Data Quality and Time Synchronization

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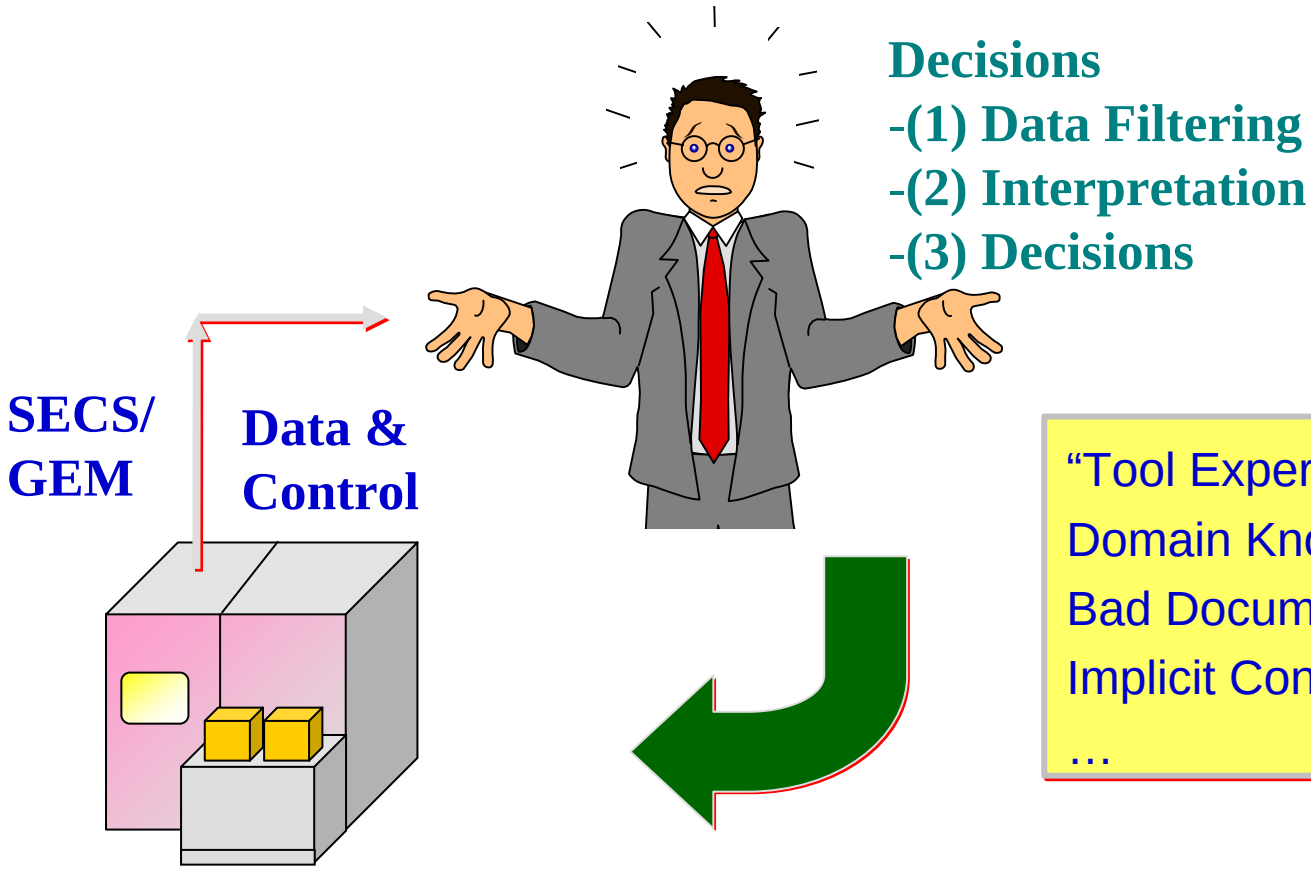
Outline

- Data Quality Background
- Member Company Experiences
- Time Synchronization
  - Background
  - Standards Ballot
    - Key Features
  - Guidelines
    - Timing Matrix
- Data Quality Key Messages

Data Quality Introduction

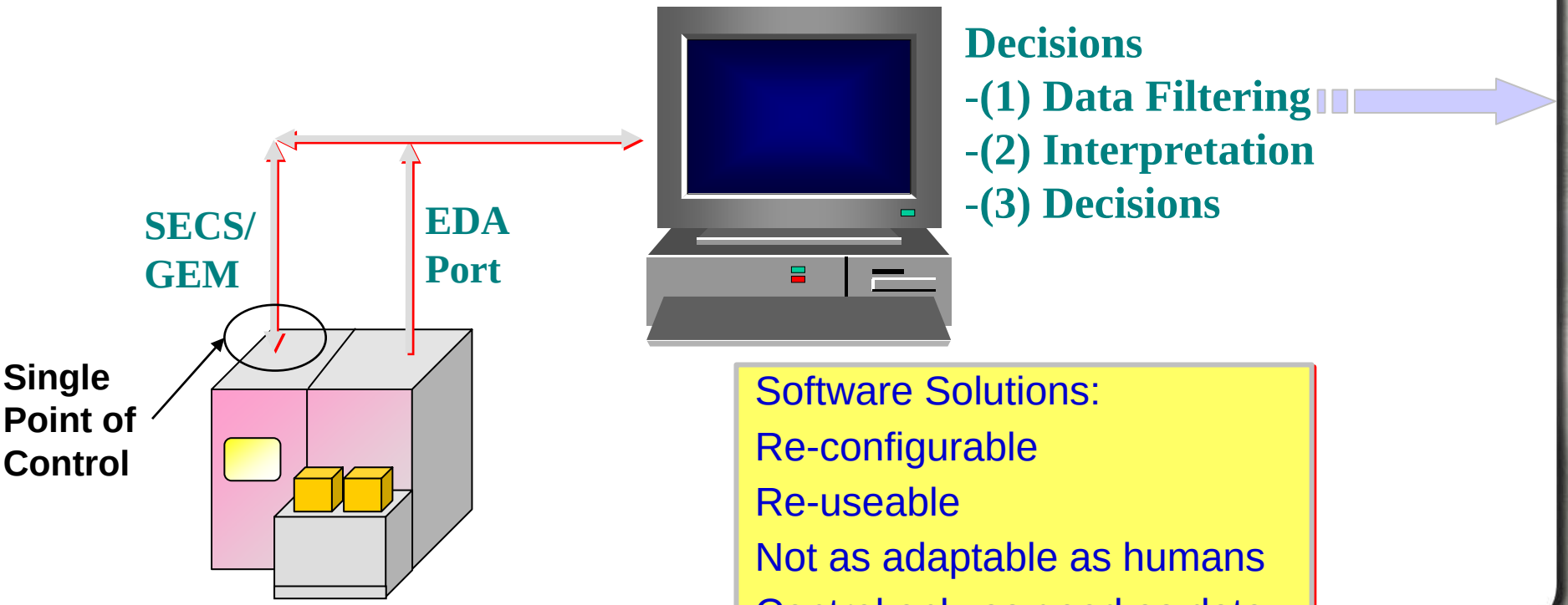
- **In the past, humans interpreted tool output**
  - **Complex and very adaptable minds**



"Tool Experts"
Domain Knowledge
Bad Documentation
Implicit Control Models
…

Data Quality Introduction

- **We are moving towards automated data filtering, interpretation, and control**



Software Solutions:
Re-configurable
Re-useable
Not as adaptable as humans
Control only as good as data
...

Data Quality and Time Synchronization Background

- **Background**
  - As the industry moves toward e-Manufacturing, the data each tool generates is critical to improve equipment productivity
  - Today, the quality of data is poor; it must be dramatically improved if applications are to effectively apply collected data
  - Message integrity, data accuracy, data resolution, sensor data calibration, data transmission rates, proper triggering, and data noise filtering must all be accurate, reliable, timely, and complete
- **Challenge in the past to reach agreement on data quality definitions**
  - Today, leverage definitions from standard sources, e.g., NIST, ISO, IEEE for Time Synchronization
- **SEMI Time Synchronization Working Group membership**
  - IC makers and sensor/equipment/software suppliers
  - To participate, contact: Harvey.Wohlwend@ismi.sematech.org

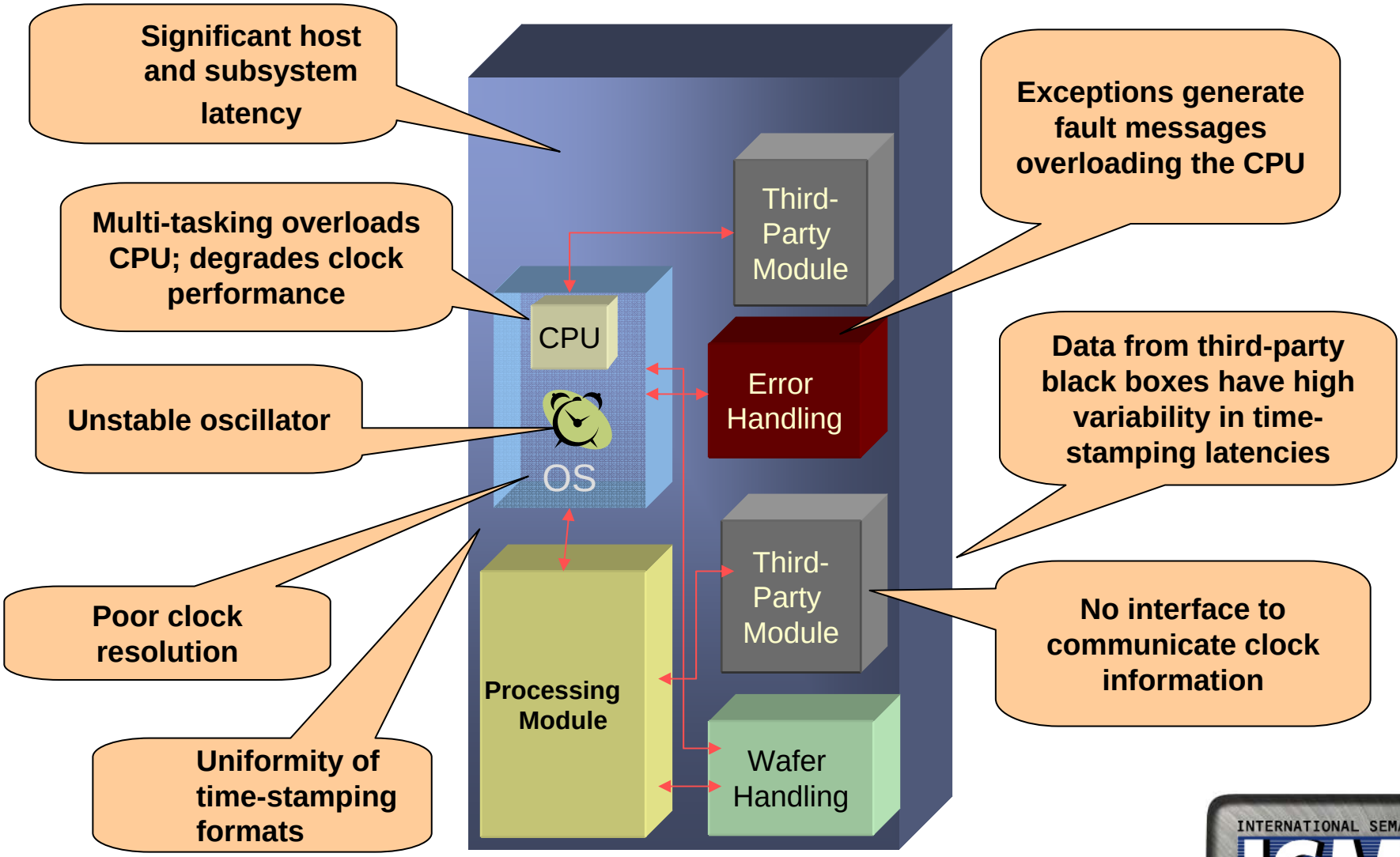
Equipment Data Quality Principles

- **Data must be provided with sufficient accuracy, resolution, and sampling frequency to allow high fidelity extraction of relevant data features for process/equipment characterization, fault detection, failure diagnosis, and process control.**
- **Event data and context information must be complete, consistent, and correct as well as reflect the actual time of and conditions pertaining to the occurrence of the indicated event.**
- **Timely transfer of data is necessary to achieve fault interdiction.**
- **All data streams provided by the equipment must be complete, consistent, timely, accurate, and properly sampled and possess high enough resolution to serve their intended purposes.**

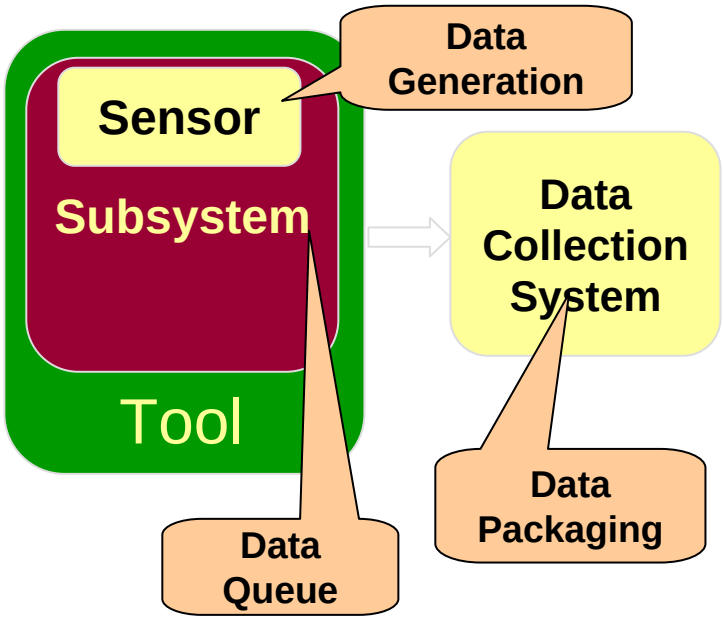
IC Maker Consensus Experiences

- **Issues Experienced**
  - Equipment interface has software defects
  - Documentation does not match software
  - Reports send wrong format of data
  - Equipment performance affected by data collection
    - Resulting in lost data
  - Short data collection period with a high rate can take tool down
    - Resulting in product loss
  - Missing data, including context data
  - Reporting not current data
  - Data report and event latency
  - Inaccurate error reporting
  - Unclear level of data collection limits, without affecting process
    - Not clear what the equipment is capable off
  - Context data missing, e.g., linking data with a wafer
  - Incorrect decisions made due to missing events or missing data
  - Non-existent time synchronization
    - Data reports cannot be used to correlate events, alarms, or process issues

Time Synch Issues: Equipment



Time Synch Issues: Data Time Stamps

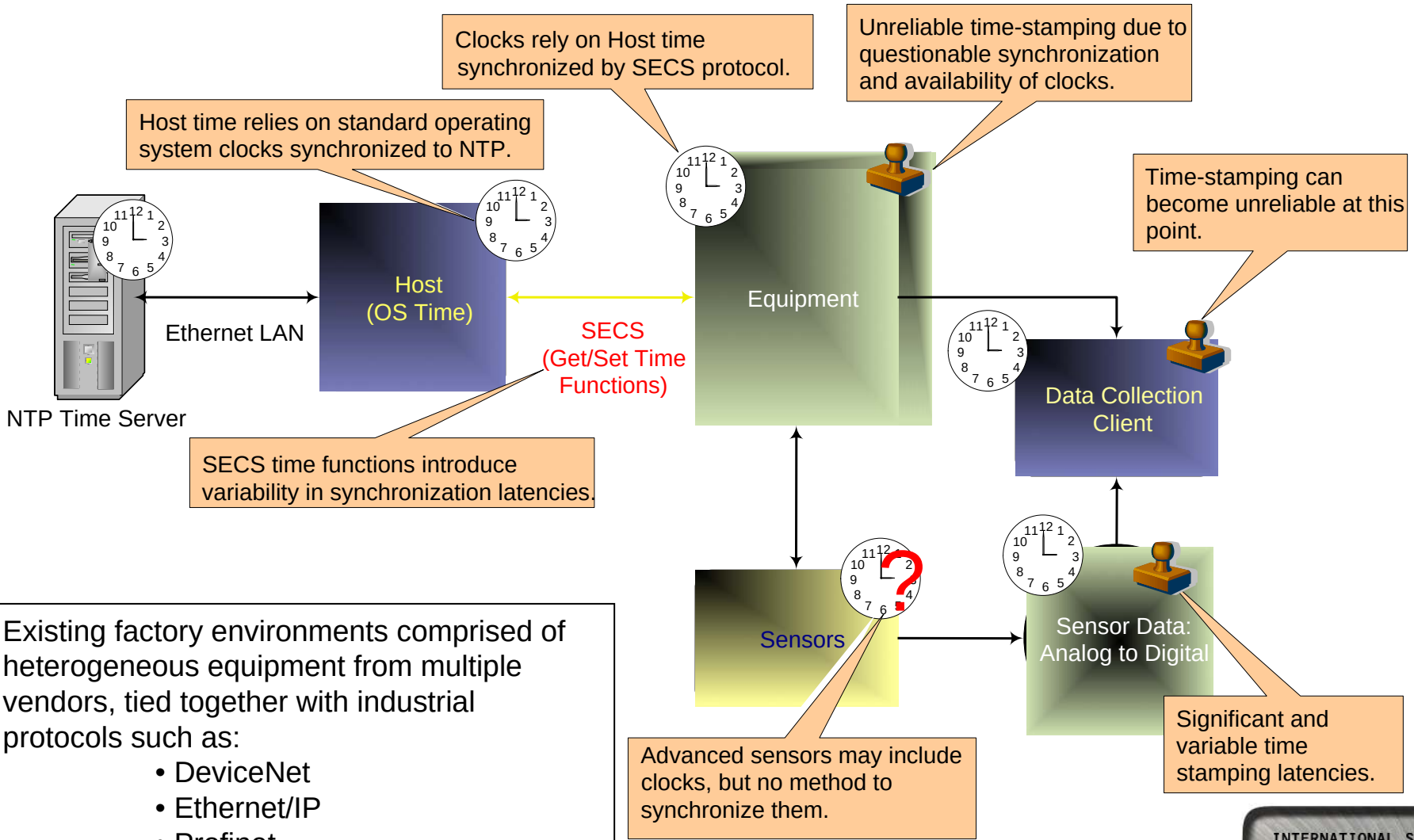


Possible Time-stamping Points

Time-stamping latencies within a single tool due to inconsistencies:

- **Format/time reference**
- **Point of time-stamping**
  - **Should reflect time of data generation**
  - **Should not include**
    - **Transmission time**
    - **Processing**
    - **Queuing time**

Issues: Factory Synchronization



Existing factory environments comprised of heterogeneous equipment from multiple vendors, tied together with industrial protocols such as:

- DeviceNet
- Ethernet/IP
- Profinet

Key obstacle is clock communication

Time Synchronization Working Group

Mission:

To encourage/require accurate equipment and factory clock synchronization for future implementations, while maintaining compatibility with legacy systems

Goals:

- Define what THE master clock is
- Factory clock synchronization precision
- Embedded clocks within equipment need to be synchronized with factory clock
- Factory applications timing requirements
- Common time-stamp format/basis
- Consistent point of time-stamping
- Time-stamp traceability/quality for verification
- Facilitate data merging

Time Synchronization Approach

1. **Publish Time Synchronization Guidelines**
   - **Characterized processes for timing accuracy and precision requirements**
2. **Specifications in new standard**
   - **Ballot (4291) submitted for Cycle 4**
3. **Update existing standards to support time synchronization/time-stamping**
   - **E5, E30, E…,**
   - ***Backward compatibility is an absolute requirement***

Draft Time Synchronization Guidelines Document Outline

Application Timing Requirements
On-tool Examples

Application	Description/Needs	Absolute Accuracy	Relative Accuracy	Minimum Data Sampling Interval	Precision Required
Intra-tool Sensor Integration	Connect sensors to embedded tool control system for use in real-time control and/or communication to external applications.	5 sec	5 ms	5 ms	1 ms
End-Point Detection	Analyze key equipment/process parameters to detect the end of a recipe step.	5 sec	10 ms	10 ms	1 ms
In-Situ FDC	Need to correlate sensor data, tool data, and other process data to a specific wafer/lot for multivariate analysis.	5 sec	5 ms	5 ms	1 ms
Integrated Metrology (IM)	Standard calls for synchronized clocks to accurately time stamp metrology data.	5 sec	100 ms	100 ms	1 ms

Application Timing Requirements
Fab-level Examples

Application	Description/Needs	Absolute Accuracy	Relative Accuracy	Minimum Data Sampling Interval	Precision Required
Real-Time Data Base (EES Data Repository) (Historian)	Provide high-speed storage and retrieval of detailed equipment and process data to support wide range of application needs.	5 sec	10 ms	20 ms	1 ms
Control / Fault Model Development	Analyze equipment, process, metrology, and yield information to development control models used for APC applications.	10 sec	10 ms	1 min	1 ms
Fault Detection and Classification (FDC)	Analyze equipment and process parameters to ensure tool is in its acceptable operating envelope; identify and classify (or prevent) equipment faults and interrupt processing accordingly.	5 sec	10 ms	50 ms (in process) 20 sec (post-process)	1 ms
Event / Alarm Management	Capture, analyze, communicate, and support user response to events and alarms across the production environment.	5 sec	1 sec	1 sec	1 ms
Scheduling/ Dispatching (RTD)	Provides ability to accurately estimate time of completion, arrival of wafers, and to prepare a tool for wafer processing.	5 sec	2 sec	2 sec	1 ms
Factory Time Synchronization	Maintain and provide reference time for all systems in the fab.	5 sec	1 ms	10 sec	1 ms

Time Synchronization Standard – Balloted Document (4291)

Specifications in new standard

- Equipment shall support synchronization of all modules with clocks using NTP
- Time-stamping capability required
- Time-stamp reporting format (ISO 8601)
  - Format to be used by other standards
- Time-stamp quality
- Defines a clock object
  - To readily obtain information from equipment:
    - Method to record time latency/uncertainty
    - Clock quality verification
    - Time-stamp

Summary

- Data from sensors and tools cannot be readily merged today to meet factory application needs
  - Unreliable time-stamps prevent advanced analysis capabilities
  - Clocks within the tools should readily synchronize
    - All tool and tool components' clocks should support synchronization
- Synchronization solutions exist
  - The factory provides accurate timing
    - Time servers and time sources inside the factory should propagate timing information to all equipment and equipment modules using mainstream synchronization protocols
- Standards/guidelines being developed to
  - Improve synchronization communication of equipment clocks
    - Provide consistent time-stamping
  - Verify clock synchronization/time-stamping quality
- Time synchronization is an initial step to addressing the overall data quality issue

Data Quality West Key Messages

- Data producers are the equipment suppliers; they are the only ones that can improve data quality.
- Data consumers are IC makers, who are at the mercy of the producers; the quality of the decisions made is wholly dependent on the quality of the data. Garbage in, garbage out .
- Data generated by semiconductor equipment is critical to improving equipment and factory productivity .
- Data must be provided with sufficient accuracy, resolution, and sampling frequency for process/ equipment characterization, fault detection, failure diagnosis, and process development/control.
- How does your organization measure data quality?
- What are the costs associated with the lack of data quality?

Time Synchronization References

ISMI Reports

Using Network Time Protocol (NTP): Introduction and Recommended Practices

ismi.sematech.org/docubase/abstracts/4736aeng.htm

Semiconductor Factory and Equipment Clock Synchronization for e-Manufacturing

ismi.sematech.org/docubase/abstracts/4557aeng.htm

ISO 8601:2004

Internet standard for date/time format: **www.w3.org/TR/NOTE-datetime.html**

NTP

www.ntp.org

Latest official NTP RFC 1305: **www.ietf.org/rfc/rfc1305.txt**

NTP version 4 Working Draft: **www.ietf.org/internet-drafts/draft-ietf-ntp-ntpv4-proto-02.txt**

IEEE 1588

ieee1588.nist.gov