2002 ITRS

Factory Integration ITWG

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International Technology Roadmap for Semiconductors

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Agenda

1. Scope and Factory Drivers
2. 2002 Factory Integration Focus Areas
3. Difficult Challenges
4. Key Technology Requirements
5. Assessment of Key Gaps
6. Solutions Being Driven by Technology Requirements
7. Need for Integrated Solutions
8. Key Messages

Excellent Participation from Suppliers, IC Makers, Universities, and Research Institutes

Jim Ammenheuser (ISMT)	Arieh Greenberg (Infineon)	Giant Kao (TSMC)	Lisa Pivin (Intel)
Eddy Bass (Intel)	Darrell Grossen (Eskay/Daifuku)	Atsuya Kanoh (Sanyo)	Scott Pugh (Hirata)
Josef Bichlmeier (CamLine)	Chung Soo Han (AMD)	Shoichi Kodama, (Toshiba)	Adrian Pyke (Middlesex)
Dave Bloss (Intel)	Nils Hart (Muratec)	Ya-Shian Li (NIST)	Joe Reiss (Brooks-PRIA)
Ray Bunkofske (IBM)	Hiroki Hasegawa (Sanyo)	James Martin (Intel)	Lance Rist (ISMT)
Al Chasey (ASU)	Ton Govaarts (Philips)	Dave Miller (IBM)	Georg Roeder (Fraunhofer IIS-B)
Hugo Chang (Winbond)	Randy Goodall (ISMT)	Akira Mitsui (Matsushita)	Claus Schneider (Fraunhofer)
Eric Christensen (AMD)	Arieh Greenberg (Infineon)	Ryouji Mori (Daifuku)	Doug Scott (Brooks-PRIA)
Brian Compian (Asyst)	Darrell Grossen (Eskay/Daifuku)	Eckhard Müller (M&W Zander)	Steve Seall (Intel)
Blaine Crandell (TI)	Chung Soo Han (AMD)	Rohan Nageswaran (Intel)	Marlin Shopbell (AMD)
Gino Crispieri (ISMT)	Nils Hart (Muratec)	Hideki Nakajima (Muratec)	Court Skinner (SRC)
Klaus Eberhardt (M+W Zandar)	Hiroki Hasegawa (Sanyo)	Seiichi Nakazawa (F-RIC)	Pat Stafford (Asyst)
Anne Eldar (Intel)	Yoshio Hayashi (Rohm)	Ted Nariai (Shinko)	Tim Stanley (ISMT)
Neil Fisher (Eskay/Daifuku)	Harald Heinrich (Infineon)	Torsten Niekisch (Infineon)	Arnold Steinman (ION Systems)
Bill Fosnight (Brooks-PRI)	Joost van Herk (Philips)	John O'Reilly (ION Systems)	Keisuke Tanimoto (ASET)
Len Foster (TI)	George Horn (Middlesex)	Kunio Oishi (Ebara)	Jeff Toth (AMD)
John Fowler (ASU)	Duane Howard (IBM)	Yoshiyasu Okamoto (Murata)	Toshiyuki Uchino (Trecenti)
Masazumi Fukushima (Muratec)	Michio Honma (NEC)	Doug Oler (Hirata)	Brad Van Eck (ISMT)
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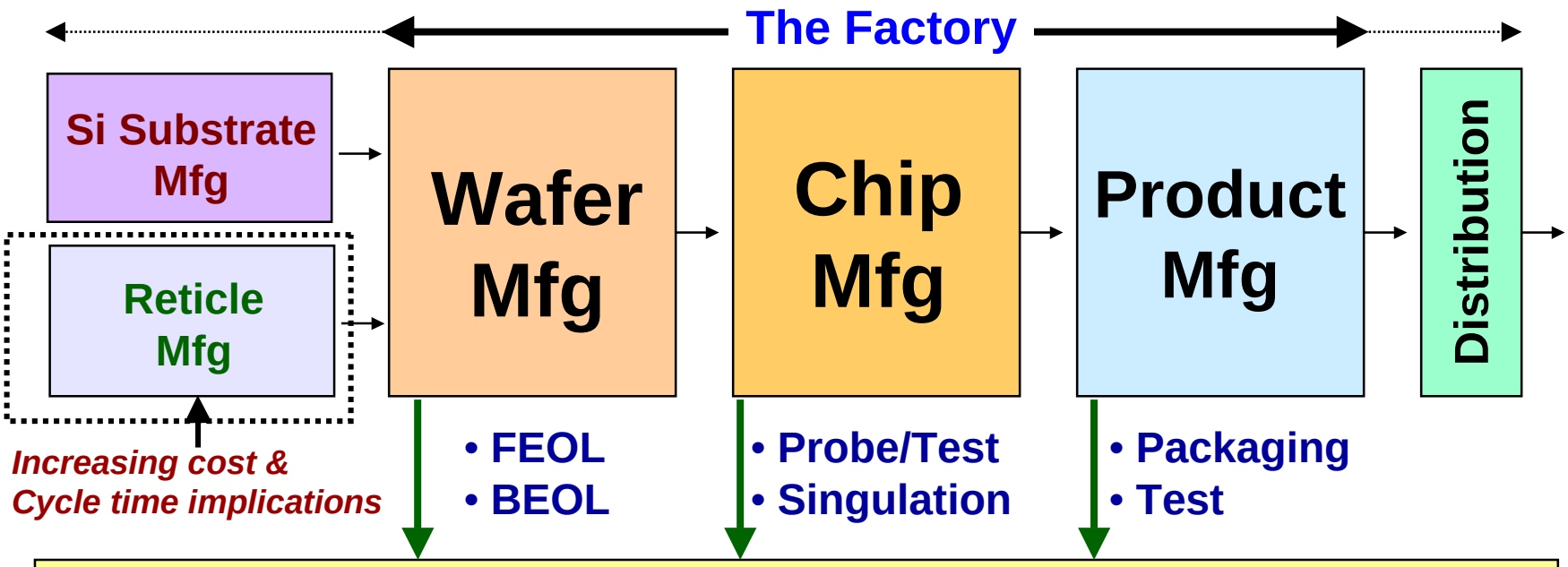
Ashwin Ghatalia (Philips)	Melvin Jung (Intel)	Richard Oechsner (Fraunhofer)	Hiromi Yajima (Toshiba)
Barbara Goldstein (NIST)	Giichi Inoue (Toshiba)	Jeff Pettinato (Intel)	Yoshio Watanabe (Fujitsu)
Ton Govaarts (Philips)	Junji Iwasaki (Mitsubishi)	Dev Pillai (Intel)	Alan Weber (NIST)
Randy Goodall (ISMT)			

Many Participants from Around the World have Contributed

2002 Factory Integration Scope Includes Wafer, Chip and Product Manufacturing



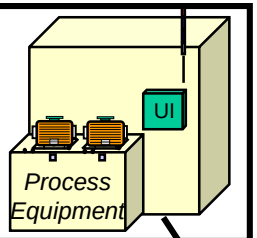
Factory is driven by Cost, Productivity, and Speed:

- Reduce factory capital and operating costs per function
- Enable efficient high-volume production with operational models for high and low product mixes and other business strategies
- Increase factory and equipment reuse, reliability, and overall efficiency
- Enable rapid process technology shrinks and wafer size changes
- Faster delivery of new and volume products to the end customer

Factory Integration Requirements and Solutions are Expressed through 6 Functional Areas

Production Equipment

- Process and Metrology equipment
- Mainframe and process chambers
- Wafer Handling Robots, Load Ports
- Internal software & computers



Facilities

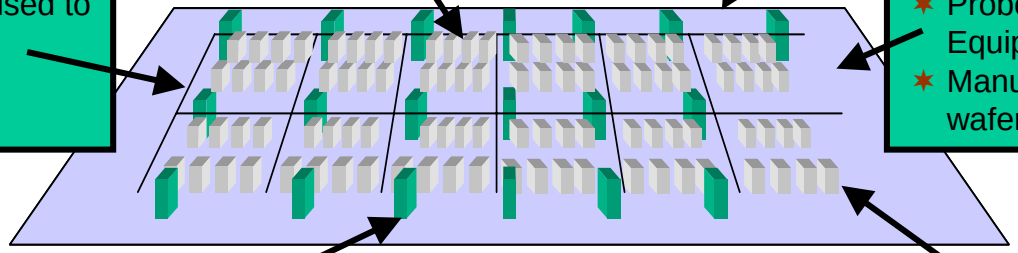
- Cleanroom, Labs, Central Utility Building
- Facilities Control and Monitoring Systems
- Power, Plumbing, HVAC, Utilities, Pipes, UPS
- Life safety systems, waste treatment

Factory Operations

- Policies and procedures used to plan, monitor and control production
- Direct factory labor

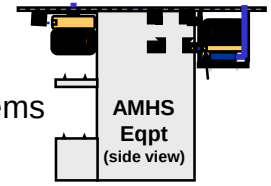
Test Manufacturing

- Prober, Handler, and Test Equipment
- Manufacturing processes to test wafers and chips



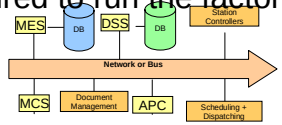
Material Handling Systems

- Wafer and Reticle Carriers
- Automated storage systems
- Interbay & intrabay transport systems
- Personnel guided vehicles
- Internal Software & computers



Factory Information & Control

- Data and Control systems required to run the factory
- Decision support
- Process control
- Plan, Schedule, Dispatch
- Computers, databases, software outside equipment



2002 Factory Integration Focus Areas

1. New business requirements driving changes to the factory design
   - **Combination of many different industry business models: IDM, Foundry, Joint Ventures, Collaborations, other Outsourcing, etc**
   - **Faster new product delivery from design to customer delivery**
   - **Need for better Integration of the Factory with the process technology and product development cycle [New Term = <u>Engineering Chain</u>]**
2. Implications of 300mm factory sizes reaching 30k-40k wspm on facilities, AMHS, and factory control systems
3. Gaps Factory productivity/Equipment OEE and methods to improve including Equipment Engineering Capabilities (EEC)
   - **EEC includes e-diagnostic, fault detection, process control, on-line manuals, spares management etc.**
4. Factory modeling needs and gaps to do design analysis, demand planning, optimization tradeoff analysis, etc.
5. Preparing for more 2003 focus on Packaging & Test Manufacturing driven by cost, business requirements, and increased product integration needs

2002 Difficult Challenges

> 65nm through 2007

- Managing Complexity
  - **Quickly and effectively integrating rapid changes in semiconductor technologies and market conditions**
  - **Need to integrate the entire product development process**
- Factory Optimization
  - **Productivity increases are not keeping pace with needs**
- Flexibility, Extendibility, Scalability
  - **Ability to quickly convert to new semiconductor technologies while reusing equipment, facilities, and skills**

< 65nm after 2007

- Post Conventional CMOS Manufacturing Uncertainty
  - **Inability to predict factory requirements associated with different manufacturing requirements**
- 450mm Wafer Size Conversion
  - **Timing and manufacturing paradigm for this wafer size conversion**

Key change: Need to improve integrated product development cycle time

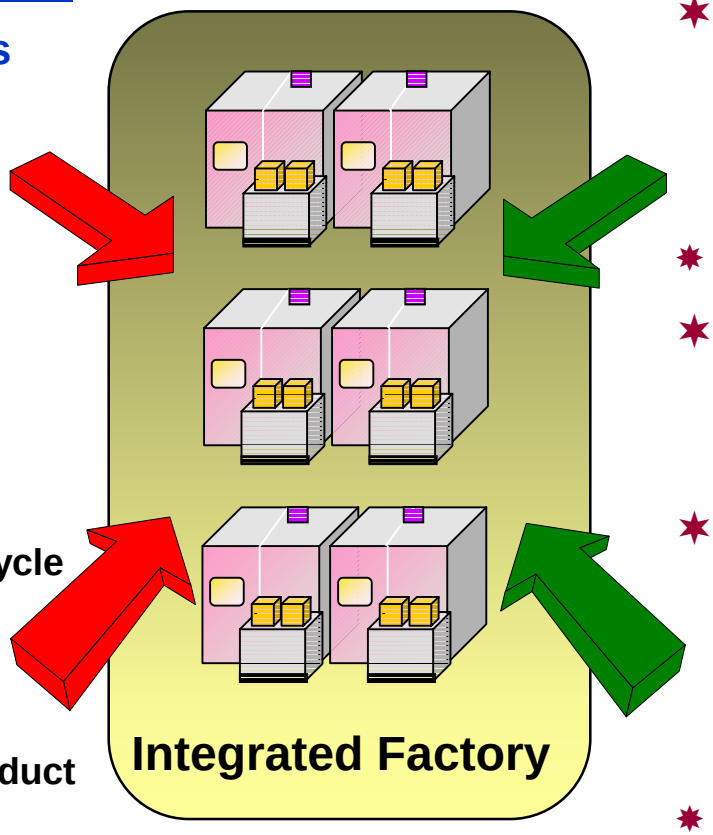
Integrated Solutions are Essential to Meet Needs

Technology Requirements

1. **New disruptive process technologies**
   - 157nm litho
   - High K gate stack
   - Low k dielectrics
   - Copper processing

+

2. **Improved Productivity**
   - Decreased Factory Cycle Time (QTAT)
   - Improved Equipment Efficiency
   - Reduction in non-product (I.e. test) wafer usage
   - More efficient direct labor
   - Faster factory conversion at technology nodes



Goal = Meet Factory Challenges and Technology Requirements

Integrated Solutions

- **Agile Manufacturing**
  - Equipment Engineering Capabilities
  - Single wafer control
- **Engineering Chain Mgmt**
- **Process Control**
  - FDC, R2R, W2W control
  - IM and M2M matching
- **Material Handling**
  - Direct Transport for Send Ahead, monitors, hot lots
  - Integrated Sorters, Stockers, Metrology?
- **Flexible Factory Designs**
  - Quick ramp-up operation
  - Extend & Scale quickly
  - Convert quickly

Key Factory Operations, Production Equipment, and Facilities Technology Requirements

	Year of Production	2001	2002	2003	2004	2005	2006	2007	2010	2013	2016
	Wafer Diameter	300mm	300mm	300mm	300mm	300mm	300mm	300mm	300mm	450mm	450mm
Factory Operations	Factory cycle time per mask layer (non-hot lot) (days)	1.2	1.2	1.2	1.1	1.1	1.1	1	0.9	0.95	0.8
Factory Operations	Factory cycle time per mask layer (hot lot) (days)	0.75	0.6	0.6	0.55	0.5	0.45	0.4	0.4	0.4	0.35
Production Equipment	Number of lots per carrier (lot)	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple
Production Equipment	Bottleneck equipment OEE	75%	78%	80%	82%	84%	87%	88%	90%	91%	92%
Production Equipment	Average equipment OEE	55%	58%	60%	63%	65%	67%	70%	72%	74%	75%
Production Equipment	Overall factory non-product wafer usage as a % of production	<16%	<15%	<14%	<13%	<12%	<11%	<11%	<10%	<9%	<9%
Production Equipment	Ability to run different recipes and parameters for each wafer	Partial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

- No significant changes to values
- High mix cycle time values and solutions beyond 2003 are under discussion
- 2003 will propose adding new product cycle time to the metrics (analysis on-going)
- **Progress lacking in OEE improvements, NPW reduction, and ability to run different process parameters for each wafer**

Key Material Handling, Factory Info and Control Systems, and Facilities Requirements

	Year of Production	2001	2002	2003	2004	2005	2006	2007	2010	2013	2016
	Wafer Diameter	300mm	300mm	300mm	300mm	300mm	300mm	300mm	300mm	450mm	450mm
Factory Info & Control	**Ability to run different recipes/parameters for each wafer**	**Partial**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Material Handling	Wafer Transport system capability	Separate interbay/ intrabay	Separate interbay/ intrabay	Separate interbay/ intrabay	**Some Separate Some Direct**	**Direct tool**	**Direct tool**	**Direct tool**	**Direct tool**	**Direct tool to tool**	**Direct tool to tool**
Material Handling	AMHS throughput [40k wspm Factory]										
Material Handling	· Interbay transport (moves/hour)	**2400**	**2600**	**2800**	**3000**	**3250**	**3500**	**3750**	**4000**	**4000**	**4000**
Material Handling	· Intrabay transport (moves/hour)	**170**	**180**	**190**	**200**	**3250**	**3500**	**3750**			
Facilities	Factory construction time (months) from ground break to all facility ready	**12**	**12**	**12**	**10**	**10**	**10**	**10**	**10**	**10**	**10**

Notes:

- No significant changes to values
- AMHS system throughput numbers adjusted for 20k & 40k wspm sized factories

\+ **Good progress on AMHS single transport hardware system development**

? Need to assess software systems (scheduling, dispatching, etc) readiness for single transport system

\- **Facilities momentum needed to reduce cycle time (Standards, prefabrication, etc.)**

2002 Assessment of Key Gaps

- Technology Gaps that Need Attention Today
  1. **Integrated intrabay readiness for 300mm Factories**
  2. **Ability to run different process parameters for each wafer**
  3. **Production equipment OEE**
  4. **NPW Reduction**
  5. **Hot Lot and normal cycle times for high mix factories**
  6. **Faster Product delivery**
  7. **Efficient Product development**
  8. **Better modeling capabilities**
- Future Technology Gaps and Focus Areas
  1. **Factory software systems to support Direct Transport AMHS**
  2. **Equipment Engineering Capabilities and Standards**
  3. **Engineering Chain Management Systems**
  4. **Impact of 157nm and Next Generation Litho on the Factory**
  5. **Post Conventional CMOS Manufacturing**
  6. **450mm Wafer Processing**

These are Key Focus areas for Factory Integration for 2003

Translating Metrics to Reality

Metric	Potential Solution it is driving
Production Equipment Overall Equipment Efficiency (OEE)	a) Equipment Engineering Capabilities including: e-Diagnostics, APC, spares management, fault detection, on-line manuals to improve MTTR b) Integrated factory scheduling and dispatching capabilities to improve equipment utilization
Ability to run different process parameters for each wafer on equipment	a) Implement embedded controller standards b) MES capabilities to handle standard and non-standard operational scenarios
Non-product wafers as a % of factory wafer starts	a) Techniques to design equipment for reliability b) Advanced Process Control systems
Hot-Lot and regular lot cycle time per mask layer for the factory	a) Direct transport systems integrated with factory schedulers for tool to tool moves b) Innovative carrier/wafer level control systems
Number of transport types in the factory	a) Direct tool transport using conveyors b) Direct tool transport using overhead hoist
AMHS system throughput for interbay and intrabay	a) Electrical, mechanical, and control systems for transport types: OHS, OHT, RGV, AGV, PGV b) Improved Scheduling/Dispatching for direct tool transport, hot lots, send ahead wafer, etc.

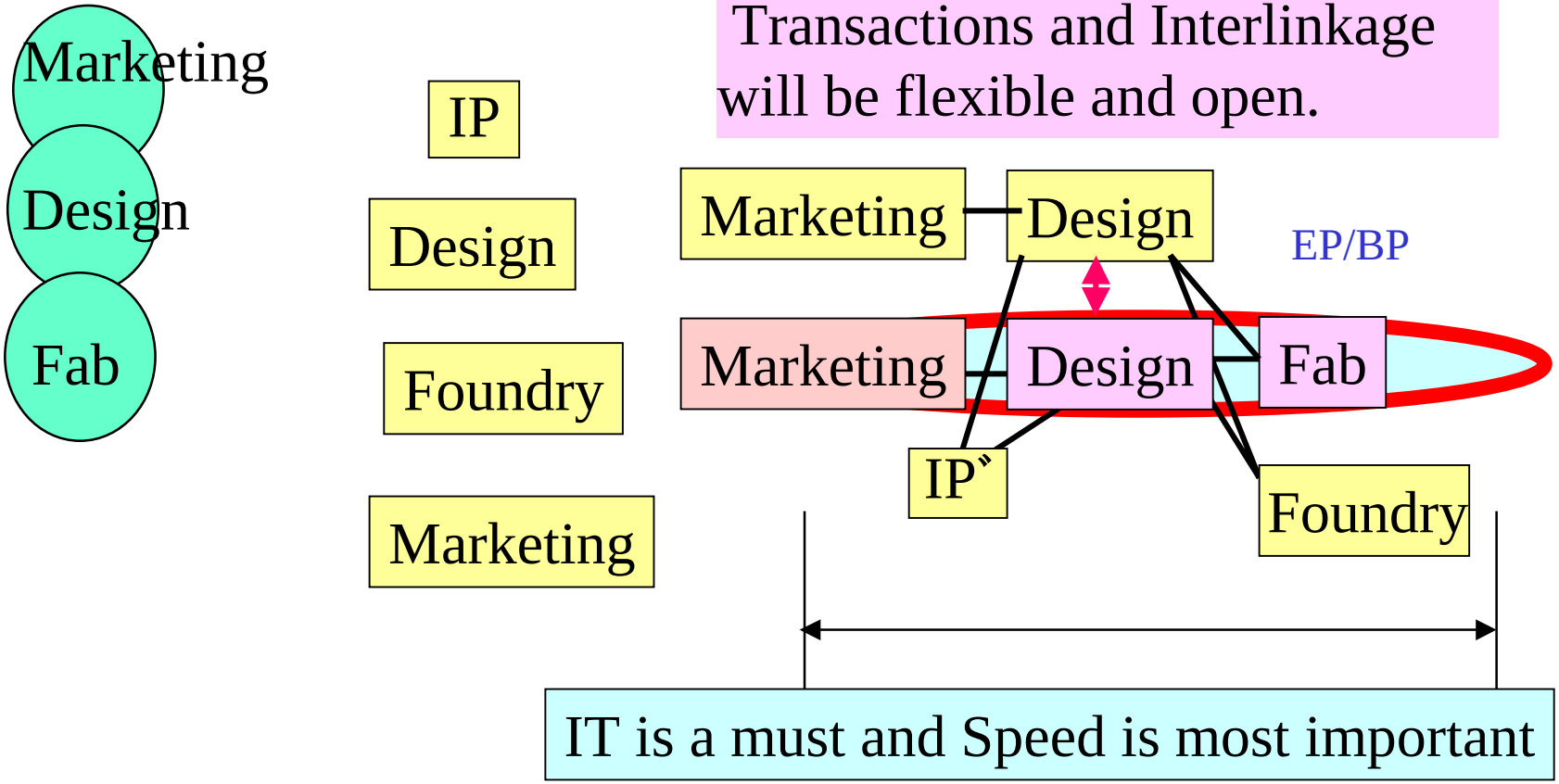
Industry Business Model Is Changing

IDM Age

Foundry/Fabless Age

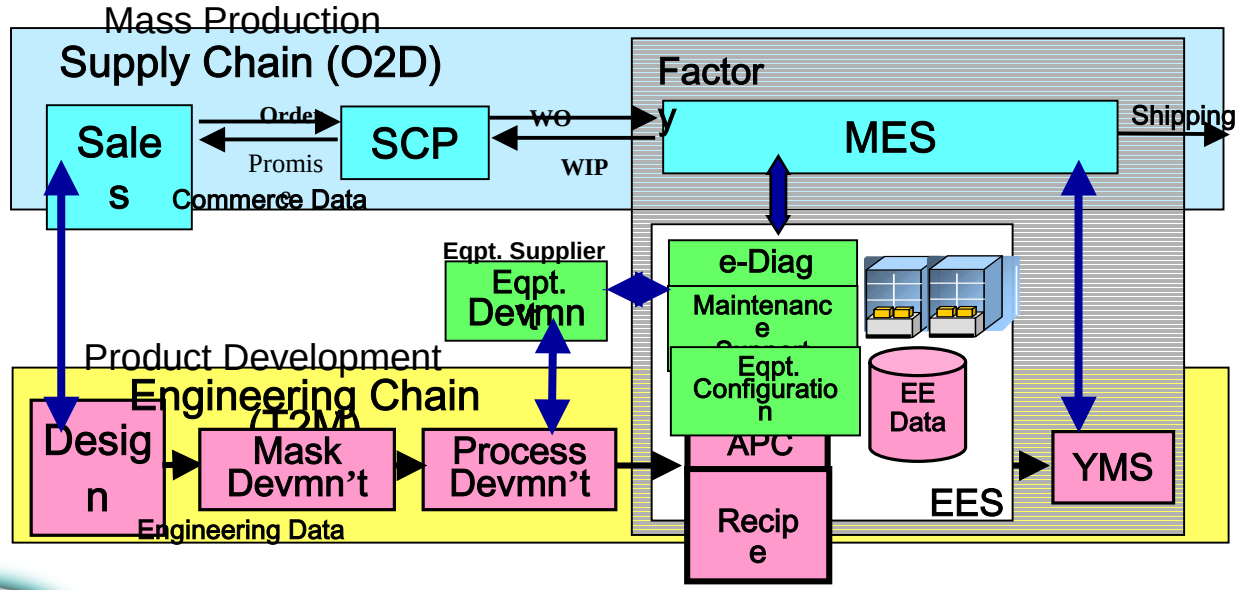
Collaboration Age

Transactions and Interlinkage will be flexible and open.

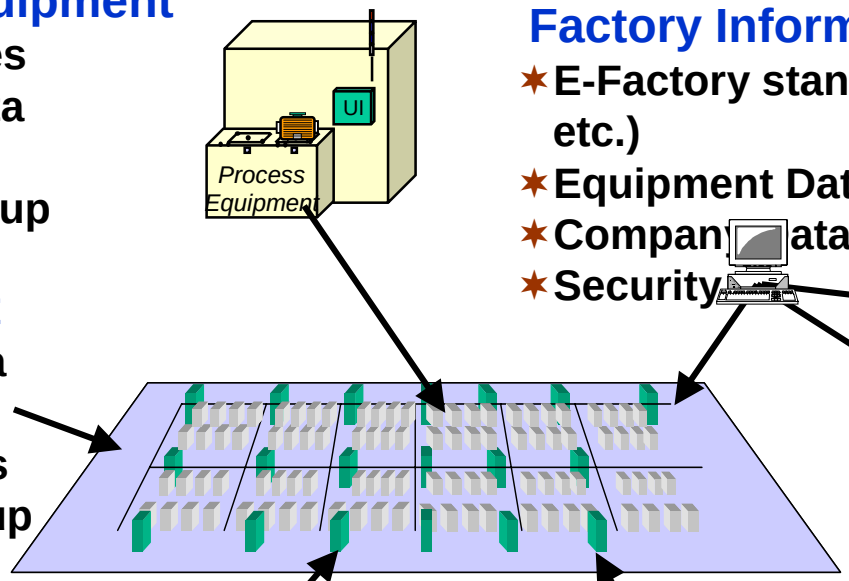


Engineering Chain Management

- Customers want new products delivered faster [design ➜ ship]
- The Engineering Chain integrates the development flow from design specification to customer delivery for a new product through engineering data exchange
  - **Engineering Chain = Design ➜ Reticle ➜ Process Integration ➜ Customer ➜ High Volume**
  - **This is different from supply chain mgmt which focuses on efficient volume production**
- Engineering chain management ensures customer cycle times are met, while new products are properly integrated with the process



Continued Standardization is needed to Reduce Integration Time, Cost, and Complexity



Production Equipment
- AMHS interfaces
- Automation data interfaces
- Facilities hook-up
- ESD

Test Equipment
- Automation data interfaces
- AMHS interfaces
- Facilities hook-up
- ESD

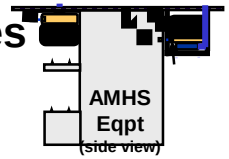
Factory Information & Control
- E-Factory standards (EEC, APC, etc.)
- Equipment Data Interfaces
- Company Data Interfaces
- Security

Partner

Security Firewall

Customer / Supplier

Material Handling Systems
- Production Equipment Interfaces
- Automation data interfaces
- Facilities hook-up
- Carriers



Facilities
- Height, weight, temperature
- Equipment Hook-up
- Safety

Not an exhaustive list

Potential Solutions driving R&D Agenda

- Engineering chain management models, data integration and interface standards
- Factory capacity planning and supply chain management systems integrated with actual factory data
- Internet based Manufacturing and Engineering systems
- Advanced Factory/Mfg Modeling Tools and Capabilities
- Equipment Engineering Capabilities (EEC)
  - e-diagnostic, fault detection, advanced process control, on-line manuals, spares management, etc.
- Scheduling, Dispatching, and MES integration for Direct Transport AMHS
- Additional Industry Standards for Equipment, AMHS, Facilities, and Information/Control Systems

Key Messages

1. Improving the Factory's Cost, Productivity and Speed is essential
2. Business strategies, market demands, and process technology changes continue to make factories difficult to integrate
3. More focus must be spent on new product development and high mix factory cycle times
4. Gaps in Production Equipment OEE, Factory NPW usage, and Factory modeling must be improved.
5. e-Factory concepts are being developed to solve complexity, integration and equipment OEE issues
6. Standards have been very effective in 300mm, but must be implemented more consistently in some areas
7. More focus must be given to Post-Fab manufacturing (Assembly, Test, etc.) to improve productivity