

# ITRS Factory Integration Presentation

**Mani Janakiram**

**July 2006**

**San Francisco, USA**

**Global Co-Chairs:**

**Europe: Arie Greenberg**

**Japan: Shige Kobayashi, Michio Honma**

**Korea: C. S. Park/ S. H. Park**

**Taiwan: Thomas Chen**

**US: Mani Janakiram**



# Agenda

- 1. Scope and Difficult Challenges**
- 2. Technology Requirements & Potential Solutions**
- 3. Top Factory Integration Focus Areas**
- 4. Factory Integration Cross-Cut Issues**
- 5. Summary**



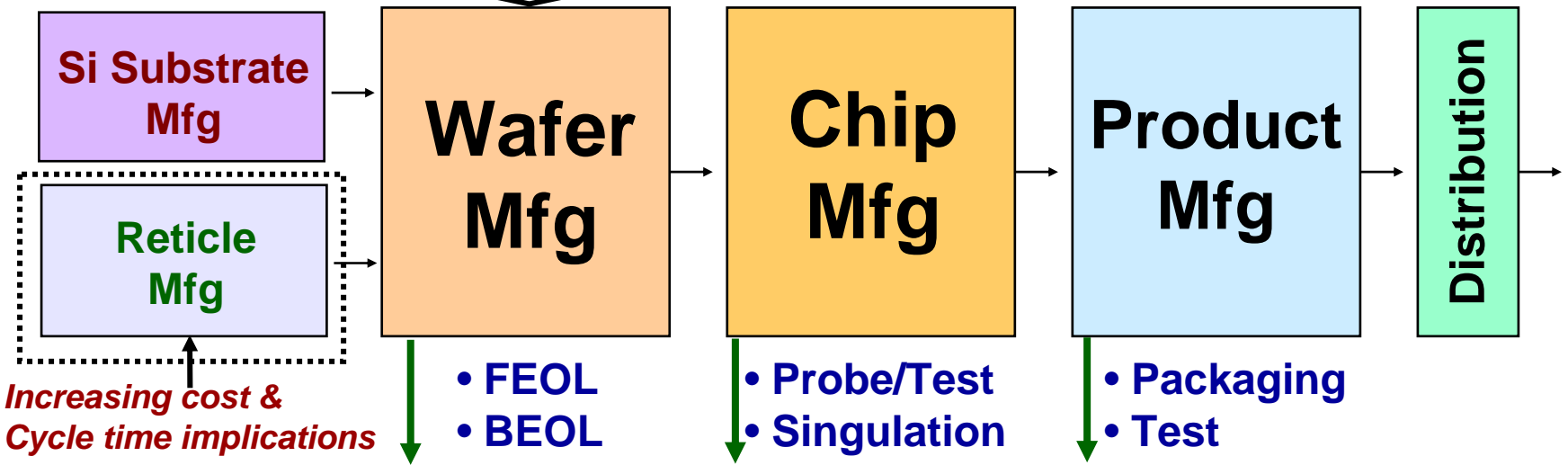
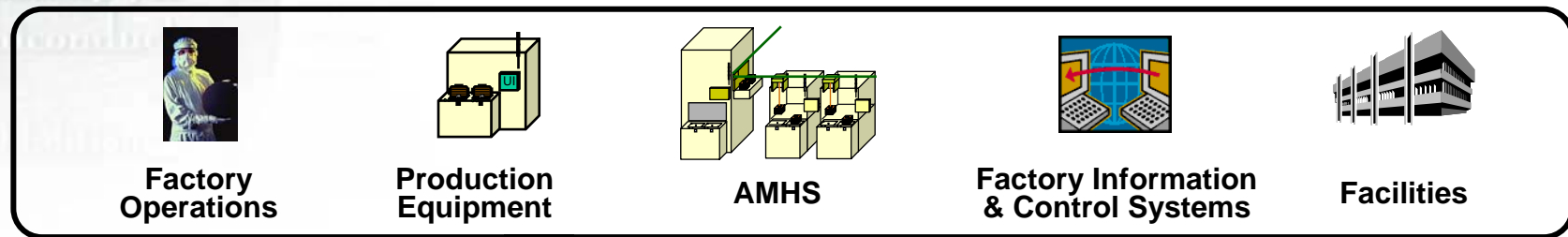
# ITRS FI Participants - Excellent participation!

Hiroyuki Akimori (Selete)	Masazumi Fukushima (Muratec)	Shoichi Kodama (Toshiba)	Adrian Pyke (Middlesex)
Jim Ammenheuser (ISMT)	Ashwin Ghatalia (Philips)	Todd Lasater (Intel)	JB Ragothaman (Intel)
Robert Atherthon (Sun)	Detlev Glueen (AMD)	YC Lee (TSMC)	Joe Reiss (Asyst-Shinko)
Mohammad Avishan (Intel)	Barbara Goldstein (NIST)	Ya-Shian Li (NIST)	Ralph Richardson (Air Force)
Robert Bachrach (AMAT)	Ton Govaarts (Philips)	Span Lu (TSMC)	Lance Rist (ISMT)
Marie-France Bernard (STM)	Arieh Greenberg (Infineon)	Tom Mariano (Brooks)	Georg Rosen (Fraunhofer ISE)
Josef Bichlmeier (CamLine)	Dave Gross (AMD)	Les Mashall (AMD)	Christopher Schaefer (Fraunhofer IISB)
Michael Bufano (Brooks)	Sven Hahn (Infineon)	Don Martin (IBM)	David Sklar (ASMT)
David Bouldin (TI)	Chung Soo Han (AMD)	James Martin (Intel)	John Smithey (Intel)
Hugo Chang (Winbond)	Clint Harris (Brooks)	Leon McGinnis (Georgia Tech)	William Shopbell (AMD)
Jonathan Chang (TSMC)	Parris Hawkins (AMAT)	Dave Miller (IBM)	Court Skinner (SRC)
Al Chasey (ASU)	Yoshio Hayashi (Rohm)	Akira Mitani (ASMT)	Arnie Steinman (ION Systems)
Allan Chen (TSMC)	Harald Heinrich (Infineon)	Ryuji Mizuno (ASMT)	Dan Stevens (Hirata)
PH Chen (TSMC)	Larry Hennessy (IDC)	Michael M. M. (M&W Zander)	Abol Taghizadeh (National Semiconductor)
Thomas Chen (TSMC)	Donald Hicks (UT Dallas)	Yoshiaki Nagawa (Sony)	Junichi Takeuchi (Seiko Epson)
Ivan Chou (Compaq)	Michio Honma (NEC Electronics)	Seiki Nakajima (Muratec)	Keisuke Tanimoto (Sharp)
Mars Chou (UMC)	Yasutaka Horii (IBM)	Seiichi Nakazawa (F-RIC)	Toshiyuki Uchino (Trecenti)
Eric Christensen (AMD)	CJ Huang (TSMC)	Andreas Neuber (MW-Zander)	Kensuke Uriga (TI)
Blaine Crandell (Consultant)	Roy Hsu (ASMT)	Richard Oechsner (Fraunhofer IISE)	KR Vadivazhagu (Infineon)
Jean-Francois Delbes (STM)	Chang-Ho Lee (ASMT)	Shuzo Ohshio (Fujitsu)	Brad Van Eck (ISMT)
Ron Denison (Muratec)	Chang-Ho Lee (ASMT)	Doug Oler (Hirata)	Joost van Herk (Philips)
Ed Dobson (STM)	Chang-Ho Lee (ASMT)	Mikio Otani (Asyst-Shinko)	Philippe Vialletelle (STM)
Hans Martin Duden (ASMT)	Chang-Ho Lee (ASMT)	SH Park (Samsung)	Tikara Wada (Taikisha)
Klaus Eberhard (ASMT)	Chang-Ho Lee (ASMT)	Mike Patterson (Intel)	Alan Weber (NIST)
Anne Eberhard (ASMT)	Chang-Ho Lee (ASMT)	Will Perakis (Asyst-Shinko)	Harvey Wohlwend (ISMT)
Franklin Kalk (Dupont Photomask)	Chang-Ho Lee (ASMT)	Jeff Pettinato (Intel)	Rex Wright (Asyst-Shinko)
N. Fisher (SK Daifuku)	Chang-Ho Lee (ASMT)	Dev Pillai (Intel)	Bevan Wu (Consultant)
Len Foster (TI)	Chang-Ho Lee (ASMT)	Lisa Pivin (Intel)	Hiromi Yajima (Toshiba)
John Fowler (ASU)	Chang-Ho Lee (ASMT)	Scott Pugh (Hirata)	Makoto Yamamoto (Murata)

**Over 115 members contributed to the Factory Integration Chapter – Thanks!**



# Factory Integration Scope and Drivers



**Factory is driven by Cost, Quality, Productivity, and Speed**

- ☞ Reduce factory capital and operating costs per function
- ☞ Faster delivery of new and volume products to the end customer
- ☞ Efficient/Effective volume/mix production, high reliability, & high equipment reuse
- ☞ Enable rapid process technology shrinks and wafer size changes



# Key Technologies that will Impact Factory Design

- ★ 2006 and future years are targeted to meet productivity and capture technology requirements
- ★ Key process and device technology intercepts that will impact the factory design are Extreme Ultraviolet Litho (EUVL), New Device Structures, new materials and the next wafer size conversion

Near Term Years						
Year	2005	2006	2007	2008	2009	2010
Technology trend (nm)	80	70	65	55	50	45
Wafer Size (mm)	300	300	300	300	300	300

Start Planning for 450mm  
Started discussions

Long Term Years										
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Technology trend (nm)	40	35	32	28	25	22	20	18	16	14
Wafer Size (mm)	300	450	450	450	450	450	450	450	450	450

New Device Structures?

EUVL in Production?

Next Wafer Size in Production?



# Difficult Challenges Summary

E=Economic/Business  
P=Process Technology  
M=Manufacturing

## Near Term: 2005 to 2010 $\geq 45\text{nm}$

1. Responding to rapidly changing and complex business requirements [E]
2. Meeting growth targets while margins are declining [E]
3. Managing ever increasing factory complexity [M]
4. Meeting factory and equipment reliability, capability or productivity requirements per the roadmap [M]
5. Meeting the Flexibility, Extendibility, and Scalability needs of a cost effective, leading edge factory [M]
6. Meeting process requirements at 65nm and 45nm nodes running production volumes [P]
7. Increasing global restrictions on environmental issues [E]

## Long Term: 2011 to 2020 $< 45\text{nm}$

1. Post conventional CMOS manufacturing uncertainty [P]
2. 300'/450mm factory paradigm changes [M] [E]

Economic and business challenges are equal to our manufacturing and process technology challenges in scope and breadth to attain efficiency and effectiveness







# FI Sub team – July 2006 Status



	Subteam	July 2006
1	<b><u>Factory Operations (FO)</u></b> Focus: 1) Reduce Lot Cycle times, 2) Improve Equipment Utilization, 3) Reduce Losses from High Mix	Good progress on technology requirement tables, working on potential solutions and focus area topics, including equipment losses (“a” and “b” values) and it’s impact.
2	<b><u>Production Equipment (PE)</u></b> Focus: 1) NPW reduction, 2) Reliability Improvement, 3) Run rate (throughput) improvement	Good progress on technology requirement tables and focus area topics. Working on setup time reduction proposal, NPW metric value, completed discussion with FF on adapter plate metric.
3	<b><u>Automated Material Handling Systems (AMHS)</u></b> Focus: 1) Increase throughput for Traditional and Unified Transport, 2) Reduce Average Delivery times, 3) Improve Reliability	AMHS team has agreed on changes to Requirements Table, Discussed High Mix potential implications for AMHS (Wafers per carrier/MPH/ Reliability/Storage).
4	<b><u>Factory Information &amp; Control Systems (FICS)</u></b> Focus: 1) Increase Reliability, 2) Increase Factory Throughput, 3) Reduce or Maintain Mask Shop Cycle Time,	Good progress on technology requirement tables and focus area discussions. Significant FICS drivers are: Smaller lot sizes, Increasing data volume (Eng data, time sync). Several changes planned for 2007 since the table values seem to be saturated/flat.
5	<b><u>Facilities</u></b> Focus: 1) Reduce Costs 2) Utility 3) Footprint	Working on tables and focus areas (Adapter plate (AP), Green Fab, Energy conservation). SEMI standards work kicked off on AP; metric discussions around green fab & DFF mtg. planned;



# 2006 FI Focus Area Summary

	Focus Areas	Description
1	Design for Facilities (DFF) including adapter plate 	Enable standard, efficient solution for facility design for Architectural, Mechanical, Waste, Exhaust, Electrical, Operational, Tool Installation.
2	“Proactive Visual” manufacturing 	Conquer the of high mix, small lot, productivity losses and provide metrics for fab operations.
4	300’/450mm Transition 	<u>Target:</u> Historical 30% improvement in cost/cm <sup>2</sup> and 50% cycle time reduction in days per mask layer. FI will work with International Sematech and will continue to define technology requirements for 450mm and 300’ in 2006-2007
5	FI Cross-cut issues 	Address key FI key issues with FEP (SWP vs. Batch), Litho (EUVL), ESH (DFF, Energy), YE (Temp & Humidity) and Metrology (Wafer map standards)

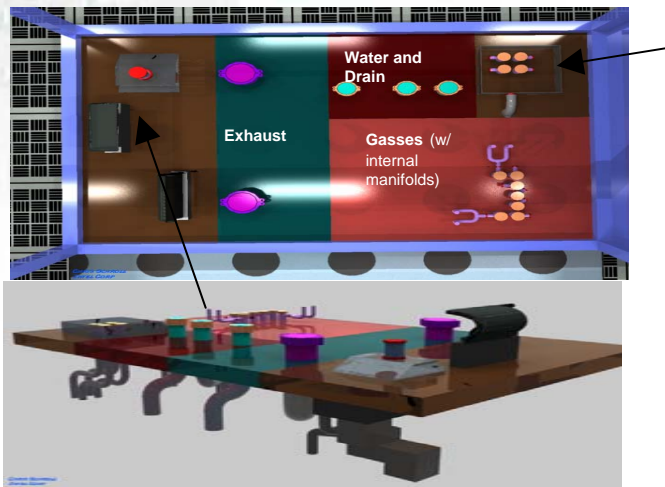
Factory Integration will update Technology Requirements tables & Potential Solutions tables in addition to working on these focus areas in 2006



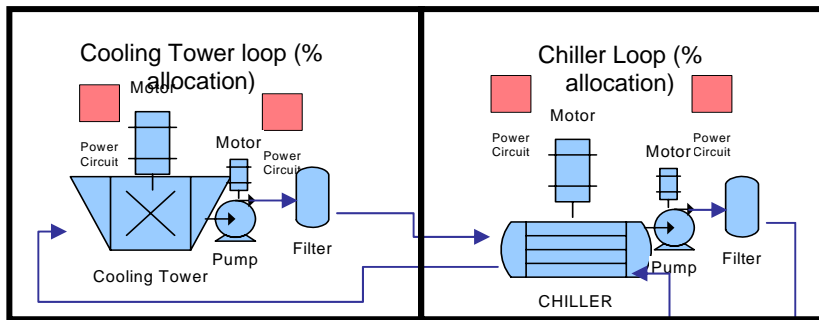
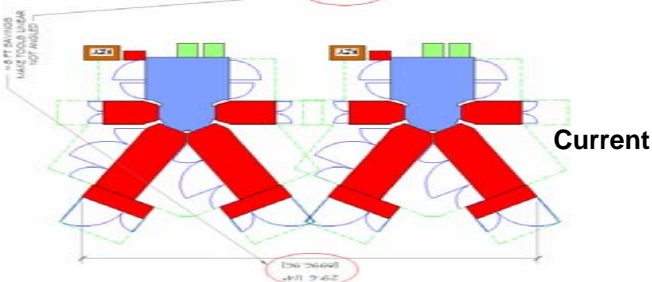
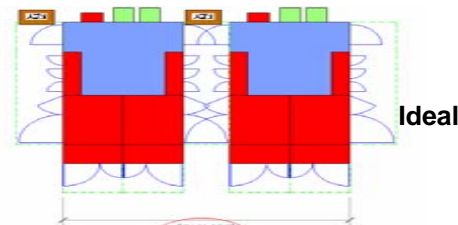
# Design for Facilities (DFF)



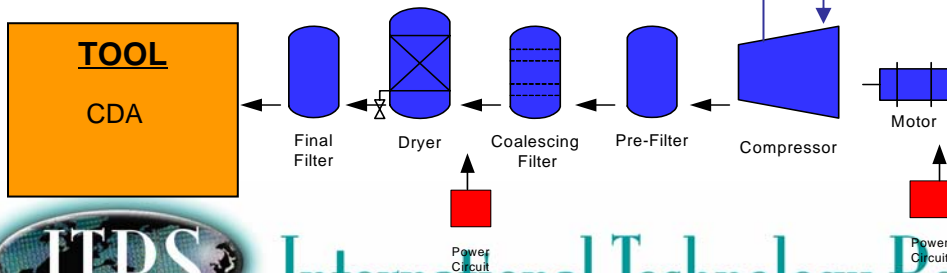
Layout design – Optimal footprint



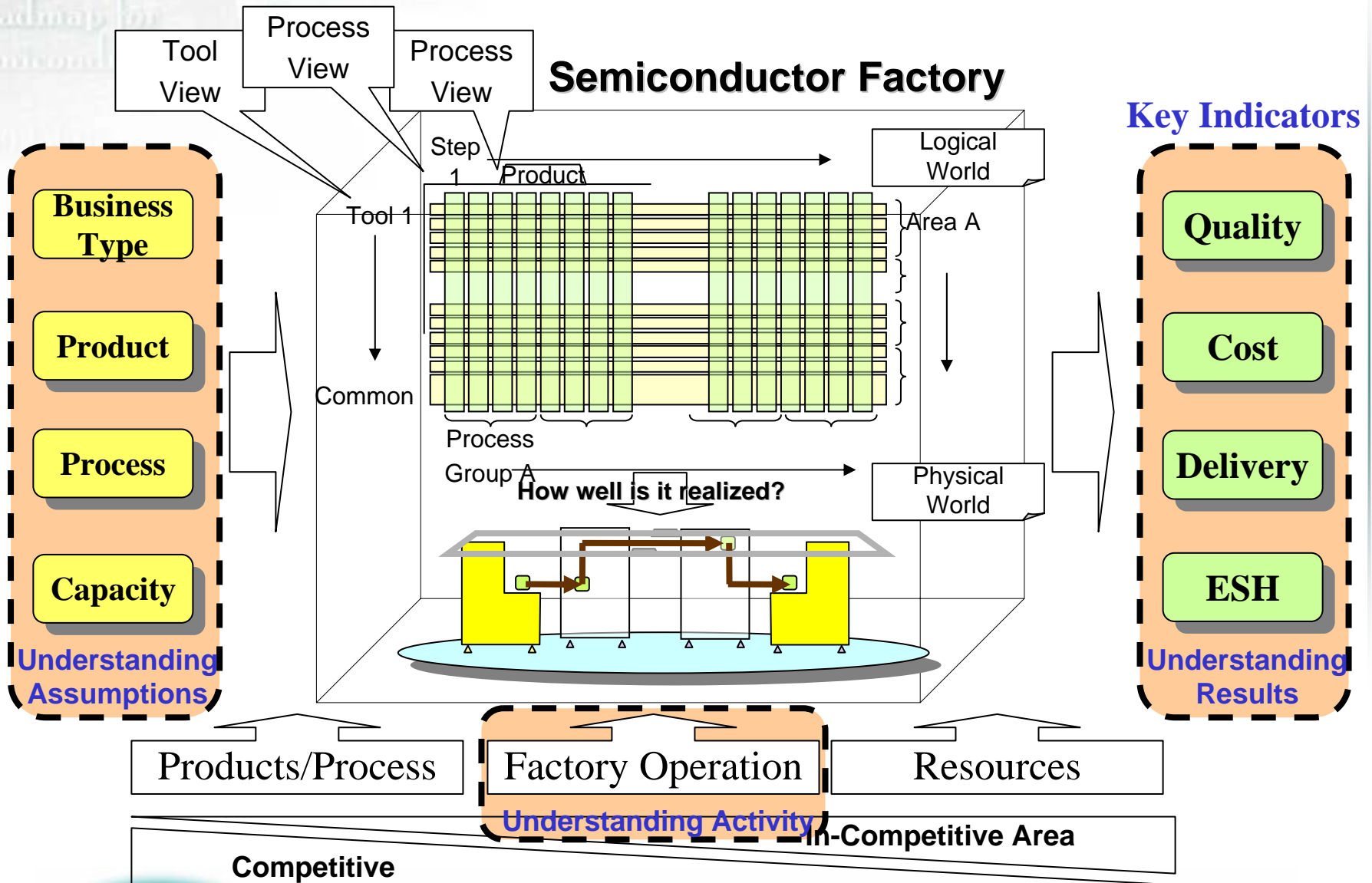
Adapter Plate – Efficient installation



Utility – optimal design/use



# Factory Visualization Metrics



# Enhance Visibility of Equipment Activity

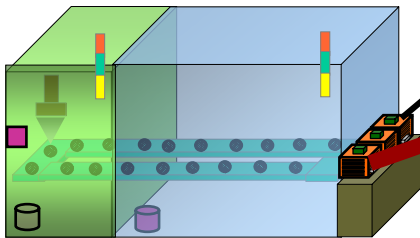
★ The 2<sup>nd</sup> port is intended to provide information as described in EEC Guidelines

☞ The obvious use of the 2<sup>nd</sup> port data has not been addressed other than in EEC Guidelines

★ FI is working on putting the 2<sup>nd</sup> port requirements in ITRS tables

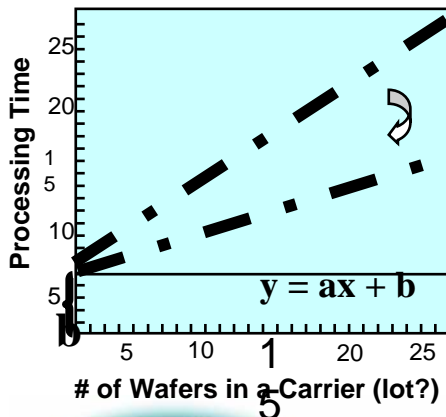
☞ Required for data contents meeting the equipment performance needs

☞ Required for enhanced equipment quality management and assurance

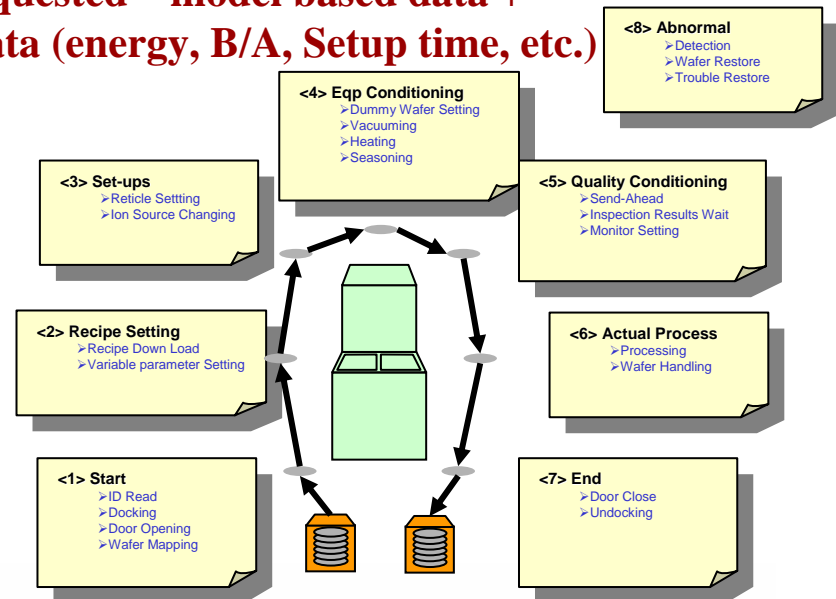


SECS data port exist – raw data

2<sup>nd</sup> data port requested – model based data + activity/event data (energy, B/A, Setup time, etc.)

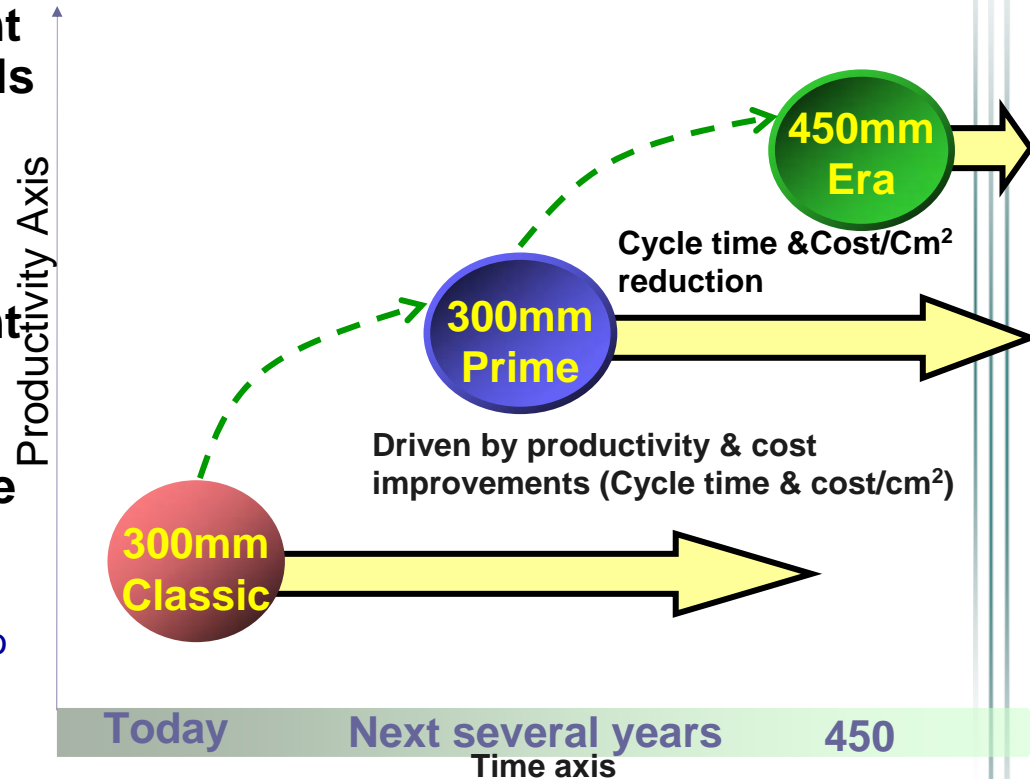


setup time contributors



# Productivity Improvement Roadmap drivers

- **Comprehend the needs of different IC maker/Foundry business models**
  - These models (including high mix) will influence current 300mm configurations before transition to 450mm occurs
- **300 Prime will close the gaps identified in current 300 equipment**
  - New capabilities extendible to 450
- **450mm transition can be a simplified scale-up from 300 Prime**
  - Compared to 200mm → 300mm transition
  - Extending 300mm capability to 450mm
  - Minimizing the number of configurations to develop, test and deploy
- **Global participation is very important to define requirements, priorities and due dates**



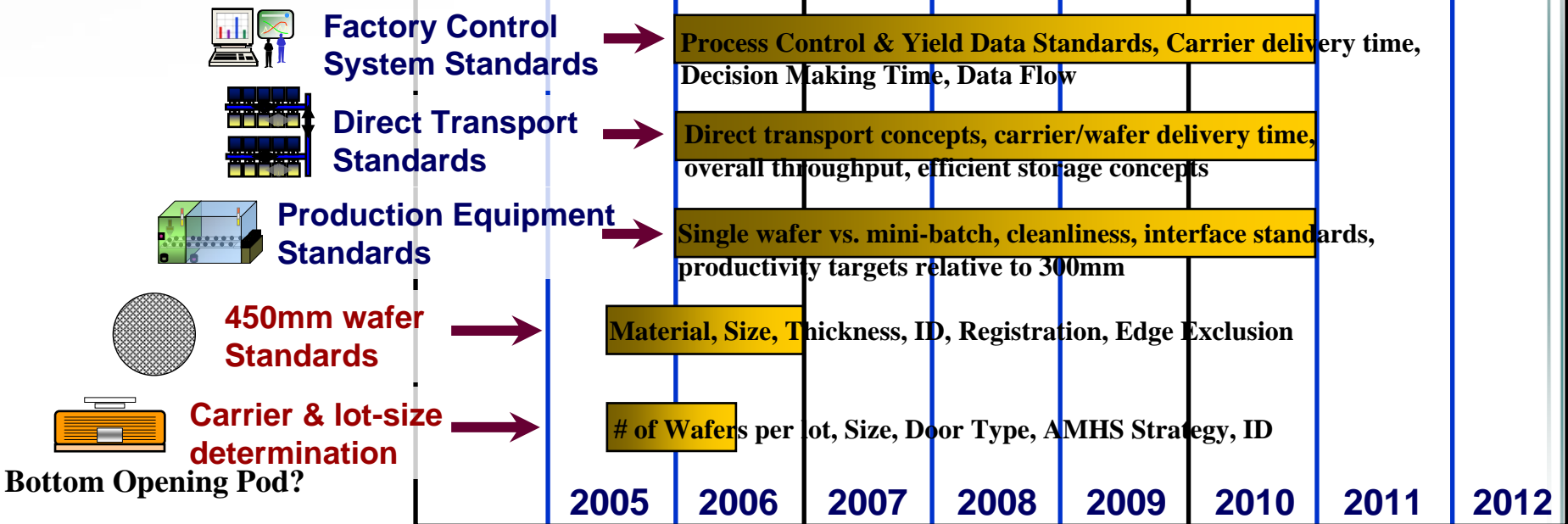
**Key drivers are significant cycle time and cost/cm<sup>2</sup> reduction  
→ Productivity Improvements**



# What is needed for 450mm transition



Scope/Timeline will be sync'd with ISMI 450mm program



Many technology issues in 450mm need to be addressed!  
 FI is working with ISMI 300P/450mm Program to be in-sync.



# 2006 FI Cross Cut Issues to be addressed

<i>Crosscut Area</i>	<i>Factory integration related key challenges</i>
Front end Process (FEP)	SWP/Batch/Mini-batch for thermal processes (for 450mm) – proposal is to create initial process template and form a small cross-cut team. No solution exists for 1.5mm WEE, may have to revert to 2mm and target 1.5mm for 300' (~2008)
Litho	EUVL (power, consumables, weight) impact on FI and FI will provide facility weight threshold to Litho; Need to coordinate YE inputs on wafer quality (temp & humidity). Product/process centric mask metrics are in the Litho tables but many others mask related metrics need to be addressed.
ESH	ESH/FI to identify which tools are ideal candidates for equipment sleep mode (may be phased implementation) and ESH to incorporate sleep mode metric in their 2007 tables for energy conservation. ESH/FI to define boundary conditions jointly by Dec'06.
Metrology	Temperature & Humidity specs for Metrology tools. Off-line/in-line/in-situ Metrology will be included in the 2007 chapter (Wafer metrology versus Sensors data). FI to provide input on off-line/in-line/in-situ document.
Yield Enhancement	YE decided to include temperature and humidity metrics with FI referencing these tables. YE working with FI & ESH on developing a feasibility study on equipment sleep mode to conserve energy.



# Key Messages

- 1. Business strategies, market demands, and process technology changes continue to make factories difficult to integrate**
- 2. Factory's speed and flexibility are vital to accommodate various production technologies**  
High Mix, Cycle time improvement, equipment utilization, direct transport AMHS, etc.
- 3. Gaps in Production Equipment performance, Setup time, AMHS, Facilities and Factory operations must be improved**  
Metrics needed to cover versatility, productivity, agility, quality, environment compatibility  
Wafer view oriented productivity visualization needed
- 4. Key cross-TWG issues need to be addressed**  
450mm, Abatement, DFF, EUVL requirements, Wafer Edge Exclusion; Equipment energy conservation
- 5. Proactive visualization/usage of factory/equipment data is required**  
Delivery time, Intrinsic equipment losses, etc.  
2<sup>nd</sup> data port needed to understand equipment data and setup losses
- 6. Productivity Improvement Roadmap Comprehend the needs of different IC maker/Foundry business models**  
Productivity improvement: Cycle time & Cost/Cm<sup>2</sup>: 300 Classic → 300 Prime → 450 Era  
Gradual/ Easier than 200mm to 300mm transition → working w/ ISMI  
Global participation required!

**Thanks!**



International Technology Roadmap for Semiconductors

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# Backup



# Factory Operations Technology Requirements

Year of Production	2005	2006	2007	2008	2009	2010	2012	2013	2015	2016	2018	2019	2020
Technology Node	80	70	65	55	50	45	40	35	32	28	25		
Wafer Diameter (mm)	300	300	300	300	300	300	300	450	450	450	450	450	450
Non-hot lot (average of 94% lots)													
Cycle time per mask layer (days)	1.6	1.5	1.5	1.5	1.4	1.4	1.2	1.2	1.13	1.13	1.05	1.05	1.05
X-Factor [1]	3.2	3.1	3.1	3.1	3.05	3.05	3.05	3.05	3.05	3.05	3	3	3
Hot lot (average top 5% of lots)													
Cycle time per mask layer (days)	0.62	0.55	0.55	0.55	0.51	0.51	0.47	0.47	0.44	0.44	0.39	0.39	0.39
X-Factor [1]	1.4	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.1	1.1	1.1
Super hot lot (average top 1% of lots)													
Cycle time per mask layer (days)	0.33	0.32	0.32	0.32	0.31	0.31	0.3	0.3	0.3	0.3	0.3	0.3	0.3
High-mix capacity degradation	11.67%	10%	8.33%	6.67%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Bottleneck equipment [2] [3]													
Utilization	90%	92%	92%	92%	94%	94%	94%	94%	94%	94%	94%	94%	94%
Availability	92%	94%	94%	94%	96%	96%	96%	96%	96%	96%	96%	96%	96%
Wafer layers/day/head count	55	61	61	61	67	67	73	73	81	81	89	89	89
Number of lots per carrier (high mix) [4]	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple
Facilities cycle time (months)													
1st tool to 1st full loop wafer out	3.5	3	3	2.5	2.5	2.5	2	2	1.5	1.5	1	1	1
Node -to-node change-over (weeks)	13	12	12	12	11	11	10	10	9.5	9.5	9	9	9
Floor space effectiveness	1x	1x	1x	1x	1x	1x	1x	1x	1x	1x	1x	1x	1x
Average number of wafers between reticle changes	40	35	30	25	20	20	20	20	15	15	13	13	13

## Key Objectives: Speed & Flexibility

1) Reduce mfg cycle times, 2) Improve Equipment Utilization, 3) Reduce Losses from High Mix

□ Solution exists    ■ Solution being developed    ■ Solution required



# Production Equipment Technology Requirements

Year of Production	2005	2006	2007	2008	2009	2010	2012	2013	2015	2016	2018	2019	2020
Technology Node	80	70	65	55	50	45	40	35	32	28	25		
Wafer Diameter (mm)	300	300	300	300	300	300	300	450	450	450	450	450	450
Throughput improvement (run-rate) per year	4%	4%	New base	4%	4%	New base	4%	>0%	4%	4%	4%	4%	4%
New non-product wafers (NPW) as a % of wafer starts per week	<14%	<13%	<12%	<11%	<11%	<11%	<10%	<10%	<9%	<9%	<9%	<9%	<9%
Overall NPW activities versus production wafers activities	10%	7%	7%	7%	5%	5%	5%	5%	5%	5%	5%	5%	5%
% capital equipment reused from previous node	>90%	>90%	>90%	>90%	>90%	>90%	>90%	Limited	Limited	Limited	>70%	>70%	>70%
Wafer edge exclusion	2mm	2mm	1.5mm	1.5mm	1.5mm	1.5mm	1.5mm	1.5mm	1.5mm	1.5mm	1.5mm	1.5mm	1.5mm
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	4 wks	4 wks	4 wks	4 wks	4 wks
Process availability (A80)	92%	>92%	>94%	>95%	>95%	>95%	>95%	>95%	>95%	>95%	>95%	>95%	>95%
Metrology availability (A80)	96%	96%	96%	>96%	>97%	>98%	>98%	>98%	>98%	>98%	>98%	>98%	>98%
Intrinsic setup time reduction, vs. base	6%	10%	12%	12%	15%	15%	17%	> 17%	> 17%	> 17%	>20%	>20%	>20%
Ability to run different recipes and parameters for each wafer	Partial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
248 nm lithography scanner productivity (wafers outs per week per tool)	7400	7400	7700	7700	8000	8000	8000	8000	8000	8000	8000	8000	8000
193 nm lithography scanner productivity (wafers outs per week per tool)	5300	5300	5600	5600	6000	6000	6000	6300	6300	6300	6500	6500	6500
Maximum allowed electrostatic field on wafer and mask surfaces (V/cm)	90	80	70	60	50	50	35	35	25	25	18	18	18

**Key Objectives: 1) NPW reduction, 2) Reliability Improvement, 3) Run rate (throughput) improvement → Productivity & Cost**

□ Solution exists    ◻ Solution being developed    ■ Solution required



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# Material Handling Technology Requirements

Year of Production	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Technology Node			hp65			hp45			hp32			hp22				
DRAM ½ Pitch (nm)	80	70	65	55	50	45	40	35	32	28	25	22	20	18		
MPU/ASIC ½ Pitch (nm) (Un-contacted Poly)	80	70	65	55	50	45		35	32	28	25	22	20	18		
Wafer Diameter (mm)	300	300	300	300	300	300		450	450	450	450	450	450	450	450	450
Transport E-MTTR (minutes) per SEMI E10	10	9	9	8	8	8	8	8	8	8	7	7	7	6	6	6
Storage E-MTTR (minutes) per SEMI E10	25	25	20	20	20	20	20	20	20	20	15	15	15	10	10	10
Transport MMBF	8,000	11,000	15,000	25,000	35,000	35,000	35,000	45,000	45,000	45,000	55,000	55,000	55,000	65,000	65,000	65,000
Storage MCBF	25,000	35,000	45,000	55,000	60,000	60,000	60,000	70,000	70,000	70,000	80,000	80,000	80,000	100,000	100,000	100,000
Peak system throughput (40K WSPM)																
Interbay transport (moves/hour)	2250	2500	2575	2660	2660	2660	2660	2660	2660	2660	2660	2660	2660	2660	2660	2660
Intrabay transport (moves/hour) — high throughput bay	250	260	270	280	290	300	300	300	300	300	300	300	300	300	300	300
Transport (moves/hour)—unified system	4240	4740	4900	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Stocker cycle time (seconds) (100 bin capacity)	12	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Average delivery time (minutes)	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Peak delivery time (minutes)	12	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Hot lot average delivery time (minutes)	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AMHS lead time (weeks)	12	<9	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8
AMHS install time (weeks)	24	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Downtime to extend system capacity when previously planned (minutes)	120	<30	<15	<15	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0
Time required to integrate process tools to AMHS (minutes per LP)	15	12	12	10	10	5	5	5	5	5	5	5	5	5	5	5

**Key Objectives: 1) Increase throughput for Traditional and Unified Transport, 2) Reduce Average Delivery times, 3) Improve Reliability**

□ Solution exists    ■ Solution being developed    ■ Solution required



# FICS Technology Requirements

Year of Production	2005	2006	2007	2008	2009	2010	2012	2013	2015	2016	2018	2019	2020
Technology Node	80	70	65	55	50	45	40	35	32	28	25		
Wafer Diameter (mm)	300	300	300	300	300	300	300	450	450	450	450	450	450
Availability of mission critical applications (% per year)	99.98	99.986	99.987	99.99	99.991	99.991	99.994	99.994	99.999	99.999	99.999		
Downtime of mission critical applications (minutes per year)	105 min	75 min	75 min	68 min	53 min	45 min	30 min	30 min	8 min	8 min	4 min		
Full factory down due to unscheduled FICS downtime (minutes per year)	120 min	60 min	60 min	60 min	<15 min	<15 min	<15 min	<15 min	<15 min	<15 min	<15 min	<15 min	<15 min
Full factory down due to scheduled FICS downtime (minutes per year)	180 min	180 min	180 min	120 min	120 min	120 min	60 min	60 min	0 min	0 min	0 min	0 min	0 min
Mean time to recover for mission critical applications (minutes down per year)	30	15	<15	<15	<15	<15	<15	<15	5	5	2	2	2
MCS design to support peak number of AMHS transport moves (moves/hr)	12.7	14.2	14.7	15K	15K	15K	12.3K	12.7	14.2	14.7	15K	15K	15K
FICS design to support peak number of AMHS direct transport moves (moves/hr)	1270	1420	1470	1500	1500	1500	N/A	1270	1420	1470	1500	1500	1500
Time to send and load tape-out data into mask shop data system (hours)	6-12	6-12	6-12	6-12	6-12	6-12	6-12	6-12	6-12	6-12	6-12	6-12	6-12
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	4-8	4-8	4-8	4-8
Time for OPC calculations only (days)	3-6	3-6	3-6	3-6	3-6	3-6	3-6	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%	>93%	>93%	>93%	>93%	>93%	>93%
Wafer-level recipe/parameter adjustment	Partial	Partial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Within-wafer recipe/parameter adjustment	Partial	Partial	Partial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

**Key Objectives: 1) Increase Reliability, 2) Increase Factory Throughput, 3) Reduce or Maintain Mask Shop Cycle Time, 4) Reduce Costs**

□ Solution exists    ◻ Solution being developed    ■ Solution required



# Facilities Technology Requirements



Year of Production	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DRAM $\lambda$ Pitch (nm) (contacted)	80	70	65	57	50	45	40	35	32	28	25	22	20	18	16	14
	85	76	67	60	54	48	42	38	34	30	27	24	21	19	17	15
Wafer Diameter (mm)	300	300	300	300	300	300	300	450	450	450	450	450	450	450	450	450
Manufacturing (cleanroom) area/wafer starts per month (m <sup>2</sup> /WSPM) (low mix only)	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
SubFab to Fab ratio	1	1	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Facility service life (in three-year nodes)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Facility cleanliness level (ISO 14644) [1]	Class 6	Class 6	Class 6	Class 6	Class 6	Class 6	Class 6	Class 7	Class 7	Class 7	Class 7	Class 7	Class 7	Class 7	Class 8	Class 8
Facility cleanliness level (Airborne molecular contamination AMC) - ppt M	<i>Discussed in Yield Enhancement Tables</i>															
Facility critical vibration areas (lithography, metrology, other) (micrometers per second) [2]	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)	6.25 (VC D)
Facility non-critical vibration areas (micrometers per second) [2]	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)	50 (VC A)
Maximum allowable electrostatic field on facility surfaces (V/cm)	90	80	70	60	50	50	35	35	35	35	25	25	25	18		
Gas, water, chemical purity	<i>Discussed in Yield Enhancement Chapter</i>															
Factory construction time from groundbreaking to first tool move-in (months)	10	9	9	9	8	8	9	9	9	9	9	8	8	8	8	8
Production equipment install and qualification cost as a % of capital cost	8%	8%	7%	7%	6%	6%	5%	8%	8%	8%	7%	7%	6%	6%	5%	5%
Facility operating cost (including utilities) as a % of total operating cost		13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%
Utility cost per total factory operating cost (%)																
Power, water, and chemical consumption	<i>Discussed in ESH Chapter</i>															
Energy Consumption Total Fab Support System (kWh/cm <sup>2</sup> per wafer out)	0.6	0.5	0.5	0.40	0.40	0.35	0.30	0.40				0.35				0.30
Net Feed water use (liters/cm <sup>2</sup> )	10		9		8	5					4					3

**Key Objectives: 1) Factory Extendibility, 2) AMC, 3) Rapid Install/Qualification, 4) Reduce Costs**

Solution exists   
  Solution being developed   
  Solution required

