5%**	**5%**	**5%**	**5%**	**5%**
WAS	% capital equipment reused from previous node	**>90%**		**>70%**	**>70%**		**Limited**	**Limited**		**>70%**
IS	% capital equipment reused from previous node	**>90%**	**>70%**	**>70%**	**>70%**	**>70%**	**Limited**	**Limited**	**Limited**	**>70%**
WAS	Wafer edge exclusion	**2mm**		**2mm**	**2mm**		**2mm**	**2mm**		**2mm**
IS	Wafer edge exclusion	**1mm**	**1mm**	**1mm**	**1mm**	**1mm**	**1mm**	**1mm**	**1mm**	**1mm**
WAS	Equipment lead time from setup to full throughput capable	**4 wks**		**5 wks**	**4 wks**		**4 wks**	**4 wks**		**4 wks**
IS	Equipment lead time from setup to full throughput capable	**4 wks**	**4 wks**	**5 wks**	**4 wks**	**5 wks**	**4 wks**	**4 wks**	**5 wks**	**4 wks**
WAS	Process availability (A80)	**>95%**		**>95%**	**>95%**		**>95%**	**>95%**		**>95%**
IS	Process availability (A80)	**>95%**	**>95%**	**>95%**	**>95%**	**>95%**	**>95%**	**>95%**	**>95%**	**>95%**
WAS	Metrology availability (A80)	**>98%**		**>98%**	**>98%**		**>98%**	**>98%**		**>98%**
IS	Metrology availability (A80)	**>98%**	**>98%**	**>98%**	**>98%**	**>98%**	**>98%**	**>98%**	**>98%**	**>98%**
WAS	Intrinsic setup time reduction year to year	**15%**		**17%**	**17%**		**17%**	**17%**		**20%**
IS	Intrinsic setup time reduction, vs. base	**15%**	**17%**	**17%**	**17%**	**17%**	**17%**	**17%**	**17%**	**20%**
WAS	Ability to run different recipes and parameters for each wafer	**Yes**		**Yes**	**Yes**		**Yes**	**Yes**		**Yes**
IS	Ability to run different recipes and parameters for each wafer	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
WAS	248 nm lithography scanner productivity (wafers outs per week per tool)	**8000**		**8000**	**8000**		**8300**	**8300**		**8500**
IS	248 nm lithography scanner productivity (wafers outs per week per tool)	**8000**	**8000**	**8000**	**8000**	**8000**	**8300**	**8300**	**8300**	**8500**
WAS	193 nm lithography scanner productivity (wafers outs per week per tool)	**6000**		**6000**	**6000**		**6300**	**6300**		**6500**
IS	193 nm lithography scanner productivity (wafers outs per week per tool)	**6000**	**6000**	**6000**	**6000**	**6000**	**6300**	**6300**	**6300**	**6500**
WAS	Maximum allowed electrostatic field on wafer and mask surfaces (V/cm)	**50**		**35**	**35**		**25**	**25**		**18**
IS	Maximum allowed electrostatic field on wafer and mask surfaces (V/cm)	**50**	**35**	**35**	**35**	**35**	**25**	**25**	**25**	**18**

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Explanation of Items for Production Equipment Requirements

	Item	*Explanation*
	Throughput improvement (run-rate) per year (high mix)	*Throughput improvements are achieved by reducing the processing time per wafer, and optimizing non-value added wafer handling and wafer-staging steps inside the equipment and by increasing the efficiency of the equipment embedded controller. Also eliminate any dead time between sequential wafer processing steps.* *If current run-rate is 100 wafers/hour, the required run-rate next year is (100 × 1.04) = 104 wafers/hour and (104 × 1.04) = 108 wafers/hour the following year.*
	New non-product wafers (NPW) as a % of wafer starts per week	*Ratio of new non-production wafer consumption divided by total production wafer started for the same period. Typical non-product wafers include test wafers, monitor wafers, calibration wafers, dummy wafers.*
	Overall NPW activities versus production wafers activities	*Ratio of total non-production wafer activities (process moves, including recycling wafers) divided by total production wafer activities for the same period. Typical non-product wafers include test wafers, monitor wafers, calibration wafers, dummy wafers. Consumption quantity includes both new and reused (reclaimed) non-product wafers.*
	% capital equipment reused from previous node	*% 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. Includes front and rear sides of wafer.*
	Equipment lead time from setup to full throughput capable	*Time elapsed between when tool has been installed and production ready till the time the equipment has been qualified to run wafers at the quoted throughput (wafers per hour). This is specifically applicable for lithography tools (worst case).*
WAS	*Process availability (A_{80})*	*Availability is 100% minus (scheduled downtime % - setup% + unscheduled downtime %) of the process (non-metrology) equipment (80% percentile). Scheduled downtime and unscheduled downtimes are defined in SEMI E10.*
IS	*Process availability (A_{80})*	***Availability is 100% minus (scheduled downtime % + setup% + unscheduled downtime %) of the process (non-metrology) equipment (80% percentile). Scheduled downtime and unscheduled downtimes are defined in SEMI E10.***
WAS	*Metrology availability (A_{80})*	*Availability is 100% minus (scheduled downtime % – setup% + unscheduled downtime %) of the process (non-metrology) equipment (80% percentile). Scheduled downtime and unscheduled downtimes are defined in SEMI E10.*
IS	*Metrology availability (A_{80})*	***Availability is 100% minus (scheduled downtime % + setup% + unscheduled downtime %) of the metrology equipment (80% percentile). Scheduled downtime and unscheduled downtimes are defined in SEMI E10.***
	Intrinsic setup time reduction year to year	*Intrinsic setup time reduction is mainly dependent on improvements to process equipment with quick setup capability (software, hardware improvements) and faster qualification capability. This metric will impact capacity.*
	Ability to run different recipes and parameters for each wafer	*Ability for production equipment to run a different recipe and/or parameters for each wafer within a carrier. This facilitates the ability to have multiple lots per carrier. Base requirements also include the ability to track, monitor, and control the wafer at each point the factory or within the equipment. For production equipment, it impacts the extent of "recipe cascading" that enables equipment to run in a continuous (non-stop) mode between lots in the same carrier and between sequential carriers.*
	248 nm lithography scanner productivity (wafers outs per week)	*The average number of good photo wafer alignments performed per machine per work day, considering only photo wafer alignments performed on 248 nm scanners in the Fab.*
	193 nm lithography scanner productivity (wafers outs per week)	*The average number of good photo wafer alignments performed per machine per work day, considering only photo wafer alignments performed on 193 nm scanners in the Fab.*
	Maximum allowed electrostatic field on wafer and mask surfaces (V/cm)	*Wafer and mask surface electric fields measured when they are removed from their carriers. Refer SEMI standards E78[2] and E43[3] for measurement methods.*

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[2] *SEMI E78: Electrostatic Compatibility – Guide to Assess and Control Electrostatic Discharge (ESD) and Electrostatic Attraction (ESA) for Equipment.*

[3] *SEMI E43: Guide for Measuring Static Charge on Objects and Surfaces.*

Table 87a Material Handling Systems Technology Requirements—Near-term UPDATED

	Year of Production	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
	Technology Node		*hp90*			*hp65*		
	DRAM ½ Pitch (nm)	*100*	*90*	*80*	*70*	*65*	*55*	*50*
	MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	*107*	*90*	*80*	*70*	*65*	*55*	*50*
	Wafer Diameter (mm)	*300*	*300*	*300*	*300*	*300*	*300*	*300*
	Transport E-MTTR (minutes) per SEMI E10	**15**	**12**	**10**	**9**	**9**	**8**	**8**
	Storage E-MTTR (minutes) per SEMI E10	**30**	**25**	**25**	**25**	**20**	**20**	**20**
	Transport MMBF	**5000**	**7,000**	**9,000**	**14,000**	**24,000**	**40,000**	**60,000**
	Storage MCBF	**22000**	**32,000**	**40,000**	**50,000**	**62,000**	**76,000**	**90,000**
	Peak system throughput (40K WSPM)							
WAS	Interbay transport (moves/hour)	**2075**	**2150**	**2250**	**2500**	**N/A**	**N/A**	**N/A**
IS	Interbay transport (moves/hour)	**2075**	**2150**	**2250**	**2500**	**2575**	**2660**	**2660**
WAS	Intrabay transport (moves/hour) — high throughput bay	**190**	**200**	**210**	**230**	**N/A**	**N/A**	**N/A**
IS	Intrabay transport (moves/hour) — high throughput bay	**190**	**200**	**210**	**230**	**240**	**250**	**250**
	Transport (moves/hour)—unified system	**N/A**	**4100**	**4240**	**4740**	**4900**	**5000**	**5000**
	Stocker cycle time (seconds) (100 bin capacity)	**14**	**12**	**12**	**10**	**10**	**10**	**10**
	Average delivery time (minutes)	**8**	**6**	**6**	**5**	**5**	**5**	**5**
	Peak delivery time (minutes)	**15**	**12**	**12**	**10**	**10**	**10**	**10**
	Hot lot average delivery time (minutes)	**4**	**3**	**3**	**2**	**2**	**2**	**2**
	AMHS lead time (weeks)	**<12**	**<11**	**<10**	**<9**	**<8**	**<8**	**<8**
	AMHS install time (weeks)	**<16**	**<14**	**<12**	**<10**	**<10**	**<10**	**<10**
	Downtime to extend system capacity when previously planned (minutes)	**<90**	**<60**	**<30**	**<30**	**<15**	**<15**	**<0**

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Table 87b Material Handling Systems Technology Requirements—Long-term UPDATED

	Year of Production	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
	Technology Node	*hp45*			*hp32*			*hp22*		
	DRAM ½ Pitch (nm)	*45*	*40*	*35*	*32*	*28*	*25*	*22*	*20*	*18*
	MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	*45*	*40*	*35*	*32*	*28*	*25*	*22*	*20*	*18*
	Wafer Diameter (mm)	*300*		*450*	*450*		*450*	*450*		*450*
WAS	Transport E-MTTR (minutes) per SEMI E10	**8**		**8**	**8**		**7**	**7**		**6**
IS	Transport E-MTTR (minutes) per SEMI E10	**8**	**8**	**8**	**8**	**8**	**7**	**7**	**7**	**6**
WAS	Storage E-MTTR (minutes) per SEMI E10	**20**		**20**	**20**		**15**	**15**		**10**
IS	Storage E-MTTR (minutes) per SEMI E10	**20**	**20**	**20**	**20**	**20**	**15**	**15**	**15**	**10**
WAS	Transport MMBF	**60,000**		**80,000**	**80,000**		**100,000**	**100,000**		**120,000**
IS	Transport MMBF	**60,000**	**80,000**	**80,000**	**80,000**	**80,000**	**100,000**	**100,000**	**100,000**	**120,000**
WAS	Storage MCBF	**90,000**		**105,000**	**105,000**		**120,000**	**120,000**		**135,000**
IS	Storage MCBF	**90,000**	**105,000**	**105,000**	**105,000**	**105,000**	**120,000**	**120,000**	**120,000**	**135,000**
	Peak system throughput (40K WSPM)									
WAS	Interbay transport (moves/hour)	**N/A**		**N/A**	**N/A**		**N/A**	**N/A**		**N/A**
IS	Interbay transport (moves/hour)	**2660**	**2660**	**2660**	**2660**	**2660**	**2660**	**2660**	**2660**	**2660**
WAS	Intrabay transport (moves/hour) — high throughput bay	**N/A**		**N/A**	**N/A**		**N/A**	**N/A**		**N/A**
IS	Intrabay transport (moves/hour) — high throughput bay	**250**	**250**	**250**	**250**	**250**	**250**	**250**	**250**	**250**
WAS	Transport (moves/hour)—unified system	**5000**		**5000**	**5000**		**5000**	**5000**		**5000**
IS	Transport (moves/hour)—unified system	**5000**	**5000**	**5000**	**5000**	**5000**	**5000**	**5000**	**5000**	**5000**
WAS	Stocker cycle time (seconds) (100 bin capacity)	**10**		**10**	**10**		**10**	**10**		**10**
IS	Stocker cycle time (seconds) (100 bin capacity)	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
WAS	Average delivery time (minutes)	**5**		**5**	**5**		**5**	**5**		**5**
IS	Average delivery time (minutes)	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
WAS	Peak delivery time (minutes)	**10**		**10**	**10**		**10**	**10**		**10**
IS	Peak delivery time (minutes)	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
WAS	Hot lot average delivery time (minutes)	**2**		**2**	**2**		**2**	**2**		**2**
IS	Hot lot average delivery time (minutes)	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
WAS	AMHS lead time (weeks)	**<8**		**<8**	**<8**		**<8**	**<8**		**<8**
IS	AMHS lead time (weeks)	**<8**	**<8**	**<8**	**<8**	**<8**	**<8**	**<8**	**<8**	**<8**
WAS	AMHS install time (weeks)	**<10**		**<10**	**<10**		**<10**	**<10**		**<10**
IS	AMHS install time (weeks)	**<10**	**<10**	**<10**	**<10**	**<10**	**<10**	**<10**	**<10**	**<10**
WAS	Downtime to extend system capacity when previously planned (minutes)	**<0**		**<0**	**<0**		**<0**	**<0**		**<0**
IS	Downtime to extend system capacity when previously planned (minutes)	**<0**	**<0**	**<0**	**<0**	**<0**	**<0**	**<0**	**<0**	**<0**

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Explanation of Items for Material Handling Systems Requirements

	Item	*Explanation*
WAS	*Transport E-MTTR (minimum per SEMI E10)*	*Mean time to repair equipment-related failures (AMHS Storage); the average time to correct an equipment-related failure and return the equipment to a condition where it can perform its intended function; the sum of all equipment-related failure time (elapsed time, not necessarily total man hours) incurred during a specified time period (including equipment and process test time, but not maintenance delay downtime), divided by the number of equipment-related failures during that period.* *Notes: Refers to unscheduled, supplier dependent failures. Includes storage equipment load ports and embedded software. Does not include interbay or intrabay transport or incidents induced by these errors. Does not include FOUP carrier or MES level software issues. Does not include reticle system.*
IS	*Transport E-MTTR (minimum per SEMI E10)*	***Mean time to repair equipment-related failures (AMHS Transport); the average time to correct an equipment-related failure and return the equipment to a condition where it can perform its intended function; the sum of all equipment-related failure time (elapsed time, not necessarily total man hours) incurred during a specified time period (including equipment and process test time, but not maintenance delay downtime), divided by the number of equipment-related failures during that period.*** ***Notes: Refers to unscheduled, supplier dependent failures. Includes interbay and intrabay transport systems. Offline repair of components is not included in this time. Includes embedded software control systems (transport controllers). Does not include storage AMHS equipment or errors induced by the storage equipment. Does not include load port, FOUP carrier, or MES level software issues. Does not include reticle system.***
WAS	*Storage E-MTTR (minimum per SEMI E10)*	*Mean time to repair equipment-related failures (AMHS Storage); the average time to correct an equipment-related failure and return the equipment to a condition where it can perform its intended function; the sum of all equipment-related failure time (elapsed time, not necessarily total man hours) incurred during a specified time period (including equipment and process test time, but not maintenance delay downtime), divided by the number of equipment-related failures during that period.* *Notes: Refers to unscheduled, supplier dependent failures. Includes interbay and intrabay transport systems. Offline repair of components is not included in this time. Includes embedded software control systems (transport controllers). Does not include storage AMHS equipment or errors induced by the storage equipment. Does not include load port, FOUP carrier, or MES level software issues. Does not include reticle system.*
IS	*Storage E-MTTR (minimum per SEMI E10)*	***Mean time to repair equipment-related failures (AMHS Storage); the average time to correct an equipment-related failure and return the equipment to a condition where it can perform its intended function; the sum of all equipment-related failure time (elapsed time, not necessarily total man hours) incurred during a specified time period (including equipment and process test time, but not maintenance delay downtime), divided by the number of equipment-related failures during that period.*** ***Notes: Refers to unscheduled, supplier dependent failures. Includes storage equipment load ports and embedded software. Does not include interbay or intrabay transport or incidents induced by these errors. Does not include FOUP carrier or MES level software issues. Does not include reticle system.***
	Transport MMBF (mean move between failure)	*Average number cycles (delivery from point A to point B) made by AMHS interbay or intrabay transport equipment before a person has to intervene to fix a failure. Number of transport moves / Number of supplier dependent unscheduled failures. Reference transport MPH definition for details on move.*
	Storage MCBF (mean cycle between failure)	*Average number cycles (delivery from point A to point B) made by AMHS storage equipment before a person has to intervene to fix a failure. Number of storage cycles/number of supplier dependent unscheduled failures per quarter. Reference cycle time definition for details on stocker cycle.*
	Interbay transport (moves/hour)	*Number of material handling moves per hour performed by the interbay transport system. An interbay transport move is defined as a carrier move from the loading of an interbay system at a stocker interbay port to the unloading of the same load at the destination stocker. Moves are counted by the host material control system (MCS).*
	Intrabay transport (moves/hour)	*Number of material handling moves per hour performed by an intrabay transport loop. An intrabay transport move is defined as a carrier move between load ports (between stocker ports and production equipment load port, between two production equipment load ports). Moves are counted by the Host (MCS).*
	Direct transport (moves/hour) unified system	*A transport move is defined as a transfer of a carrier between any two load ports (stocker, process tool, or transfer point between transport systems). Note that stocker robot moves from/to load ports are not assumed concurrent with nor included in system throughput moves. Moves are counted by the host (MCS).*

WAS	*Stocker cycle time (seconds) (100 bin capacity)*	*Stocker cycle time is defined as the time (in seconds) from when the host (MCS) issues the move command to the time the stocker signals completion with the move complete command to the host. The physical motion is the stocker internal robot moving to a carrier at a port or storage bin, picking up the carrier, and delivering it to another port or storage bin within the same stocker. Stocker cycle time shall be determined as the average of several different types of moves over a period of time. The moves should include all ports and all shelf locations. Each move needs to alternate between different carriers.*
IS	*Stocker cycle time (seconds) (100 bin capacity)*	***Stocker cycle time is defined as the time (in seconds) from when the Host(MCS) issues the move command to the time the stocker signals completion with the move complete command to the host. The physical motion is the stocker internal robot moving to a carrier at a port or storage bin, picking up the carrier, and delivering it to another port or storage bin within the same stocker. Stocker cycle time shall be determined as the average of several different types of moves over a period of time. The moves should include all ports and all shelf locations. Each move needs to alternate between different carriers. The maximum MCS communication time is assumed to be 1 second.***
	Average delivery time (minutes)	*The time begins at the request for carrier movement from the MES and ends when the carrier arrives at the load port of the receiving equipment.*
	Peak delivery time (minutes)	*Peak delivery time is considered the peak performance capability defined as the average delivery time plus two standard deviations.*
	Hot Lot Average Delivery Time (min)	*Reference definition for Average Delivery Time. Reference Factory Operations section for further details on hot lots.*
	AMHS lead time (weeks)	*Time elapsed, in weeks, between when a purchase order has been placed for a material handling system until the time the first shipment is freight-on-board at supplier's dock. This assumes that at the time of purchase order placement the equipment configuration is fixed. This lead-time should not be affected by market demand on supplier.*
WAS	*AMHS install time (weeks)*	*Time elapsed, in weeks, between when the first component of the system is moved in from the dock until the final component is fully installed, started up, and tested to meet full designed through capability. Assume new factory and uninterrupted installation of the material handling system (assume no facility or tool delays). Based on size Fab of approximately 200 meters by 80 meters, with 15–20 short bays. Does not include reticle systems.*
IS	*AMHS install time (weeks)*	***Time elapsed, in weeks, between when the first component of the system is moved in from the dock until the final component is fully installed, started up, and tested to meet full designed throughput capability. Assume new factory and uninterrupted installation of the material handling system (assume no facility, MCS or tool delays). Based on 20K WSPM fab of approximately 200 meters by 80 meters, with 15-20 short bays. Does not include reticle systems.***
	Downtime to extend system capacity when previously planned (minutes)	*Impact to material handling system in terms of downtime, in minutes, of the material handling system, required for making connections to system track extensions or a new stocker when previsions for this expansion were incorporated in the original design.*

Table 88a Factory Information and Control Systems Technology Requirements—Near-term UPDATED

	Year of Production	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
	Technology Node		*hp90*			*hp65*		
	DRAM ½ Pitch (nm)	*100*	*90*	*80*	*70*	*65*	*55*	*50*
	MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	*107*	*90*	*80*	*70*	*65*	*55*	*50*
	Wafer Diameter (mm)	*300*	*300*	*300*	*300*	*300*	*300*	*300*
Delete	~~Availability of mission critical application (% per year)~~	~~**99.977**~~	~~**99.98**~~	~~**99.986**~~	~~**99.986**~~	~~**99.987**~~	~~**99.99**~~	~~**99.991**~~
Delete	~~Downtime of mission critical application (minutes per year)~~	~~**120 min**~~	~~**105 min**~~	~~**75 min**~~	~~**75 min**~~	~~**68 min**~~	~~**53 min**~~	~~**45 min**~~
Delete	~~Availability of the total factory system (% per year)~~	~~**99.909**~~	~~**99.92**~~	~~**99.943**~~	~~**99.943**~~	~~**99.949**~~	~~**99.96**~~	~~**99.966**~~
WAS	Factory down due to unscheduled FICS downtime due to FICS (minutes per year)	**240 min**	**180 min**	**120 min**	**120 min**	**90 min**	**90 min**	**60 min**
IS	**Full factory down due to unscheduled FICS downtime (minutes per year)**		**180 min**	**120 min**	**60 min**	**60 min**	**60 min**	**<15 min**
WAS	Factory down due to scheduled FICS downtime (minutes per year)	**240 min**	**240 min**	**180 min**	**180 min**	**180 min**	**120 min**	**120 min**
IS	**Full factory down due to scheduled FICS downtime (minutes per year)**		**240 min**	**180 min**	**180 min**	**180 min**	**120 min**	**120 min**
	Mean time to recover for mission critical applications (minutes down per year)	**60**	**45**	**30**	**15**	**<15**	**<15**	**<15**
	MCS design to support peak number of AMHS transport moves (moves/hr)	**12K**	**12.3K**	**12.7**	**14.2**	**14.7**	**15K**	**15K**
	FICS design to support peak number of AMHS direct transport moves (moves/hr)	**N/A**	**N/A**	**1270**	**1420**	**1470**	**1500**	**1500**
	Time to send and load tape-out data into mask shop data system (hours)	**5–10**	**6–12**	**6–12**	**6–12**	**6–12**	**6–12**	**6–12**
	Time for OPC calculations and data preparation for mask writer (days)	**2.5–5.5**	**4–8**	**4–8**	**4–8**	**4–8**	**4–8**	**4–8**
	Time for OPC calculations only (days)	**2–4**	**3–6**	**3–6**	**3–6**	**3–6**	**3–6**	**3–6**
	% Factory information and control systems reusable for next node	**>93%**	**>93%**	**>93%**	**>93%**	**>93%**	**>93%**	**>93%**
WAS	Ability to run/adjust different recipes/parameters within a run	**Partial**	**Partial**	**Partial**	**Partial**	**Yes**	**Yes**	**Yes**
IS	**Wafer-level recipe/parameter adjustment**		**Partial**	**Partial**	**Partial**	**Yes**	**Yes**	**Yes**
ADD	**Within-wafer recipe/parameter adjustment**	-	**Partial**	**Partial**	**Partial**	**Partial**	**Yes**	**Yes**

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Table 88b Factory Information and Control Systems Technology Requirements—Long-term UPDATED

		2010	2011	2012	2013	2014	2015	2016	2017	2018
	Year of Production	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
	Technology Node	*hp45*			*hp32*			*hp22*		
	DRAM ½ Pitch (nm)	*45*	*40*	*35*	*32*	*28*	*25*	*22*	*20*	*18*
	MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	*45*	*40*	*35*	*32*	*28*	*25*	*22*	*20*	*18*
	Wafer Diameter (mm)	*300*		*450*	*450*	*450*	*450*	*450*	*450*	*450*
Delete	~~Availability of mission critical application (% per year)~~	~~**99.991**~~		~~**99.994**~~	~~**99.994**~~		~~**99.999**~~	~~**99.999**~~		~~**99.999**~~
Delete	~~Downtime of mission critical application (minutes per year)~~	~~**45 min**~~		~~**30 min**~~	~~**30 min**~~		~~**8 min**~~	~~**8 min**~~		~~**4 min**~~
Delete	~~Availability of the total factory system (% per year)~~	~~**99.966**~~		~~**99.977**~~	~~**99.977**~~		~~**99.994**~~	~~**99.997**~~		~~**99.997**~~
WAS	Factory down due to unscheduled FICS downtime due to FICS (minutes per year)	**60 min**	**60 min**	**60 min**	**60 min**	**60 min**	**30 min**	**15 min**	**15 min**	**15 min**
IS	**Full factory down due to unscheduled FICS downtime (minutes per year)**	**< 15 min**	**<15 min**	**<15 min**	**<15 min**	**<15 min**	**<15 min**	**<15 min**	**<15 min**	**<15 min**
WAS	Factory down due to scheduled FICS downtime (minutes per year)	**120 min**		**60 min**	**60 min**		**0 min**	**0 min**		**0 min**
IS	**Full factory down due to scheduled FICS downtime (minutes per year)**	**120 min**	**60 min**	**60 min**	**60 min**	**60 min**	**0 min**	**0 min**	**0 min**	**0 min**
WAS	Mean time to recover for mission critical applications (minutes down per year)	**<15**		**<15**	**<15**		**<15**	**<15**		**<15**
IS	Mean time to recover for mission critical applications (minutes down per year)	**<15**	**<15**	**<15**	**<15**	**<15**	**<15**	**<15**	**<15**	**<15**
WAS	MCS design to support peak number of AMHS transport moves (moves/hr)	**15K**		**15K**	**15K**		**15K**	**15K**		**15K**
IS	MCS design to support peak number of AMHS transport moves (moves/hr)	**15K**	**15K**	**15K**	**15K**	**15K**	**15K**	**15K**	**15K**	**15K**
WAS	FICS design to support peak number of AMHS direct transport moves (moves/hr)	**1500**		**1500**	**1500**		**1500**	**1500**		**1500**
IS	FICS design to support peak number of AMHS direct transport moves (moves/hr)	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**
WAS	Time to send and load tape-out data into mask shop data system (hours)	**6–12**		**6–13**	**6–12**		**6–12**	**6–12**		**6–12**
IS	Time to send and load tape-out data into mask shop data system (hours)	**6–12**	**6–12**	**6–13**	**6–12**	**6–12**	**6–12**	**6–12**	**6–12**	**6–12**
WAS	Time for OPC calculations and data preparation for mask writer (days)	**4–8**		**4–8**	**4–8**		**4–8**	**4–8**		**4–8**
IS	Time for OPC calculations and data preparation for mask writer (days)	**4–8**	**4–8**	**4–8**	**4–8**	**4–8**	**4–8**	**4–8**	**4–8**	**4–8**
WAS	Time for OPC calculations only (days)	**3–6**		**3–6**	**3–6**		**3–6**	**3–6**		**3–6**
IS	Time for OPC calculations only (days)	**3–6**	**3–6**	**3–6**	**3–6**	**3–6**	**3–6**	**3–6**	**3–6**	**3–6**
WAS	% Factory information and control systems reusable for next node	**>93%**		**>80%**	**>80%**		**>80%**	**>80%**		**>80%**
IS	% Factory information and control systems reusable for next node	**>93%**	**>93%**	**>80%**	**>80%**	**>80%**	**>80%**	**>80%**	**>80%**	**>80%**
WAS	Ability to run/adjust different recipes/parameters within a run	**Yes**		**Yes**	**Yes**		**Yes**	**Yes**		**Yes**
IS	**Wafer-level recipe/parameter adjustment**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
ADD	**Within-wafer recipe/parameter adjustment**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Explanation of Items for Factory Information & Control Requirements

	Item	*Explanation*
WAS	*Factory down due to unscheduled FICS (minutes per year)*	*Full factory downtime per year due to unscheduled downtime of mission critical applications. Mission critical applications are those that are required to keep the entire wafer factory operational. Depending on factory configuration, these include the following: MES, scheduler/dispatcher, MCS, cell controller, SPC, reticle system, facilities control systems. Unscheduled downtime is defined in SEMI E10.*
IS	***Full factory down due to unscheduled FICS (minutes per year)***	*Full factory downtime per year due to unscheduled downtime of mission critical applications. Mission critical applications are those that are required to keep the entire wafer factory operational. Depending on factory configuration, these include the following: MES, scheduler/dispatcher, MCS, cell controller, SPC, reticle system, facilities control systems. Unscheduled downtime is defined in SEMI E10.*
WAS	*Factory down due to scheduled FICS (minutes per year)*	*Full factory downtime per year due to scheduled downtime of mission critical applications.*
IS	***Full factory down due to scheduled FICS (minutes per year)***	*Full factory downtime per year due to scheduled downtime of mission critical applications.*
	Mean Time to Recover for mission critical applications (minutes)	*Mean time to recover a mission critical application following an unscheduled downtime. Mean time to recover is measured in minutes per incident.*
	Peak number of AMHS transport moves supported by material control system (moves/hr)	*Maximum number of transport moves per hour supported by material control system (MCS). Able to support: peak number of moves for unified transport system × 1.5 (to translate to separate interbay/intrabay system) × 2 (safety factor for FICS)*
	Peak number of direct transport moves (moves/hr)	*Target number of direct transport moves per hour supported by FICS. Direct transport moves are defined as carrier moves directly from one production equipment tool load port to another production equipment tool load port. Assume 10% of peak number of transport moves will require direct transport*
	Time to send and load tape-out data into mask shop data system (hours)	*Time in hours to send data from mask designer to mask shop and load it into the OPC application.*
	Time for OPC calculations and data preparation for mask writer (days)	*Time in hours to perform OPC calculations + Time in hours to convert the output of the OPC engine to the format the mask writer understands + Time in hours to transmit the data into the mask writing system*
	OPC time only (days)	*Time for OPC calculations only is the time in hours to perform the OPC calculations once the OPC application has received the tape-out data from the mask designer*
	% Factory information and control systems reusable for next node	*Percentage of factory information and control systems (both computer hardware and software) that is reused from process technology node to process technology node, measured in cost.*
WAS	*Ability to run/adjust different recipes/parameters within a run*	*Ability for factory information and control systems to run a different recipe and/or parameters for each wafer within a carrier. This facilitates the ability to have multiple lots per carrier. Base requirements also include the ability to track, monitor, and control the wafer at each point the factory or within the equipment.*
IS	***Wafer-level recipe/parameter adjustment***	*Ability for factory information and control systems to run a different recipe and/or parameters for each wafer within a carrier. This facilitates the ability to have multiple lots per carrier. Base requirements also include the ability to track, monitor, and control the wafer at each point the factory or within the equipment.*
ADD	*Within-wafer recipe/parameter adjustment*	*Ability for factory information and control systems to run a different recipe and/or parameters within a wafer.*

FOUP—front opening unified pod

Table 89a Facilities Technology Requirements—Near-term

Year of Production	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Technology Node		*hp90*			*hp65*		
DRAM ½ Pitch (nm)	*100*	*90*	*80*	*70*	*65*	*55*	*50*
MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	*107*	*90*	*80*	*70*	*65*	*55*	*50*
Wafer Diameter (mm)	*300*	*300*	*300*	*300*	*300*	*300*	*300*
Cleanroom area as a % of total site building area	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**
Manufacturing (cleanroom) area/wafer starts per month (m^2/WSPM) (low mix only)	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**
Facility life (in three-year nodes)	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Tool maintenance cleanliness level (ISO 14644)[4]	**Class 4**	**Class 4**	**Class 4**	**Class 5**	**Class 5**	**Class 5**	**Class 5**
Facility cleanliness level (ISO 14644)	**Class 5**	**Class 5**	**Class 5**	**Class 6**	**Class 6**	**Class 6**	**Class 6**
Production equipment install and qualification cost as a % of capital cost	**10%**	**9%**	**8%**	**8%**	**8%**	**8%**	**8%**
Facility operating cost (including utilities) as a % of total operating cost	**13%**	**13%**	**13%**	**13%**	**13%**	**13%**	**13%**
Utility cost per total factory operating cost (%)	**3%**	**3%**	**3%**	**3%**	**3%**	**3%**	**3%**
Utility utilization (demand/installed)	**60%**	**70%**	**70%**	**70%**	**80%**	**80%**	**80%**
Facility critical vibration areas (lithography, metrology, other) (micro inches per second)	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**
Facility non-critical vibration areas (micro inches per second)	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**
Fab to sub-Fab ratio	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Maximum allowable electrostatic field on facility surfaces (V/cm)	**125**	**100**	**90**	**80**	**70**	**60**	**50**
Factory construction time from groundbreaking to first tool move-in (months)	**10**	**10**	**10**	**9**	**9**	**9**	**8**
Gas, water, chemical purity	*Discussed in Yield Enhancement Chapter*						
Power, water, and chemical consumption	*Discussed in ESH Chapter*						

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

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[4] *ISO 14644: Cleanrooms and Controlled Environments.*

Table 89b Facilities Technology Requirements—Long-term UPDATED

	Year of Production	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
	Technology Node	*hp45*			*hp32*			*hp22*		
	DRAM ½ Pitch (nm)	*45*	*40*	*35*	*32*	*28*	*25*	*22*	*20*	*18*
	MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	*45*	*40*	*35*	*32*	*28*	*25*	*22*	*20*	*18*
	Wafer Diameter (mm)	*300*		*450*	*450*		*450*	*450*		*450*
WAS	Cleanroom area as a % of total site building area	**15%**		**15%**	**15%**		**15%**	**15%**		**15%**
IS	Cleanroom area as a % of total site building area	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**
WAS	Manufacturing (cleanroom) area/wafer starts per month (m^2/WSPM) (low mix only)	**0.34**		**0.34**	**0.34**		**0.34**	**0.34**		**0.34**
IS	Manufacturing (cleanroom) area/wafer starts per month (m^2/WSPM) (low mix only)	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**
WAS	Facility life (in three-year nodes)	**3**		**3**	**3**		**3**	**3**		**3**
IS	Facility life (in three-year nodes)	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
WAS	Tool maintenance cleanliness level (ISO 14644)	**Class 5**		**Class 6**	**Class 6**		**Class 6**	**Class 6**		**Class 6**
IS	Tool maintenance cleanliness level (ISO 14644)	**Class 5**	**Class 6**	**Class 6**	**Class 6**	**Class 6**	**Class 6**	**Class 6**	**Class 6**	**Class 6**
WAS	Facility cleanliness level (ISO 14644)	**Class 6**		**Class 7**	**Class 7**		**Class 8**	**Class 8**		**Class 9**
IS	Facility cleanliness level (ISO 14644)	**Class 6**	**Class 7**	**Class 7**	**Class 7**	**Class 7**	**Class 8**	**Class 8**	**Class 8**	**Class 9**
WAS	Production equipment install and qualification cost as a % of capital cost	**8%**		**10%**	**10%**		**9%**	**9%**		**8%**
IS	Production equipment install and qualification cost as a % of capital cost	**8%**	**10%**	**10%**	**10%**	**10%**	**9%**	**9%**	**9%**	**8%**
WAS	Facility operating cost (including utilities) as a % of total operating cost	**13%**		**13%**	**13%**		**13%**	**13%**		**13%**
IS	Facility operating cost (including utilities) as a % of total operating cost	**13%**	**13%**	**13%**	**13%**	**13%**	**13%**	**13%**	**13%**	**13%**

Manufacturable solutions exist, and are being optimized	☐
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Table 89b Facilities Technology Requirements—Long-term UPDATED (continued)

	Year of Production	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
	Technology Node	*hp45*			*hp32*			*hp22*		
	DRAM ½ Pitch (nm)	*45*	*40*	*35*	*32*	*28*	*25*	*22*	*20*	*18*
WAS	Utility cost per total factory operating cost (%)	**3%**		**3%**	**3%**		**3%**	**3%**		**3%**
IS	Utility cost per total factory operating cost (%)	**3%**	**3%**	**3%**	**3%**	**3%**	**3%**	**3%**	**3%**	**3%**
WAS	Utility utilization (demand/installed)	**80%**		**70%**	**70%**		**70%**	**70%**		**80%**
IS	Utility utilization (demand/installed)	**80%**	**70%**	**70%**	**70%**	**70%**	**70%**	**70%**	**70%**	**80%**
WAS	Facility critical vibration areas (lithography, metrology, other) (micro inches per second)	**250 (VC D)**		**450 (VC D)**	**450 (VC D)**		**450 (VC D)**	**450 (VC D)**		**450 (VC D)**
IS	Facility critical vibration areas (lithography, metrology, other) (micro inches per second)	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**	**250 (VC D)**
WAS	Facility non-critical vibration areas (micro inches per second)	**2000 (VC A)**		**2000 (VC A)**	**2000 (VC A)**		**2000 (VC A)**	**2000 (VC A)**		**2000 (VC A)**
IS	Facility non-critical vibration areas (micro inches per second)	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**	**2000 (VC A)**
WAS	Fab to sub-Fab ratio	**1**		**1**	**1**		**1**	**1**		**1**
IS	Fab to sub-Fab ratio	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
WAS	Maximum allowable electrostatic field on facility surfaces (V/cm)	**50**		**35**	**35**		**25**	**25**		**18**
IS	Maximum allowable electrostatic field on facility surfaces (V/cm)	**50**	**35**	**35**	**35**	**35**	**25**	**25**	**25**	**18**
WAS	Factory construction time from groundbreaking to first tool move-in (months)	**8**		**9**	**9**		**9**	**8**		**8**
IS	Factory construction time from groundbreaking to first tool move-in (months)	**8**	**9**	**9**	**9**	**9**	**9**	**8**	**8**	**8**
WAS	Gas, water, chemical purity	*Discussed in Yield Enhancement Chapter*								
IS	Gas, water, chemical purity	*Discussed in Yield Enhancement Chapter*								
WAS	Power, water, and chemical consumption	*Discussed in ESH Chapter*								
IS	Power, water, and chemical consumption	*Discussed in ESH Chapter*								

Manufacturable solutions exist, and are being optimized	⬜
Manufacturable solutions are known	🟨
Interim solutions are known	◆
Manufacturable solutions are NOT known	🟥

Explanation of Items for Facilities requirements:

Item	*Explanation*
Cleanroom area as a % of total site building area	*Ration of cleanroom to total building area. Manufacturing (cleanroom) area is defined as the space in square meters containing the process and metrology equipment used for direct manufacturing processes such as photolithograph, diffusion, etch, thin films, CMP, excluding sub-Fab spaces containing support equipment and facility infrastructure systems. Total site building area is defined as the total constructed factory including building shell, office space, factory cleanroom, support spaces, central utility pad or building.*
Manufacturing (cleanroom) area/wafer starts per month (m^2/WSPM)	*"Manufacturing (cleanroom) area" is defined as the space in square meters containing the process and metrology equipment used for direct manufacturing processes such as photolithograph, diffusion, etch, thin films, CMP, excluding subFab spaces containing support equipment and facility infrastructure systems.*
Facility life (in three-year nodes)	*Facility service (system) life is the number of nodes (process changes) that the system is available before major renovation is required to meet process requirements.*
Tool maintenance cleanliness class (ISO 14644)	*Cleanliness classification of area immediately around the tool required during maintenance in the cleanroom as defined by ISO 14644-1.*
Facility cleanliness class (ISO 14644)	*Cleanliness classification of wafer factory manufacturing (cleanroom) area as defined by ISO 14644-1.*
Production equipment install and qualification cost as a % of capital cost	*"Production equipment installation cost" is defined as the cost of all labor and materials necessary to accept, move-in, and connects production equipment to the facility infrastructure systems to make the production equipment operational. This includes qualification, but excludes facility infrastructure systems and upgrades, and the cost of the production equipment.*
Facility operating cost (inc. utilities) as a % of total operating cost	*"Facility operating cost" is defined as all facility expenses directly related to supporting manufacturing including depreciation, utility, labor and maintenance costs.*
Utility cost per total factory operating cost (%)	*"Utility cost" is defined as the cost of power, water, gases, and chemicals required to support manufacturing, including the factory material and consumables.*
Utility utilization (demand/installed)	*"Utility utilization" is defined as the real-time utility consumption for the entire tool set divided by the design and operating capacity of the utility infrastructure support system.*
Facility critical vibration areas (litho, metro, other) (micro inches per second)	*"Vibration critical" is defined as area of the primary manufacturing floor in which a significant portion of the equipment is highly sensitive to floor vibration, the mitigation was not provided at the tool itself, and excessive vibrations can have serious deleterious effects on product. Extensive measures may be required in the facility's structural and mechanical equipment design based upon the needs of this space category. Vibration criteria are limits on vibration amplitudes at the floor or other support of a tool, given as VC-x, where x is a letter designation from A through E, each corresponding to a specific vibration amplitude spectrum. Refer to IEST-RP-DTE012.1[5] for definition of amplitudes, measurement methods, and signal processing requirements*
Facility non-critical vibration areas (micro inches per second)	*"Vibration non-critical" is defined as area of the primary manufacturing floor in which all or some of the equipment is only moderately vibration sensitive, and the structural system performance can be reduced. Vibration criteria are limits on vibration amplitudes at the floor or other support of a tool, given as VC-x, where x is a letter designation from A through E, each corresponding to a specific vibration amplitude spectrum. Refer to IEST-RP-DTE012.1 for definition of amplitudes, measurement methods, and signal processing requirements.*
Fab to sub-Fab ratio	*"Fab to sub-Fab ratio" is defined as the footprint of the manufacturing area to the production equipment support plan area below. Relates to and extends factory operations "floor space effectiveness."*
Maximum allowable electrostatic field on facility surfaces (V/cm)	*Facility surface electric field limits apply to all factory materials-construction materials, furniture, people, equipment and carriers Refer to SEMI standards E129[6], E78[7] and E43[8] for measurement methods.*
Factory construction time from groundbreaking to first tool move-in (months)	*Factory construction time is defined as the period of time in months from first concrete placement to the time that the first tool is moved into the manufacturing area and is ready for hookup, i.e., building systems have passed inspection sufficient to begin the tool installation process.*

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[5] *IEST-RP-DTE012.1: Handbook for Dynamic Data Acquisition and Analysis.*

[6] *SEMI E129: Guide to Assess and Control Electrostatic Charge in A Semiconductor Manufacturing Facility.*

[7] *SEMI E78: Electrostatic Compatibility – Guide to Assess and Control Electrostatic Discharge (ESD) and Electrostatic Attraction (ESA) for Equipment.*

[8] *SEMI E43: Guide for Measuring Static Charge on Objects and Surfaces.*