Smart Manufacturing Requirements Development: Process and Results

Smarter Manufacturing Through Better Data: Applications and Benefits of SEMI Interface A / EDA Standards Workshop

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Making Smart Manufacturing Work: Customer-driven Requirements Development

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Outline

- Key messages
- Importance of the equipment model
- Requirements development process
- Factory stakeholders and questions
- Specification excerpts
- Benefits to date

Robust purchase specs are key

- Smart Manufacturing depends on good data… lots of it
- Equipment models are the data collection "contracts" between factory customers and equipment suppliers
- You don't get what you pay for… you get what you require
- Purchase specifications should be based on requirements from a broad set of manufacturing stakeholders
- We have defined a rigorous process for translating stakeholder requirements into interface purchase specs
- An on-site workshop is a very effective way to gather and process requirements from a diverse group

Current EDA* purchase specifications…

…*Cover a broad spectrum*

Target

15-20 pages, complete, unambiguous expectations for standards versions, model content, performance and reliability, functional priorities, testing requirements, and expected response format

10 pages of redundant or out-of-date material copied from old versions of the standards mixed in with real requirements; difficult for OEMs to interpret and respond

3 pages,
Simple, incomplete list of standards with no additional guidance

Good information scattered across multiple documents and spreadsheets that mix requirements, priorities, and expected response formats

* EDA = SEMI's Equipment Data Acquisition standards suite

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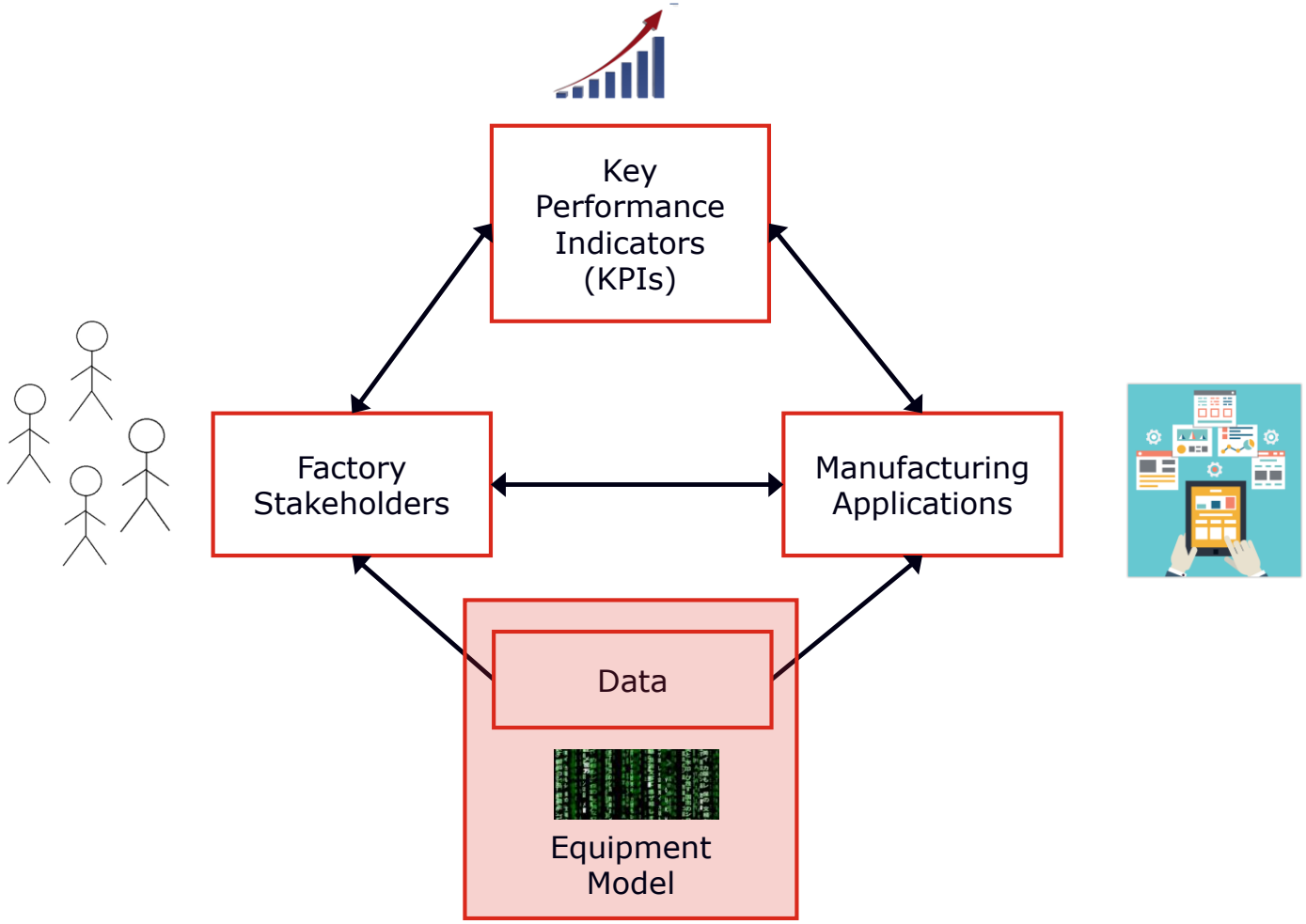
KPIs, stakeholders, applications, …

Importance of the equipment model



The equipment model value chain

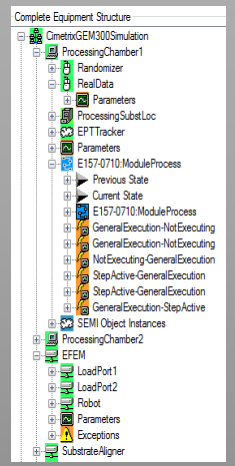
Equipment Components

Equipment Developers

Software Toolkits

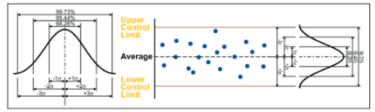
Standard E164 Model

Equipment Model



Pilot Factory Operations

Process Engineering



High-Volume Manufacturing

KPIs (metrics)

- Time to money
- Yield
- Productivity
- Throughput
- Cycle time
- Capacity
- Scrap rate
- EHS

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Workshop objectives

- Create EDA additions to SK hynix "Equipment Software Specification for Factory Automation"
  - Involve full range of stakeholders
  - Enable evolution of smart factory systems
  - Build foundation for next 5+ years of equipment purchases
- Discuss/demonstrate EDA implementation technologies for potential SK hynix use cases
  - EDA testing (Standards Compliance and Performance)
  - External sensor integration, equipment log file processing
- Build agenda for "Supplier Day" as part of rollout process
  - Communicate goals and answer questions in open forum
- Answer participant questions about the EDA standards

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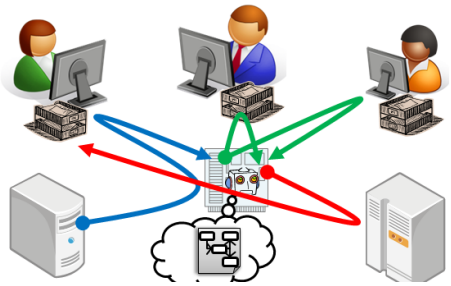
Principles of spec development

- Each question potentially impacts the automation requirements
  - If the answer to any portion of a question is “Yes,” “Maybe,” or something more specific, it will generate one or more requirements in the final spec document
- The EDA additions to the current requirements spec should stand alone
  - Where they impact or augment the existing material, this should initially be done by reference, and later integrated as necessary
- The structure of the Supplier Response Sheet should exactly match the requirements spec
  - Simplifies the supplier responses and subsequent evaluation by supplier relations
  - Options for these responses should be limited to a fixed set (Comply, Partially Comply, Comply by <date>, Do Not Comply, Not Applicable) and further explained in a Notes section where appropriate
- Some requirements may be considered optional or not applicable for certain equipment types
  - This should also be clearly indicated in the Supplier Response Sheet

Factory stakeholders
and their priorities (engineering)

- Process engineers
  - Develop and maintain robust manufacturing processes that achieve device operational specifications (speed, power, size)
- Equipment engineers
  - Fleet matching and management to minimize or eliminate the need to dedicate certain equipment sets for critical process steps and thereby simplify the overall factory scheduling process
- Maintenance engineers
  - Minimize equipment downtime, MTTR (mean time to repair), and test wafer usage required to bring equipment back to production-ready state
- Industrial engineers
  - Monitor equipment and factory throughput in real-time, identify opportunities to eliminate wait time waste in individual equipment types as well as the overall factory, and address bottlenecks as they shift and emerge
- Facilities engineers
  - Collect and integrate sub-fab data from pumps, chillers, exhaust systems, and other complex subsystems into the production data management infrastructure for use by a growing range of analysis applications

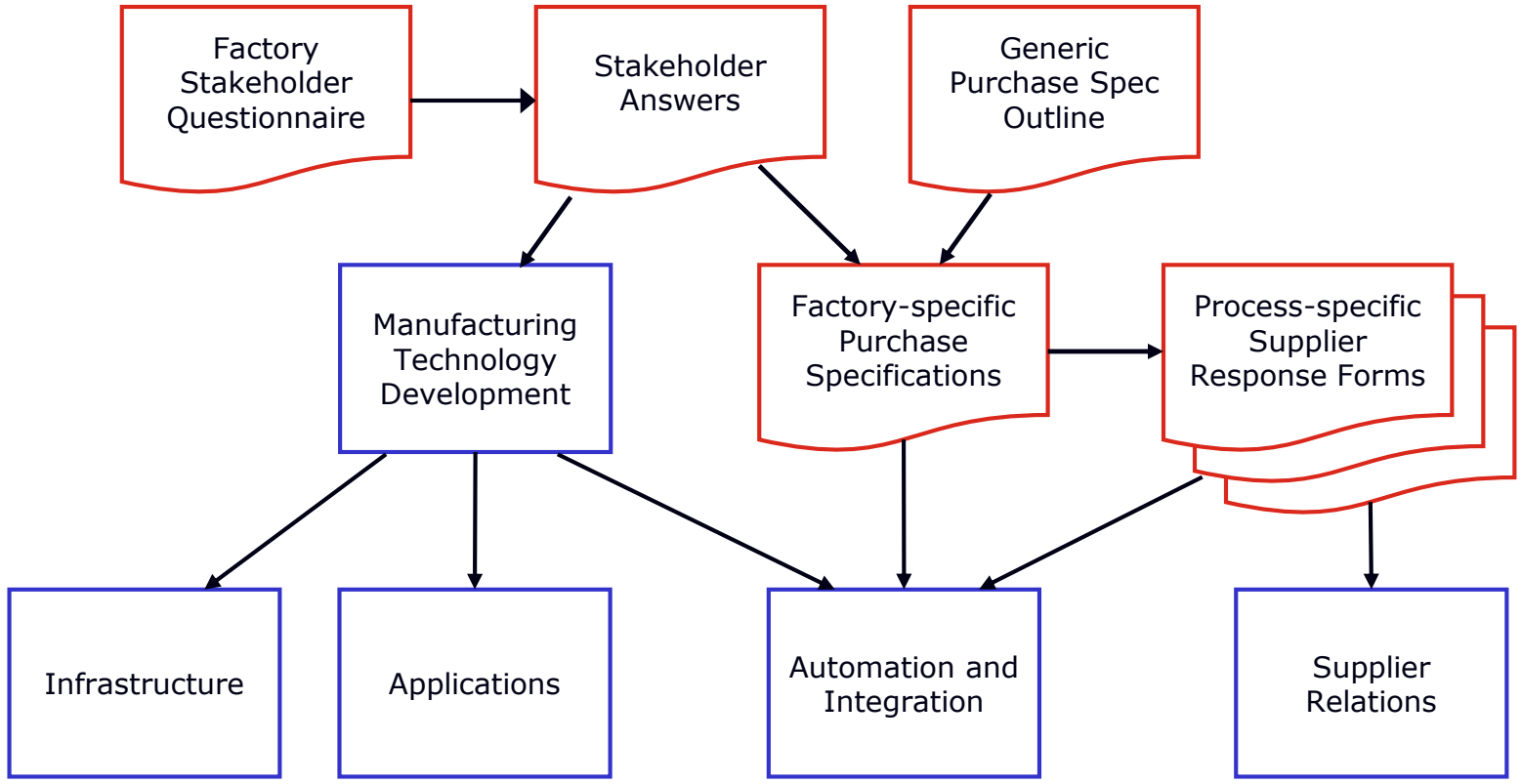
Factory stakeholders
and their priorities (operations, other)



- Production control staff
  - Determine the material release schedule and manage the factory scheduling/dispatching systems to accommodate changes in customer orders and/or factory status;
- Application and infrastructure developers
  - Define overall factory system design and implementation roadmap to achieve and maintain competitive advantage, and provide applications that achieve productivity, quality, and reliability objectives of the industrial, process, and equipment engineers
- Automation and integration specialists
  - Connect equipment to factory system infrastructure and related applications and verify compliance to automation purchase specifications
- Procurement/Supplier Relations
  - Manage the overall purchasing process to support factory customers while achieving capital budget targets
- Factory management
  - Responsible to executive management for competitive manufacturing results

Requirements development

Process and resulting artifacts



Stakeholder questionnaire
Sample questions (1)

- Manufacturing Automation/Technology Development
  - Is SEMI E157 (Module Process Tracking) implemented in any of your current equipment, and if so, do you monitor those events?
  - Do you require that all state machines, states, state transition events, and attributes of the objects defined in the referenced 300mm SEMI Standards be implemented? If not, why not?
  - Do you currently use information from sub-fab systems in any of your on-line production applications, like FDC, PHM, R2R control, or others? If so, what range of equipment is supported, and how (pumps, chillers, abatement systems …)?
  - How do you express performance expectations for process variable reporting, such as sampling frequency, # parameters per chamber, report sizes, total bandwidth of all data reported, maximum latency of event generation, etc.?

Stakeholder questionnaire
Sample questions (2)

- Production Operations and Engineering Support
  - How do you schedule carrier pick-up and delivery from/to equipment, respectively? Is this done using algorithms in the AMHS/MCS/OHT system components, or do you get real-time updates from the equipment about pending lot completion and tool availability?
  - Do you require your suppliers to provide built-in data collection schemes (pre-defined reports, macros, etc.) to support common monitoring, maintenance, or diagnostic processes?
  - Do you have a list of parameters/events that must be collectable to support your production application portfolio?
  - Do you monitor any of the low-level actuator/sensor signals in the various mechanisms that make up a manufacturing tool (say, for a fingerprinting application)?

Stakeholder questionnaire
Sample questions (3)

- Procurement and Supplier Relations
  - What compliance tests/reports do you require of the equipment suppliers before they ship equipment to your factories? Do you ever/sometimes/always visit the supplier's site to observe this process? What about *after* delivery?
  - Do you have a standard supplier response sheet or checklist for your automation requirements? If so, are you satisfied with its clarity, completeness, and ease of use for evaluating responses?
  - At what point in the equipment purchasing cycle do you review the capabilities of the interface software (event/parameter lists, model structure/content, projected performance, etc.)? When are these capabilities validated?
  - Do you assign a monetary value (say, some % of the equipment purchase price) to the interface software?

Sample purchase specification
Major sections

Purchase Spec
- Standards
- Platform
- E120, E125, …
- Process info
- Performance
- Testing
- Life cycle

- References to standards required (SEMI, other)
- Platform and system architecture
- Standard-specific items (E120, E125, E132, E134, E164…)
- Model content (by process, use case)
- Performance and data quality
- Acceptance testing (pre-/post-delivery)
- Life cycle interactions

…and

- Consistently formatted Supplier Response Checklist

Valid Entries:
Comply
Comply by (Date)
Partially Comply (Notes)
Do no comply
N/A

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Sample purchase specification
Selected excerpts (1)

- Section 1: References to standards required (SEMI, other)
  - Supplier must provide a Freeze II compatible EDA interface.
  - EDA interface must use a superset of the standard WSDL files available from SEMI.
- Section 2: Platform and system architecture (hardware and software)
  - The computer running the EDA interface software should be dedicated to this purpose and not shared with other functions (maintenance database, operator interface, GEM communications, etc.).
  - The equipment must monitor key performance parameters of the EDA computing platform such as CPU utilization (%), memory utilization (GB, %), disk utilization (GB, %) and access rate, etc. using system utilities such as Perfmon (for Windows systems) and store this history in a log file.
  - Supplier must provide written high-level documentation of the EDA interface.
  - The EDA interface should be configurable to the extent that it enables factory automation staff to set limits on key performance parameters.
  - The equipment must generate software log files to support EDA interface performance analysis and debugging when necessary.

Sample purchase specification
Selected excerpts (2)

- Section 3: Standard-specific items (E120, E125, E132, E134, E164…)
  - The hierarchical depth of the metadata model should include at least the "field replaceable unit" (FRU) level, and one or two levels below this for complex sub-systems.
  - Equipment should make the EDA computing platform performance parameters available as parameters of an E120 logical element that represents the EDA interface software itself.
  - The metadata model must include all the information collectible via the SECS/GEM interface.
  - Information currently captured in equipment log files should be collectible using built-in DCPs provided by the supplier.
  - The metadata model must include control parameters for all significant operating mechanisms and subsystems in the equipment.
  - The metadata model must include whatever additional usage counters, timers, and other parameters that may be useful in time-based, usage-based, and condition-based maintenance scheduling algorithms.
  - Suppliers must provide a written description of the update rates, recommended sampling intervals, normal operating ranges and behaviors, and high/low/rate-of-change limits for all key process parameters.
  - Supplier must provide built-in DCPs to support common equipment performance monitoring, diagnostic, and maintenance processes that are well known to the supplier.
  - Priorities within the E164 EDA Common Metadata standard are expressed in a separate spreadsheet.

Sample purchase specification
Selected excerpts (3)

- Section 4: Performance and Data Quality
  - The EDA interface must be capable of reporting at least 2000 parameters at a Sampling Interval of 0.1 seconds (10Hz) with a Group Size of 1, for a total data collection capacity (bandwidth) of 20,000 parameters per second.
  - The EDA interface must support simultaneous data collection from at least 5 clients while still achieving a total bandwidth of 20,000 parameters per second.
  - For large equipment, a total bandwidth of 60,000 parameters per second should be possible. Group Sizes greater than 1 and report buffering may be used to achieve this level of performance.
  - Equipment parameters provided through the EDA interface must exhibit a number of data quality characteristics, including, but not limited to: an internal sampling/update rate sufficient to represent the underlying signal accurately; timing of trace reports that is consistent with the sampling interval within +/- 1.0%; values in adjacent trace reports must contain then-current values at the specified sampling interval; and rejection of obvious outliers.

Sample purchase specification
Selected excerpts (4)

- Section 5: EDA Interface Testing
  - Compliance tests must be run on a commercial tester that has been validated to thoroughly implement the ISMI EDA Evaluation Method referenced in Section 1.
  - Supplier must test the EDA interface across the full range of performance criteria specified in section 4 (Performance and Data Quality).
  - The Metadata Conformance Analyzer (MCA) Version 1.2 created by NIST under contract with ISMI will be used to check the equipment metadata model for conformance to the SEMI E164 requirements.
  - Supplier must demonstrate that this performance is possible over a range of specific data collection deployment strategies, meaning different #s and sizes of DCPs, different sampling intervals, Group Sizes, etc. without causing the EDA interface to reach one of its "Performance Warning" states

Total Parameters per second	# Parameters per DCP	10		50		100		250		1000		2000	
	# DCPs	1	2	1	2	1	2	1	2	1	2	1	2
Trace Interval (ms)	1000	10	20	50	100	100	200	250	500	1000	2000	2000	4000
	500	20	40	100	200	200	400	500	1000	2000	4000	4000	8000
	100	100	200	500	1000	1000	2000	2500	5000	10000	20000	20000	40000
	50	200	400	1000	2000	2000	4000	5000	10000	20000	40000	40000	80000

Benefits of EDA to date

with more to come…

- Greater commonality of delivered equipment metadata models resulted from emphasis on SEMI E164 and Freeze II version
- Increased data quality and stability in situations that require high frequency data collection
- Higher performance of EDA *and* GEM interfaces due to explicit requirements and test specifications
- More consistent application behavior (especially FDC) across equipment types from all of the above

Thank you

- 감사합니다
- 谢谢
- Danke
- 謝謝
- Merci
- ありがとうございます
- Gracias