FACTORY INTEGRATION

Table 65 Factory Integration Difficult Challenges [Update]

	Difficult Challenges ≥65 nm, Through 2007	*Summary of Issues*
Was	Complexity Management	• Rapid changes to business needs, demand, and globalization trends • Increasing rate of new product and technology introductions • Globally disparate factories run as single "virtual factory" • Need to meet regulations in different geographical areas • Effectively manage complex supply chains • Increasing process and product complexity • Explosive growth of data collection/analysis requirements • Increasing number of processing steps including material movements • Multiple lots in a carrier and single wafer control/transport for an equipment group • Multiple Products on a wafer • Multiple package form factors • Larger wafers and carriers driving ergonomic solutions • Increasing expectations for integrated material handling and software control systems • Increased reliance on factory information and control systems • Multiple information and control system interdependencies • Standalone and Integrated Reliability required to keep factories operating • Co-existence of new factory information and control systems with existing (legacy) systems • Pace of standards definition and implementation is not meeting factory integration needs • Addressing complexity while keeping costs in perspective
Is	Complexity Management	• Rapid changes to business needs, demand, and globalization trends • Increasing rate of new product and technology introductions • Globally disparate factories run as single "virtual factory" • Need to meet regulations in different geographical areas • Effectively manage complex supply chains • Increasing process and product complexity • Increasing number of processing steps including material movements • Multiple lots in a carrier and single wafer control/transport for an equipment group **• Multiple Products on a wafer and multiple package form factors** • Increasing expectations for integrated material handling and software control systems • Increased reliance on factory information and control systems • Multiple information and control system interdependencies • Standalone and Integrated Reliability required to keep factories operating **• Co-existence of new factory information and control systems with existing systems** **• Pace of standards definition and implementation is not meeting needs** • Addressing complexity while keeping costs in perspective **• Explosive growth of data collection/analysis requirements driven by process and modeling needs** **• Need to meet technology restrictions with some countries while still meeting business needs**
Was	Factory Optimization	• Increased customer expectation to meet on time delivery • Balanced throughput and cycle time • Reduce time to ramp factories, products, and processes • Increased urgency for improved factory effectiveness • Ability to measure effectiveness and adjust/optimize factory output • High factory yield at startup • Reduce effects of parametric variation • Reduce wafer and product cost • Satisfy all domestic and international regulations
Is	Factory Optimization	• Increased customer expectation to meet on time delivery ~~• Balanced throughput and cycle time~~ • Reduce time to ramp factories, products, and processes • Ability to measure effectiveness and adjust/optimize factory output • High factory yield at startup • Reduce effects of parametric variation **• Reduce wafer and product cost** • Satisfy all domestic and international regulations **• Customer expectation for faster new product and volume deliveries** **• Improving both throughput and cycle time**

Table 65 Factory Integration Difficult Challenges [Update] (continued)

	Extendibility, Flexibility, and Scalability	• Reuse of building, production and support equipment, and factory information and control systems across multiple technology nodes and wafer size conversions • Factory designs that support rapid process and technology changes and retrofits • Understand up-front costs to incorporate EFS • Determine which EFS features to include and not to include • Minimize downtime to on-going operations • Comprehend tighter ESH/Code requirements • Comprehend increased purity requirements for process and materials
	Difficult Challenges ≥ 65 nm, Through 2007	*Summary of Issues*
Was	Post Bulk CMOS Manufacturing	• New devices beyond traditional bulk CMOS will drive significant changes in process technology and the factory manufacturing capabilities to support it • New production equipment must be designed and integrated with the factory • Yield and process control capabilities must be modified to new device process technology needs • Unknown changes to factory operations motivated by new device change • Potential for additional process and functional area isolation • Need to run CMOS and post CMOS processes within the same factory • Rapid technology development and ramp to support high volume manufacturing of new devices • Continued pressure to maintain 0.7× shrink per year efficiency in equivalent die size • Development and high volume ramp timeline must meet current technology node shrinks goals • Device yield and factory output must meet current roadmap targets • Reuse of buildings and equipment to enable new device technology at an affordable cost • Potential for additional process and functional area isolation an • Need to run CMOS and post CMOS processes within the same factory • Comprehend tighter ESH and code requirements
Is	Post Bulk CMOS Manufacturing	**• Identifying and implementing the new device manufacturing capabilities beyond bulk CMOS in time for a low risk industry transition** • New production equipment must be designed and integrated with the factory • Yield and process control capabilities must be modified to new device process technology needs ~~• Unknown changes to factory operations motivated by new device change~~ **• Potential for additional process and functional area isolation** • Need to run CMOS and post CMOS processes within the same factory • Rapid technology development and ramp to support high volume manufacturing of new devices • Continued pressure to maintain 0.7× shrink per year efficiency in equivalent die size • Development and high volume ramp timeline must meet current technology node shrinks goals • Device yield and factory output must meet current roadmap targets • Reuse of buildings and equipment to enable new device technology at an affordable cost • Potential for additional process and functional area isolation an • Need to run CMOS and post CMOS processes within the same factory ~~• Comprehend tighter ESH and code requirements~~
Was	450 mm Wafer Size Conversion	• Larger wafers and carriers driving changes to traditional wafer size scale-up strategy • Increased requirements for wafer level integration within the factory • Significant changes to production equipment and material handling design • Pressure to met affordability targets • Reuse of buildings and equipment to enable 450 mm at an affordable cost • Comprehend tighter ESH and code requirements
Is	450 mm Wafer Size Conversion	• Larger wafers and carriers driving changes to traditional wafer size scale-up strategy • Increased requirements for wafer level integration within the factory • Significant changes to production equipment and material handling design • Pressure to met affordability targets • Reuse of buildings and equipment to enable 450 mm at an affordable cost ~~• Comprehend tighter ESH and code requirements~~

Table 66a Factory Operations Technology Requirements—Near-term

	Year of Production	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
	DRAM ½ Pitch (nm)	*130*	*115*	*100*	*90*	*80*	*70*	*65*
	MPU / ASIC ½ Pitch (nm)	*150*	*130*	*107*	*90*	*80*	*70*	*65*
	MPU Printed Gate Length (nm)	*90*	*75*	*650*	*53*	*45*	*40*	*35*
	MPU Physical Gate Length (nm)	*65*	*53*	*45*	*37*	*32*	*28*	*25*
	Wafer Diameter	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*
	High Volume / Low Mix Factory Requirements [4, 5]							
Was	Factory cycle time per mask layer (non-hot lot) [1,2] (days)	**1.4**	**1.4**	**1.4**	**1.3**	**1.3**	**1.3**	**1.2**
Is	Factory cycle time per mask layer (non-hot lot) [1,2] (days)	**1.4**	**1.4**	**1.4**	**1.3**	**1.3**	**1.3**	**1.2**
Was	Factory cycle time per mask layer (hot lot) [1,2,7] (days)	**1**	**1**	**1**	**0.9**	**0.9**	**0.9**	**0.8**
Is	Factory cycle time per mask layer (hot lot) [1,2,7] (days)	**1**	**1**	**1**	**0.9**	**0.9**	**0.9**	**0.8**
	Number of lots per carrier (lot)	**One**	**One**	**One**	**One**	**One**	**One**	**One**
Was	Wafer layers/day/head count	**55**	**55**	**55**	**61**	**61**	**61**	**67**
Is	Wafer layers/day/head count	**55**	**55**	**55**	**61**	**61**	**61**	**67**
	High Volume / High Mix Factory Requirements [4, 5, 6]							
Was	Factory cycle time per mask layer (non-hot lot) [2,3] (days)	**1.2**	**1.2**	**1.2**	**1.1**	**1.1**	**1.1**	**1**
Is	Factory cycle time per mask layer (non-hot lot) [2,3] (days)	**1.2**	**1.2**	**1.2**	**1.1**	**1.1**	**1.1**	**1**
Was	Factory cycle time per mask layer (hot lot) [2,3,7] (days)	**0.75**	**0.75**	**0.75**	**0.65**	**0.65**	**0.65**	**0.55**
Is	Factory cycle time per mask layer (hot lot) [2,3,7] (days)	**0.75**	**0.6**	**0.6**	**0.55**	**0.5**	**0.45**	**0.4**
	Number of lots per carrier (lot)	**Multiple**	**Multiple**	**Multiple**	**Multiple**	**Multiple**	**Multiple**	**Multiple**
	Wafer layers/day/head count	**37**	**37**	**37**	**41**	**41**	**41**	**45**
	Common requirements across Both Factory Types							
Was	Groundbreaking to first tool move-in (months)	**9**	**9**	**9**	**8**	**8**	**8**	**7**
Is	Groundbreaking to first tool move-in (months).	**9**	**9**	**9**	**8**	**8**	**8**	**7**
	First tool move-in to first full loop wafer out (months)	**4**	**3.5**	**3.5**	**3**	**3**	**2.5**	**2.5**
Was	Node to Node change-over (weeks)	**13**	**13**	**13**	**12**	**12**	**12**	**11**
Is	Node to Node change-over (weeks)	**13**	**13**	**13**	**12**	**12**	**12**	**11**
	Floor space effectiveness	**1X**	**1X**	**1X**	**1X**	**1X**	**1X**	**1X**

White–Manufacturable Solutions Exist, and Are Being Optimized
Yellow–Manufacturable Solutions are Known
Red–Manufacturable Solutions are NOT Known

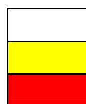

Table 66b Factory Operations Technology Requirements—Long-term

Year of Production	*2010*	*2013*	*2016*
DRAM ½ Pitch (nm)	*45*	*32*	*22*
MPU / ASIC ½ Pitch (nm)	*45*	*32*	*22*
MPU Printed Gate Length (nm)	*25*	*18*	*13*
MPU Physical Gate Length (nm)	*18*	*13*	*9*
Wafer Diameter	*300 mm*	*450 mm*	*450 mm*
High Volume / Low Mix Factory Requirements [4, 5]			
Factory cycle time per mask layer (non-hot lot) [1,2] (days)	**1.1**	**1.05**	**1**
Factory cycle time per mask layer (hot lot) [1,2,7] (days)	**0.7**	**0.65**	**0.6**
Number of lots per carrier (lot)	**One**	**One**	**One**
Wafer layers/day/head count	**73**	**81**	**89**
High Volume / High Mix Factory Requirements [4, 5, 6]			
Factory cycle time per mask layer (non-hot lot) [2,3] (days)	**0.9**	**0.95**	**0.8**
Factory cycle time per mask layer (hot lot) [2,3,7] (days)	**0.45**	**0.4**	**0.35**
Number of lots per carrier (lot)	**Multiple**	**Multiple**	**Multiple**
Wafer layers/day/head count	**49**	**54**	**60**
Common requirements across Both Factory Types			
Groundbreaking to first tool move-in (months)	**6**	**5.5**	**5**
First tool move-in to first full loop wafer out (months)	**2**	**1.5**	**1**
Node to Node change-over (weeks)	**10**	**9.5**	**9**
Floor space effectiveness	**1X**	**1X**	**1X**

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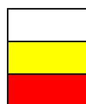

Explanation of Items for Factory Operations Technology Requirements:

	Item	*Explanation*
	Factory cycle time per mask layer (non-hot lot) [1,2]	*Assume 25 (variable) 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 20x1.5 = 30 days. A key metric of time to money.*
	Factory cycle time per mask layer (hot lot) [1,2,7]	*Same definition as of above. Factories typically prioritize these lots over conventional lots, sometimes hold tools downstream to rapidly move them through the process flow and may also reduce metrology steps and sampling rates. As a result, the cycle time for hot lots are ≤ 50% of non-hot lots. Assume 5-10 wafers per lot.*
Was	*Number of lots per carrier*	*Number of lots in each carrier that needs to be tracked, monitored, and processed at each production equipment. It impacts the extent of "recipe cascading" which enables production equipment to run in a continuous (non-stop) mode between lots in the same carrier and between sequential carriers.*
Is	*Number of lots per carrier*	*The number of lots in each carrier that need to be tracked, monitored, and processed.* ***For high mix factories, the number of lots < 25 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.***
	Wafer layers/day/head count	*Measure of productivity which includes equipment output and direct labor staffing .Equation = total wafer processed per day in the factory x # of litho mask layers/total # of direct labor employees per day.*
	Groundbreaking to first full tool move-in	*Time in months measured from groundbreaking to first move-in to the fab. Assumes site availability and all contract permits approved*
	First tool move-in to first 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 time	*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 #1 equipment.*
	Floor space effectiveness	*This is a measure of equipment installation density in the cleanroom, and drives the requirement for the smallest footprint and the fastest run rate for production equipment. Equation = (# of Processing steps in the fab * WSPM/(Floor space area*30days). 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 sq. meters of cleanroom for each new node.*

Table 67a Production Equipment Technology Requirements—Near-term

	Year of Production	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
	DRAM ½ Pitch (nm)	*130*	*115*	*100*	*90*	*80*	*70*	*65*
	MPU / ASIC ½ Pitch (nm)	*150*	*130*	*107*	*90*	*80*	*70*	*65*
	MPU Printed Gate Length (nm)	*90*	*75*	*650*	*53*	*45*	*40*	*35*
	MPU Physical Gate Length (nm)	*65*	*53*	*45*	*37*	*32*	*28*	*25*
	Wafer Diameter	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*
	Throughput improvement (run-rate) per year (reduced process time per wafer)	**Base**	**4% faster than previous year**	**4% faster than previous year**	**New base**	**4% faster than previous year**	**4% faster than previous year**	**New base**
	Relative consumables, gases, chemicals, exhaust, emissions, and utilities	**<1.0× of**	**→[8]**	**→**	**10% less of previous node**	**→**	**→**	**10% less of previous node**
	Bottleneck production equipment OEE [3]	**75%**	**78%**	**80%**	**82%**	**84%**	**87%**	**88%**
	Average production equipment OEE [3]	**55%**	**58%**	**60%**	**63%**	**65%**	**67%**	**70%**
	Relative maintenance and spares cost	**<1.0× of 200mm**	**→**	**→**		**→**	**→**	**<98% of previous node**
	Overall factory non-product wafer usage (per wafer start) as a % of production	**<16%**	**<15%**	**<14%**	**<13%**	**<12%**	**<11%**	**<11%**
	% capital equipment reused from previous node	**Limited reuse [7]**	**>90%**	**>90%**	**>90%**	**>90%**	**>90%**	**>90%**
Was	Wafer edge exclusion [4]	**2mm**	**2mm**	**2mm**	**2mm**	**2mm**	**2mm**	**2mm**
Is	Wafer edge exclusion [4]	**3mm**	**2mm**	**2mm**	**2mm**	**2mm**	**2mm**	**2mm**
	Production equipment lead time [5] from:							
	- Order to move-in (Litho)	**12 mos**	**12 mos**	**12 mos**	**12 mos**	**12 mos**	**12 mos**	**12 mos**
	- Order to move-in (all others tools)	**6 mos**	**6 mos**	**6 mos**	**6 mos**	**6 mos**	**6 mos**	**6 mos**
	- Setup to full throughput capable	**4 wks**	**4 wks**	**4 wks**	**4 wks**	**4 wks**	**4 wks**	**4 wks**
	Process/product changeover time (weeks)	**4**	**4**	**4**	**3**	**3**	**3**	**2**
	Production equipment install and qualification cost as % of its capital cost	**10%**	**8%**	**8%**	**6%**	**6%**	**6%**	**6%**
	Process equipment availability [6]	**>85%**	**>88%**	**>90%**	**>92%**	**>94%**	**>95%**	**>95%**
	Metrology equipment availability [6]	**>90%**	**92%**	**94%**	**>95%**	**95%**	**>96%**	**>97%**
Was	Number of process recipes per wafer	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Is	Ability to run different recipes and parameters for each wafer	**Partial**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
	Maximum allowable electrostatic field on wafer and mask surfaces (V/cm)	**150**	**150**	**100**	**100**	**75**	**75**	**50**
	Relative capital cost [1] of production equipment	**<1.3x of 200mm [2]**	**→**	**→**	**New base**	**→**	**→**	**New base**

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Yellow–Manufacturable Solutions are Known
Red–Manufacturable Solutions are NOT Known

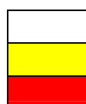


Table 67b Production Equipment Technology Requirements—Long-term

	Year of Production	*2010*	*2013*	*2016*
	DRAM ½ Pitch (nm)	*45*	*32*	*22*
	MPU / ASIC ½ Pitch (nm)	*45*	*32*	*22*
	MPU Printed Gate Length (nm)	*25*	*18*	*13*
	MPU Physical Gate Length (nm)	*18*	*13*	*9*
	Wafer Diameter	*300 mm*	*450 mm*	*450 mm*
	Throughput improvement (run-rate) per year (reduced process time per wafer)	**10–12% faster than previous node**	**10–12% faster than previous node**	**10–12% faster than previous node**
	Relative consumables, gases, chemicals, exhaust, emissions, and utilities	**10% less than previous node**	**10% less than previous node**	**10% less than previous node**
	Bottleneck production equipment OEE [3]	**90%**	**91%**	**92%**
	Average production equipment OEE [3]	**72%**	**74%**	**75%**
	Relative maintenance and spares cost	**<98% of previous node**	**<120% of previous node**	**<98% of previous node**
	Overall factory non-product wafer usage (per wafer start) as a % of production	**<10%**	**<9%**	**<9%**
	% capital equipment reused from previous node	**>70%**	**Limited reuse [7]**	**>70%**
	Wafer edge exclusion [4]	**2mm**	**2mm**	**2mm**
	Production equipment lead time [5] from:			
	- Order to move-in (Litho)	**12 mos**	**12 mos**	**12 mos**
	- Order to move-in (all others tools)	**6 mos**	**6 mos**	**6 mos**
	- Setup to full throughput capable	**4 wks**	**4 wks**	**4 wks**
	Process/product changeover time (weeks)	**2**	**2**	**2**
	Production equipment install and qualification cost as % of its capital cost	**6%**	**8%**	**6%**
	Process equipment availability [6]	**>95%**	**>95%**	**>95%**
	Metrology equipment availability [6]	**>98%**	**>98%**	**>98%**
Was	Number of process recipes per wafer	**1**	**1**	**1**
Is	**Ability to run different recipes and parameters for each wafer**	**Yes**	**Yes**	**Yes**
	Maximum allowable electrostatic field on wafer and mask surfaces (V/cm)	**50**	**25**	**25**
	Relative capital cost [1] of production equipment	**New base**	**<1.3x of 300 mm**	**New base**

White–Manufacturable Solutions Exist, and Are Being Optimized
Yellow–Manufacturable Solutions are Known
Red–Manufacturable Solutions are NOT Known

Explanation of Items for Production Equipment Requirements

Item	*Explanation*
Target throughput improvement (run-rate) per year (or reduced processing time per wafer)	*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. E.g.,: if current run-rate is 100 wafers/hour, the required run-rate next year is (100 x 1.04) = 104 wafers/hour and (104 x 1.04)=108 wafers/hour the following year.*
Relative consumables, exhaust, emissions, and utilities	*For the 130 nm node, relative consumables are 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 90 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 efficiency of the bottleneck production equipment. (Refer to SEMI E79 for OEE definition.) Bottleneck refers to the most constraint (limiting output) equipment in the factory.*
Average production equipment OEE	*Overall equipment efficiency of the average production equipment. (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 90 nm node and beyond, footprint is 98% of previous node assuming the same throughput. [Refer to SEMI E72.* [1] *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 90 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 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 technology 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.*
Production equipment lead time	*Time elapsed between when a purchase order has been placed for production equipment till the time the equipment has been qualified to run wafers at the quoted throughput (wafers per hour). Assume it is repeat order equipment, suppliers have sufficient mfg capacity, and learning achieved for fast install/qualification. For tools with long-lead items, risk reduction for equipment suppliers from order cancellation exposure may be mitigated by creative down-payment schemes.*
Process/Product changeover time (in weeks)	*Total time elapsed for old equipment move-out, new equipment move-in, install/hook-up and supplier qualification complete. Also assumes new equipment has space to move-in and major utility laterals are in place. Assume same wafer size, factory does not shut down and ≥ 90% of existing equipment is reused.*
Production equipment install & qualification cost as a % of capital equipment cost	*Ratio of production equipment (installation cost + hook-up cost + qualification cost) divided by its upfront capital cost, expressed as a percentage. Equipment and facilities hook-up standardization will reduce this cost.*
Process equipment availability	*Availability is 100% minus (scheduled downtime % + unscheduled downtime %) of the process (non-metrology) equipment. Scheduled downtime and unscheduled downtimes are defined in SEMI E10.*
Metrology equipment availability	*Availability is 100% minus (scheduled downtime % + unscheduled downtime %) of the metrology equipment. Scheduled downtime and unscheduled downtimes are defined in SEMI E10.*

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

Explanation of Items for Production Equipment Requirements (continued)

Was	*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. Indicates the ability to process each wafer differently.*
Is	***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" which enables equipment to run in a continuous (non-stop) mode between lots in the same carrier and between sequential carriers.***
	Maximum allowable electro static 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 and E43 for measurement methods.*
Was	*Relative capital cost of production equipment*	*For 130 nm nodes, 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 90 nm node and beyond, capital cost is a new baseline, positively influenced by run-rate(wafers/hour) increases at each year.*
Is	*Relative capital cost of production equipment*	*For 130 nm nodes, 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 90 nm node and beyond, capital cost is a new baseline, positively influenced by run-rate(wafers/hour) increases at each year.* ***The ratio is an aggregate to the entire set of production equipment for a fab, not to any individual piece of equipment. The ratio is an overall cost guideline based on the relative run rate (wafers per hour) of the 300mm equipment compared to its 200mm counterpart and is intended for technology assessment only and is without regard to any commercial considerations pertaining to individual equipment.***

Table 68a Material Handling Systems Technology Requirements—Near-term (40K WSPM) [7]*

	Year of Production	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
	DRAM ½ Pitch (nm)	*130*	*115*	*100*	*90*	*80*	*70*	*65*
	MPU / ASIC ½ Pitch (nm)	*150*	*130*	*107*	*90*	*80*	*70*	*65*
	MPU Printed Gate Length (nm)	*90*	*75*	*650*	*53*	*45*	*40*	*35*
	MPU Physical Gate Length (nm)	*65*	*53*	*45*	*37*	*32*	*28*	*25*
	Material handling total capital cost as a % of total capital cost	< 3% [1]	< 3%	< 3%	< 2% [2]	< 2%	< 2%	< 2%
Was	# Of transport system types within a factory	2 [3]	2	2	Some 1 and some 2	1 [4]	1	1
Is	Wafer Transport system capability	Separate interbay & intrabay	Separate interbay & intrabay	Separate interbay & intrabay	Some interbay & intrabay, Some Direct tool to tool	Direct tool to tool	Direct tool to tool	Direct tool to tool
Was	MTTR (minutes) (SEMI E10)	4	20	18	15	15	15	15
Is	MTTR (minutes) (SEMI E10)	24	20	18	15	15	15	15
	Failures per 24-hour day over total system (SEMI E10)	<1	<1	<0.75	<0.5	<0.5	<0.5	<0.5
	System throughput							
Was	• Interbay transport (moves/hour)	1200	1300	1400	1500	1625 [4]	1750	1875
Is	• Interbay transport (moves/hour) [40K WSPM]	2400	2600	2800	3000	3250 [4]	3500	3750
Was	• Intrabay transport (moves/hour)	170	180	190	200	1625 [4]	1750	1875
Is	• Intrabay transport (moves/hour) [40K WSPM]	170	180	190	200	3250 [4]	3500	3750
	Stocker cycle time (seconds)	15	15	14	12	12	10	10
	Average factory wide carrier delivery time (in minutes)	10	10	10	8	5	5	5
	Maximum factory wide carrier delivery time	20	20	20	15	15	15	15
	Stocker storage density (% Total WIP carrier volume / Total stocker volume) [5]							
	Small stocker (%)	> 25	>30	>30	>40	>40	>40	>50
	Nominal stocker (%)	>30	>35	>35	>45	>50	>50	>60
Was	Material handling equipment lead time (weeks)	<16	<14	<12	<11	<10	<9	<8
Is	Material handling equipment lead time (weeks)	<16	<14	<12	<11	<10	<9	<8
	Material handling equipment installation time (weeks)	<8	<8	<7	<7	<6	<5	<4
Was	System downtime required to extend system capacity when previously planned (minutes) [6]	<180	<90	<90	<60	<30	<30	<15
Is	System downtime required to extend system capacity when previously planned (minutes) [6]	<180	<90	<90	<60	<30	<30	<15

Add **WSPM—wafer starts per month*

White–Manufacturable Solutions Exist, and Are Being Optimized
Yellow–Manufacturable Solutions are Known
Red–Manufacturable Solutions are NOT Known

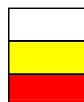
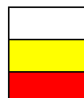


Table 68b Material Handling Systems Technology Requirements—Long-term (40K WSPM) [7]*

	Year of Production	*2010*	*2013*	*2016*
	DRAM ½ Pitch (nm)	*45*	*32*	*22*
	MPU / ASIC ½ Pitch (nm)	*45*	*32*	*22*
	MPU Printed Gate Length (nm)	*25*	*18*	*13*
	MPU Physical Gate Length (nm)	*18*	*13*	*9*
	Wafer Diameter	*300 mm*	*450 mm*	*450 mm*
	Material handling total capital cost as a % of total capital cost	< 2%	< 3%	< 3%
Was	# Of transport system types within a factory	1	1	1
Is	Wafer Transport system capability	Direct tool to tool	Direct tool to tool	Direct tool to tool
	MTTR (minutes) (SEMI E10)	12	10	8
	Failures per 24-hour day over total system (SEMI E10)	<0.5	<0.5	<0.3
Was	System throughput			
	• Interbay transport (moves/hour) • Intrabay transport (moves/hour)	2000	2000	2000
Is	System throughput			
	• Interbay transport (moves/hour) [40K WSPM] • Intrabay transport (moves/hour) [40K WSPM]	4000	4000	4000
	Stocker cycle time (seconds)	8	10	10
	Average factory wide carrier delivery time (in minutes)	5	5	5
	Maximum factory wide carrier delivery time	12	10	8
	Stocker storage density (% Total WIP carrier volume / Total stocker volume) [5]			
	Small stocker (%)	>50	>50	>50
	Nominal stocker (%)	>60	>60	>60
	Material handling equipment lead time (weeks)	<8	<8	<8
	Material handling equipment installation time (weeks)	<4	<4	<4
	System downtime required to extend system capacity when previously planned (minutes) [6]	30	30	30

Add **WSPM—wafer starts per month*



White–Manufacturable Solutions Exist, and Are Being Optimized
Yellow–Manufacturable Solutions are Known
Red–Manufacturable Solutions are NOT Known

Notes for Material Handling Systems Technology Requirements Tables:

[1] Year 2002—High throughput transportation

[2] Year 2005—Ability for Direct tool-to tool-delivery ~~Direct transportation~~ and fewer stockers

[3] Interbay and intrabay transport system types

[4] ~~Single direct transport system~~ Transport system capable of achieving factory wide direct tool-to-tool delivery

[5] Required external maintenance access space is not included in these values. However, it is expected that required maintenance access, except for electrical power distribution access on the back, should be designed for internal to the stocker, with the proper clearance for entering/exiting the stocker.

[6] These values are do not include downtimes associated with software upgrades, which are addressed by the Factory Information and Control Systems requirements (see Table 55) for unavailability of a mission critical application in a working factory due to install/upgrade (minutes)

Add *[7] All values in the table are based on a 40K WSPM factory unless otherwise specified.*

Explanation of Items for Material Handling Systems Requirements

	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%.*
Was	*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.*
Is	***Wafer Transport system capability***	***Capability of*** *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 for* ***the transport system to be capable of achieving factory wide direct tool-to-tool delivery.*** *This does not imply* ***one system*** *or even one system from one supplier. The system may be 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.*
Was	*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.)*
Is	*Failures per 24 hour day (over total system)*	*Number of* ***AMHS Equipment*** *component failures allowed throughout the system in a 24-hour day (or period). An* ***Equipment Failure is defined as any unplanned interruption or variance from the specifications of equipment operation other than assists. An assist is defined as an unplanned interruption that occurs during an equipment cycle where all three of the following conditions apply:*** • ***The interrupted equipment cycle is resumed through external intervention (e.g., by an operator or user, either human or host computer).*** • ***There is no replacement of a part, other than specified consumables.*** • ***There is not further variation from specifications of equipment operation.***
	System throughput	*Number of material handling moves per hour by the sub-system as defined below. Note that stocker robot moves from/to load ports are not assumed concurrent with nor included in system throughput moves*
Was	*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 vehicle at a stocker interbay port to the unloading of the same vehicle at the destination stocker*
Is	*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 vehicle at a stocker interbay port to the unloading of the same vehicle at the destination stocker.* ***This is sized for either 20k or 40k wspm factories.***
Was	*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 from a stocker storage bin to a production equipment load port.*
Is	*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 from a stocker storage bin to a production equipment load port.* ***This is sized for either 20k or 40k wspm factories.***

Explanation of Items for Material Handling Systems Requirements (continued)

Was	*Stocker cycle time*	*Time required, in seconds, for the stocker internal robot to move 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.*
Is	*Stocker cycle time*	***Stocker cycle time is defined as the time (in seconds) from when the Host 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.***
Was	*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.*
Is	*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.*
	Stocker storage density (% Total WIP Carrier Volume/Total Stocker Volume)	*Total WIP carrier volume that can be stored in a stocker divided by the total volume enclosed by the stocker, expressed as a percent (%). Carrier volume represented as a rectangular box enclosing all carrier handling features.*
	Small Stocker (%)	*Total WIP carrier volume that can be stored in a small stocker (defined as a stocker with capacity of 50 carriers or less) divided by the total volume enclosed by the small stocker, expressed as a percent.*
	Nominal Stocker (%)	*Total WIP carrier volume that can be stored in a Nominal stocker (defined as a stocker with capacity of 100 carriers) divided by the total volume enclosed by the nominal stocker, expressed as a percent.*
	Material Handling Equipment lead time (Weeks from order to move in)	*Time elapsed, in weeks, between when a purchase order has been placed for a material handling system until the time the final system component is FOB at supplier's dock. Based on size fab of approximately 200 meters by 80 meters, with 15-20 short bays. This lead time should not be affected by market demand on supplier.*
	Material Handling Equipment Installation time (Weeks from installation to full throughput capability)	*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. Based on size fab of approximately 200 meters by 80 meters, with 15-20 short bays.*
	Ease of extending capacity	*Impact to material handling system, in terms of downtime minutes required for making connections to track extension or a new stocker. Adding new AMHS vehicles should require no system downtime.*
	System downtime required 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 69a Factory Information and Control Systems Technology Requirements—Near-term[1]

	Year of Production	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
	DRAM ½ Pitch (nm)	*130*	*115*	*100*	*90*	*80*	*70*	*65*
	MPU / ASIC ½ Pitch (nm)	*150*	*130*	*107*	*90*	*80*	*70*	*65*
	MPU Printed Gate Length (nm)	*90*	*75*	*650*	*53*	*45*	*40*	*35*
	MPU Physical Gate Length (nm)	*65*	*53*	*45*	*37*	*32*	*28*	*25*
Was	MTBF for mission critical applications (months)	**>6**	**>7**	**>8**	**>8**	**>9**	**>9**	**>10**
Is	**Availability of mission critical system (%)**	**99.975%**	**99.975%**	**99.975%**	**99.980%**	**99.980%**	**99.980%**	**99.990%**
Was	Mean Time to Recover for mission critical applications (minutes)	**<90**	**<45**	**<45**	**<30**	**<30**	**<30**	**<15**
Is	Mean Time to Recover for mission critical applications (minutes)	**<30**	**<30**	**<30**	**<30**	**<30**	**<30**	**<15**
Was	Maximum long full fab down incidents due to unscheduled downtime of a mission critical application (per year)	**4**	**4**	**4**	**2**	**2**	**2**	**0**
Is	**Availability of the total factory system (%)**	**99.80%**	**99.80%**	**99.80%**	**99.90%**	**99.90%**	**99.90%**	**99.95%**
	Peak number of AMHS transport moves supported by material control system (moves/hr)	**8,000**	**8200**	**8400**	**8600**	**8850**	**9150**	**9450**
	% Factory information and control systems reusable for next node	**>93% of previous year**	**>93% of previous year**	**>93% of previous year**	**>93% of previous year**	**>93% of previous year**	**>93% of previous year**	**>93% of previous year**
Was	Time to create FICS interface standard (months)	**<12**	**<12**	**<6**	**<6**	**<6**	**<6**	**<6**
Is	Time to create FICS **industry** standard (months)	**<12**	**<12**	**<6**	**<6**	**<6**	**<6**	**<6**
Was	Lead time for software to conform to standards	**>18**	**<9**	**<9**	**<6**	**<6**	**<6**	**<6**
Is	Lead time for **solutions** to conform to standards	**>18**	**<9**	**<9**	**<6**	**<6**	**<6**	**<6**
	FICS cost including integration as a % of capital	**<2%**	**<2%**	**<2%**	**<2%**	**<2%**	**<2%**	**<2%**
Add	**Ability to run different recipes/parameters for each wafer**	**Partial**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

White–Manufacturable Solutions Exist, and Are Being Optimized
Yellow–Manufacturable Solutions are Known
Red–Manufacturable Solutions are NOT Known

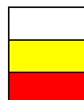


Table 69b Factory Information and Control Systems Technology Requirements—Long-term[1]

	Year of Production	*2010*	*2013*	*2016*
	DRAM ½ Pitch (nm)	*45*	*32*	*22*
	MPU / ASIC ½ Pitch (nm)	*45*	*32*	*22*
	MPU Printed Gate Length (nm)	*25*	*18*	*13*
	MPU Physical Gate Length (nm)	*18*	*13*	*9*
Was	MTBF for mission critical applications (months)	**>12**	**>12**	**>24**
Is	**Availability of mission critical system (%)**	**99.990%**	**99.990%**	**99.990%**
	Mean Time to Recover for mission critical applications (minutes)	**15**	**10**	**5**
Was	Maximum long full fab down incidents due to unscheduled downtime of a mission critical application (per year)	**0**	**0**	**0**
Is	**Availability of the total factory system (%)**	**99.98%**	**99.99%**	**99.99%**
	Peak number of AMHS transport moves supported by material control system (moves/hr)	**9700**	**9700**	**9700**
	% Factory information and control systems reusable for next node	**>80% of previous node**	**>80% of previous node**	**>80% of previous node**
Was	Time to create FICS interface standard (months)	**<6**	**<6**	**4**
Is	Time to create FICS **industry** standard (months)	**<6**	**<6**	**4**
Was	Lead time for software to conform to standards	**<4**	**<4**	**<4**
Is	Lead time for **solutions** to conform to standards	**<4**	**<4**	**<4**
Was	FICS cost including integration as a % of capital	**<2%**	**<2%**	**<2%**
Add	**Ability to run different recipes/parameters for each wafer**	**Yes**	**Yes**	**Yes**

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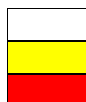
Red–Manufacturable Solutions are NOT Known



Explanation of Items for Factory Information and Control Requirements

	Item	Explanation
Was	MTBF for mission critical applications (months)	Mean Time Between Failure (MTBF) for mission critical applications (unscheduled) downtime. Mission critical applications within the factory information and control 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.
Is	**Availability of mission critical system (%)**	**Availability (A) is 100% minus (scheduled downtime % + unscheduled downtime %). Scheduled downtime and unscheduled downtimes are defined in SEMI E10.**
	Mean Time to Recover for mission critical applications (minutes)	Mean time to recover a mission critical application following an unscheduled downtime. Mission critical applications within the factory information and control systems are those that are required to keep the entire wafer factory operational. Mean time to recover is measured in minutes per incident.
	Unavailability of a mission critical application in a working factory due to install/upgrade (minutes)	Scheduled downtime, in minutes, to install or upgrade a mission critical application while the factory is in production. This includes the time to upgraded hardware, software, and database portions of an overall factory application. Database upgrades include changes to database schema and updates to the database contents.
Was	Maximum long full fab down incidents due to unscheduled downtime of a mission critical application (per year)	Number of full factory downtime incidents > 60 minute due to unscheduled downtime of a mission critical application (e.g. MES, MCS, etc)
Is	**Availability of the total factory system (%)**	**Availability (A_i) is 100% minus (scheduled downtime % + unscheduled downtime %) for each mission critical factory information and control system applications. Scheduled downtime and unscheduled downtimes are defined in SEMI E10. The total availability of the factory = [$A_1 * A_2 * A_3 * A_4 * A_5 * A_n$] where n is the total number of mission critical applications within the factory. The metric values assume that there are up to 6 mission critical applications within a factor.**
	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 [2 x (average number of interbay moves/hr) + (average number of intrabay moves/ hour)]
	% Factory and Information 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.
	Time to integrate new FICS application into existing factory Factory-wide system (weeks) Equipment control system (weeks)	Time to integrate a new FICS application into an existing factory and/or add additional capability to existing FICS system. Factory-wide systems include MES integration, MCS integration, APC Framework integration, etc. Equipment control systems include development and integration of equipment host controller systems, FDC rules, APC algorithms, etc.
Was	Time to create interface standard (months)	Time to create a new FICS interface standard required for open inter-process communication. Time is measured in months from initiation to published standard.
Is	Time to create **industry** standard (months)	**Time to create a new FICS standard. Examples include standards to communicate with equipment or open inter-process communication standards. Time is measured in months from initiation to published standard.**
Was	Lead time for FICS to conform to standards (months)	Time for factory information and control systems to comply with defined industry standard interfaces for open inter-process communication.
Is	Lead time for **solutions** to conform to standards (months)	Time for factory information and control systems to comply with defined industry standards**, like** interfaces for open inter-process communication
	Factory Information and Control Systems cost (% of capital)	Percentage of overall factory cost spent on factory information and control 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. FICS cost does not include cost of control systems software internal to production or AMHS equipment.
Add	**Ability to run different recipes/parameters for each wafer**	**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.**

Table 70a Facilities Technology Requirements—Near-term

	Year of Production	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
	DRAM ½ Pitch (nm)	*130*	*115*	*100*	*90*	*80*	*70*	*65*
	MPU / ASIC ½ Pitch (nm)	*150*	*130*	*107*	*90*	*80*	*70*	*65*
	MPU Printed Gate Length (nm)	*90*	*75*	*650*	*53*	*45*	*40*	*35*
	MPU Physical Gate Length (nm)	*65*	*53*	*45*	*37*	*32*	*28*	*25*
	Wafer Diameter	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*
	Cleanroom area as a % of total site building area	**17%**	**17%**	**17%**	**17%**	**17%**	**17%**	**17%**
Was	Cleanroom area (m2) / wafer starts per month	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Is	**Manufacturing (Cleanroom) area/Wafer starts per month (m2/WSPM)**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**	**0.34**
Was	Classification of air cleanliness in the manufacturing (cleanroom) area	**ISO Class 5 (Fed Class 100) or better**	**ISO Class 5 (Fed Class 100) or better**	**ISO Class 5 (Fed Class 100) or better**	**ISO Class 6 (Fed Class 1000 or worse)**	**ISO Class 6 (Fed Class 1000 or worse)**	**ISO Class 6 (Fed Class 1000 or worse)**	**ISO Class 6 (Fed Class 1000 or worse)**
Is	Classification of air cleanliness in the manufacturing (cleanroom) area	ISO Class 5	ISO Class 5	ISO Class 5	ISO Class 6	ISO Class 6	ISO Class 6	ISO Class 6
	Power utilization (demand/installed)							
	Gas and chemical purity	*Performance requirements enabling facilities to prevent defects and maintain process critical fluids and materials purity requirements are discussed in the Yield Enhancement Chapter*						
	Power and water consumption	*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.*						
	Factory construction time from ground break to all facility systems operational (months)	**12**	**12**	**12**	**10**	**10**	**10**	**10**
	Facility capital cost as a % of total factory capital cost (includes equipment)	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**	**15%**
Was	Production equipment install and qualification cost as a % of capital cost	**10%**	**8%**	**8%**	**6%**	**6%**	**6%**	**6%**
Is	Production equipment install and qualification cost as a % of capital cost	**10%**	**8%**	**8%**	**6%**	**6%**	**6%**	**6%**
	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%**
	Maximum allowable electrostatic field on facility surfaces (V/cm)	**150**	**150**	**100**	**100**	**75**	**75**	**50**

White–Manufacturable Solutions Exist, and Are Being Optimized
Yellow–Manufacturable Solutions are Known
Red–Manufacturable Solutions are NOT Known

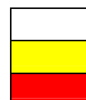
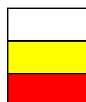


Table 70b Facilities Technology Requirements —Long-term

	Year of Production	*2010*	*2013*	*2016*
	DRAM ½ Pitch (nm)	*45*	*32*	*22*
	MPU / ASIC ½ Pitch (nm)	*45*	*32*	*22*
	MPU Printed Gate Length (nm)	*25*	*18*	*13*
	MPU Physical Gate Length (nm)	*18*	*13*	*9*
	Wafer Diameter	*300 mm*	*450 mm*	*450 mm*
	Cleanroom area as a % of total site building area	**17%**	**17%**	**17%**
Was	Cleanroom area (m2) / wafer starts per month	**1.5**	**1.5**	**1.5**
Is	**Manufacturing (Cleanroom) area/Wafer starts per month (m2/WSPM)**	**0.34**	**0.34**	**0.34**
Was	Classification of air cleanliness in the manufacturing (cleanroom) area	**ISO Class 6 (Fed Class 1000 or worse)**	**ISO Class 6 (Fed Class 1000 or worse)**	**ISO Class 6 (Fed Class 1000 or worse)**
Is	Classification of air cleanliness in the manufacturing (cleanroom) area	**ISO Class 7**	**ISO Class 8**	**ISO Class 9**
	Power utilization (demand/installed)	**80%**	**70%**	**80%**
	Gas and chemical purity	*Performance requirements enabling facilities to prevent defects and maintain process critical fluids and materials purity requirements are discussed in the Yield Enhancement Chapter*		
	Power and water consumption	*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.*		
	Factory construction time from ground break to all facility systems operational (months)	**10**	**10**	**10**
	Facility capital cost as a % of total factory capital cost (includes equipment)	**15%**	**15%**	**15%**
	Production equipment install and qualification cost as a % of capital cost	**6%**	**8%**	**6%**
	Facility operating cost including utilities as a % of total operating cost	**13%**	**13%**	**13%**
	Utility cost per total factory operating cost (%)	**3%**	**3%**	**3%**
	Maximum allowable electrostatic field on facility surfaces (V/cm)	**50**	**25**	**25**

White–Manufacturable Solutions Exist, and Are Being Optimized
Yellow–Manufacturable Solutions are Known
Red–Manufacturable Solutions are NOT Known



Explanation of Items for Facilities requirements:

	Item	Explanation
Was	*Manufacturing (Cleanroom) Area (m^2)*	*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.*
Is	*Manufacturing (Cleanroom) area/**Wafer starts per month (m2/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.*
	Total site building Area (m^2)	*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.*
	Wafer start per month ($/WSPM)	*Wafer starts per month is defined as the number of new 300 mm wafers introduced into production for processing during a given seven day work week.*
	Classification of Air Cleanliness	*Cleanliness classification of wafer factory manufacturing (cleanroom) area as defined by ISO 14644-1 (and Fed Std. 209E).*
	Power Utilization (percent)	*Power 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.*
	Factory Construction Time from Groundbreaking to all Facility Systems Operational	*Factory construction time is defined as the period of time in months from first concrete placement to the time that all the facility infrastructure systems are functional, i.e., have passed inspection, and are capable of providing services required to run the complete set of production equipment necessary for processing the first full loop wafer out.*
	Facility Capital Cost	*Factory Capital Cost is defined as all labor and material costs necessary to complete factory design, site work, construction and construction management to build a new semiconductor factory. This includes construction of the factory building shell, office space, manufacturing (cleanroom) areas, 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 provided by the production equipment supplier.*
	Total Factory Capital Cost	*Total factory Capital Cost is defined as all labor and material costs necessary to complete a new semiconductor factory including production equipment and facility capital cost. This excludes costs for land.*
	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 connect 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.*
	Production Equipment Capital Cost	*Production Equipment Capital Cost is defined as actual cost paid for production equipment including all support systems provided by the supplier. This excludes installation and qualification costs.*
	Facility 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	*Utility cost is defined as the cost of power, water, gases and chemicals required to support manufacturing, including the factory material and consumables.*
	Total Factory Operating Cost	*Total Factory Operating cost is defined as the total annual operating expenses necessary for operating the factory including depreciation, materials, maintenance, and labor.*
	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 E78 and E43 for measurement methods.*

Table 71a Probe/Test Manufacturing Technology Requirements —Near-term

Year of Production	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
DRAM ½ Pitch (nm)	*130*	*115*	*100*	*90*	*80*	*70*	*65*
MPU / ASIC ½ Pitch (nm)	*150*	*130*	*107*	*90*	*80*	*70*	*65*
MPU Printed Gate Length (nm)	*90*	*75*	*650*	*53*	*45*	*40*	*35*
MPU Physical Gate Length (nm)	*65*	*53*	*45*	*37*	*32*	*28*	*25*
Wafer Diameter	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*	*300 mm*
Test product setup time improvement from previous year (complex devices)	**0%**	**0%**	**0%**	**20%**	**10%**	**5%**	**5%**
Test product setup time improvement from previous year (simple devices)	**0%**	**0%**	**0%**	**5%**	**5%**	**5%**	**5%**
1st article test equipment integration time improvement from previous year	**0%**	**0%**	**30%**	**20%**	**20%**	**10%**	**10%**
Mass produced test equipment integration time improvement from previous year	**0%**	**0%**	**10%**	**10%**	**10%**	**5%**	**5%**

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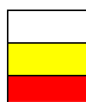

Table 71b Probe/Test Manufacturing Technology Requirements—Long-term

Year of Production	*2010*	*2013*	*2016*
DRAM ½ Pitch (nm)	*45*	*32*	*22*
MPU / ASIC ½ Pitch (nm)	*45*	*32*	*22*
MPU Printed Gate Length (nm)	*25*	*18*	*13*
MPU Physical Gate Length (nm)	*18*	*13*	*9*
Wafer Diameter	*300 mm*	*450 mm*	*450 mm*
Test product setup time improvement from previous year (complex devices)	**5%**	**5%**	**5%**
Test product setup time improvement from previous year (simple devices)	**5%**	**5%**	**5%**
1st article test equipment integration time improvement from previous year	**10%**	**10%**	**10%**
Mass produced test equipment integration time improvement from previous year	**5%**	**5%**	**5%**

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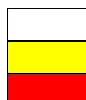

Explanation of Items for Probe/Test Manufacturing Technology Requirements:

	Item	*Explanation*
Delete	~~*Complex Devices*~~	~~*Devices with >5M gates (e.g. high performance, general purpose CPUs). Generally resulting in larger test programs (gigabytes), tester data output (10's of megabytes) and low product mix test cells.*~~
Delete	~~*Simple Devices*~~	~~*Devices with <5M gates (e.g. micro controllers, xRAMs). Generally resulting in smaller test programs (megabytes), tester data output (kilobytes) and high product mix test cells.*~~
Delete	~~*Product Setup Time*~~	~~*The time to perform the automated setup of a test cell (lot introduction, process program download, initialization) prior to material processing*~~
Add	***Test product setup time improvement from previous year (complex devices)***	***Percent improvement in the time required to set up test equipment to test a complex semiconductor devices. Complex devices are defined as having >5M gates (e.g. high-performance, general purpose CPUs). Generally resulting in larger test programs (gigabytes), tester data output (10's of megabytes) and low product mix test cells.***
Add	***Test product setup time improvement from previous year (simple devices)***	***Percent improvement in the time required to set up test equipment to test a simple semiconductor devices. Simple devices are defined as having<5M gates (e.g. micro controllers, xRAMs). Generally resulting in smaller test programs (megabytes), tester data output (kilobytes) and high product mix test cells.***
Was	*1st Article Equipment Integration Time*	*The elapsed time required to submit requirements, analyze, design, implement and test the automated functionality of the first instance of equipment delivered to a given IC manufacturer.*
Is	*1st Article Equipment Integration Time* ***improvement from previous year***	*Percent improvement from year to year in the elapsed time required to submit requirements, analyze, design, implement and test the automated functionality of the first instance of equipment delivered to a given IC manufacturer.*
Was	*Mass Produced Equipment Integration Time*	*The elapsed time required to qualify for production the automated functionality of subsequent instances of equipment (from a given IC manufacturer's perspective).*
Is	*Mass Produced Equipment Integration Time* ***improvement from previous year***	*Percent improvement from year to year in the elapsed time required to qualify for production the automated functionality of subsequent instances of equipment (from a given IC manufacturer's perspective).*
Delete	~~*SEM*~~	~~*Specific Equipment Model. A SEM is a type of industry standard that describes the way a particular type of equipment behaves and communicates with the factory information and control system. The minimal equipment control behavior, messaging syntax/sequencing, data content, data collection and data modification mechanisms are specified in this type of standard.*~~