ISMI RaP Prototype

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Standards Technical Education Program on the Recipe and Parameter Management Standard (SEMI E139)

Prototype Motivations

- **Improve the RaP specification**
  - **Clarity and organization of the document**
  - **Completeness and consistency of the information**
- **Verify that RaP is implementable**
  - **Identify design and implementation issues related to the RaP specification content**
  - **Modify the specification to make implementation easier, where practical**
  - **Demonstrate RaP usage scenarios**

Challenges to Prototyping

- **When To Do It**
  - Too early – specification isn't firm enough
  - Too late – specification is too rigid
  - Accidentally chose a good solution
    - Just after the concepts specification is approved and during development of implementation standards
- **Flexibility Is Critical**
  - Some parts of the document continue to change during the prototyping process
    - To some degree, because of the prototype effort
  - Must accept that the prototype will not represent the final SEMI specification 100%
  - But must react to changes that have substantial effects on the result

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Prototype Approach

- **Simulate the process a supplier will use to add RaP support to equipment**
  - Generate detailed software requirements for adding RaP support
  - Design and build a prototype implementation
- **Deliver a lessons-learned report at the end of each SW development phase**
  - Provide feedback to the RaP Task Force as soon as possible

Prototype Phases

- Protocol Mapping
  - Created a “stand-in” SECS-II mapping
- Requirements Analysis
  - RaP support for the TrackSys TS-400 tool
- System Analysis
  - Impact on tool HW & SW
  - Relationship to other SEMI standards
- Design
- Implementation
- Demonstration

} of a RaP Prototype

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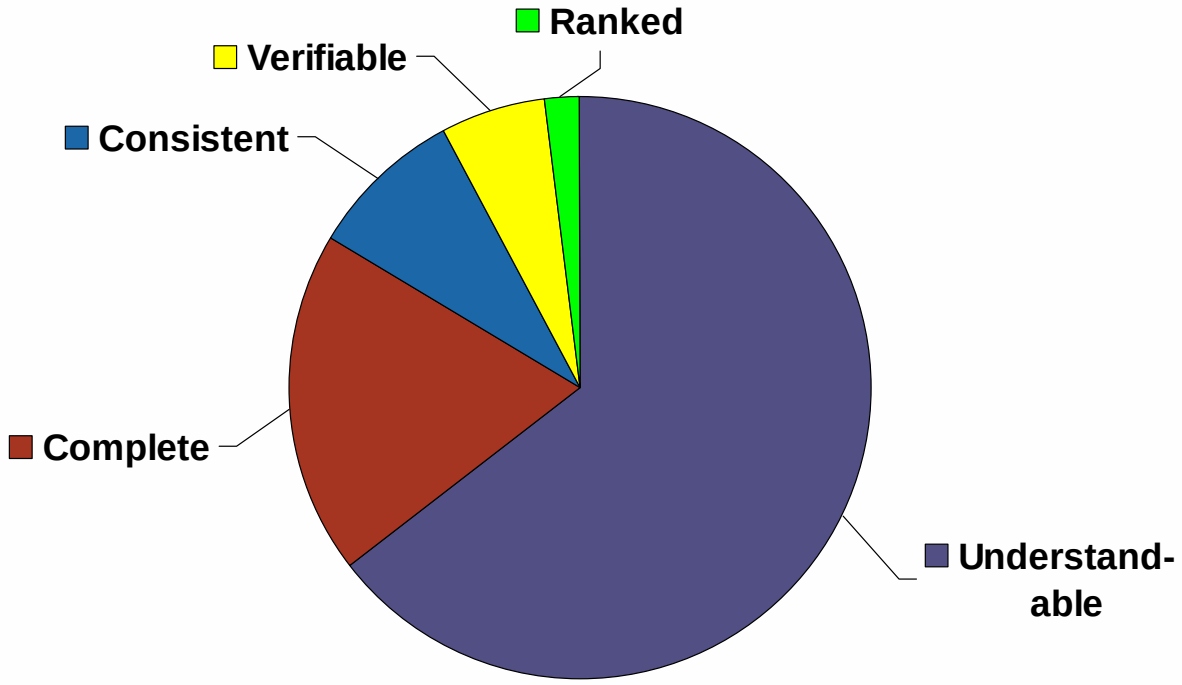
RaP Requirements Assessment

- Assess the RaP specification as a set of software requirements
  - Assessment criteria used were a subset of the criteria in the IEEE Software Requirements Recommendation (IEEE Std 830-1998)
    - Unambiguous (Understandable)
    - Complete
    - Consistent
    - Ranked
    - Verifiable
- Assessment is contained in “TrackSys TS-400 Software Requirements” deliverable

Requirements Issues Breakdown



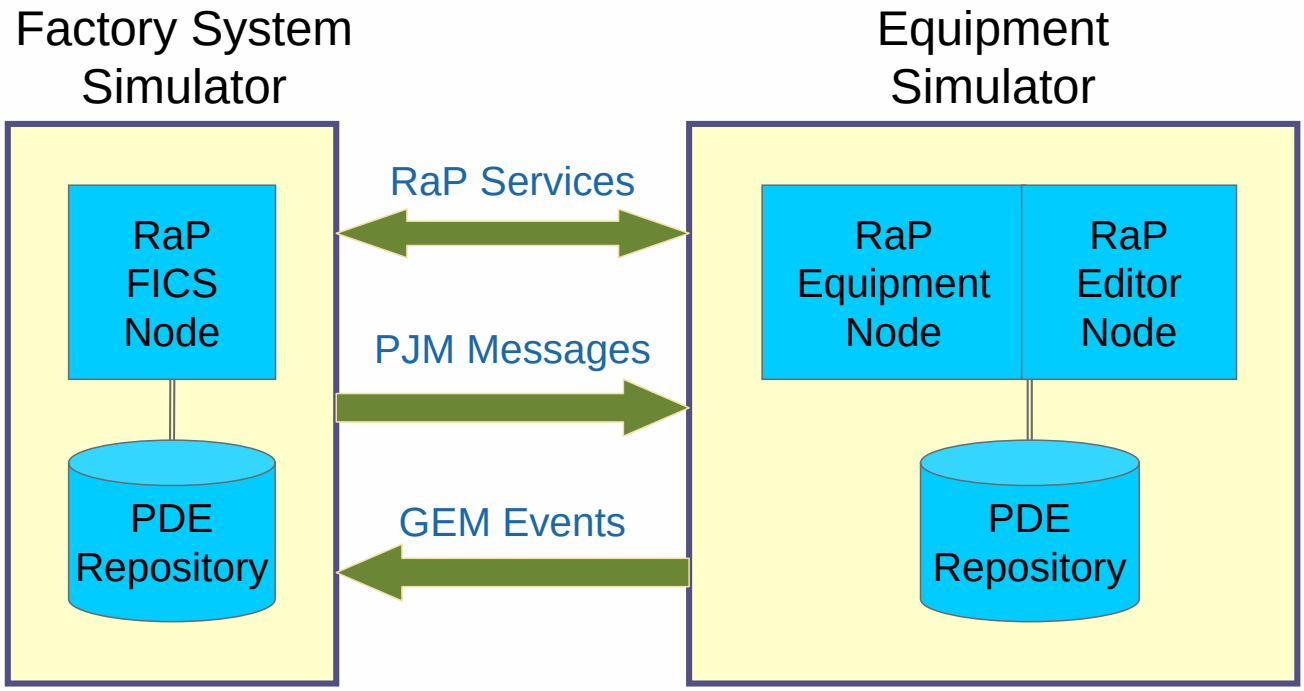
104 issues identified during Requirements Phase

Sample Requirements Issues

- **Understandability**
  - 8.4.3 The text says “This PDEeditor shall be capable of initiating transfer of PDEs to and from the equipment.” What if the equipment and editor share recipe storage area?
- **Completeness**
  - 8.3.5 The description of the TransferContainer manifest does not describe the content of the manifest when PDEheaders are being transferred.
- **Consistency**
  - 8.3.3, Table 16: The entry for tcid says its form is UUID; the entry for uid says its form is String, and there is no entry for gid. These should all (tcid, uid, gid) have consistent data types.

Note: PDE -> Process Definition Element = Recipe Component

RaP Prototype Components



- **The prototype consists of two applications:**
  - **Factory System Simulator**
  - **Equipment Simulator**

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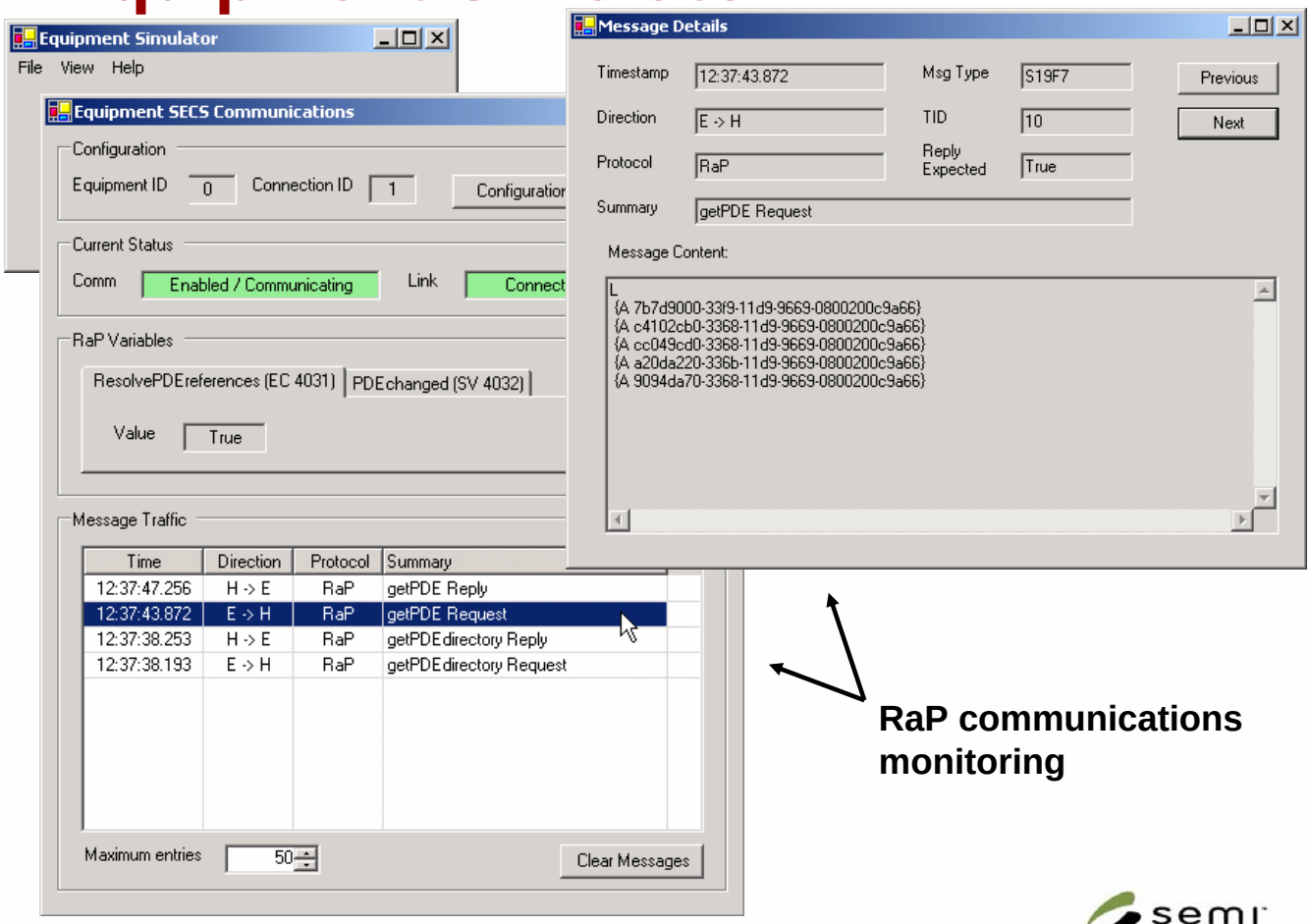
RaP Prototype Implementation

- **Technologies Used**
  - **Microsoft .NET and C#**
  - **Cimetrix CIMConnect for SECS-II and HSMS communications**
  - **SQLite (a lightweight RDB) for persistent storage of recipe metadata**
    - **Windows file system for recipe body storage**
  - **SharpZipLib for recipe compression and multi-file archive support**

Note: None of these technology choices were dictated by the RaP specification

Equipment Simulator



RaP communications monitoring

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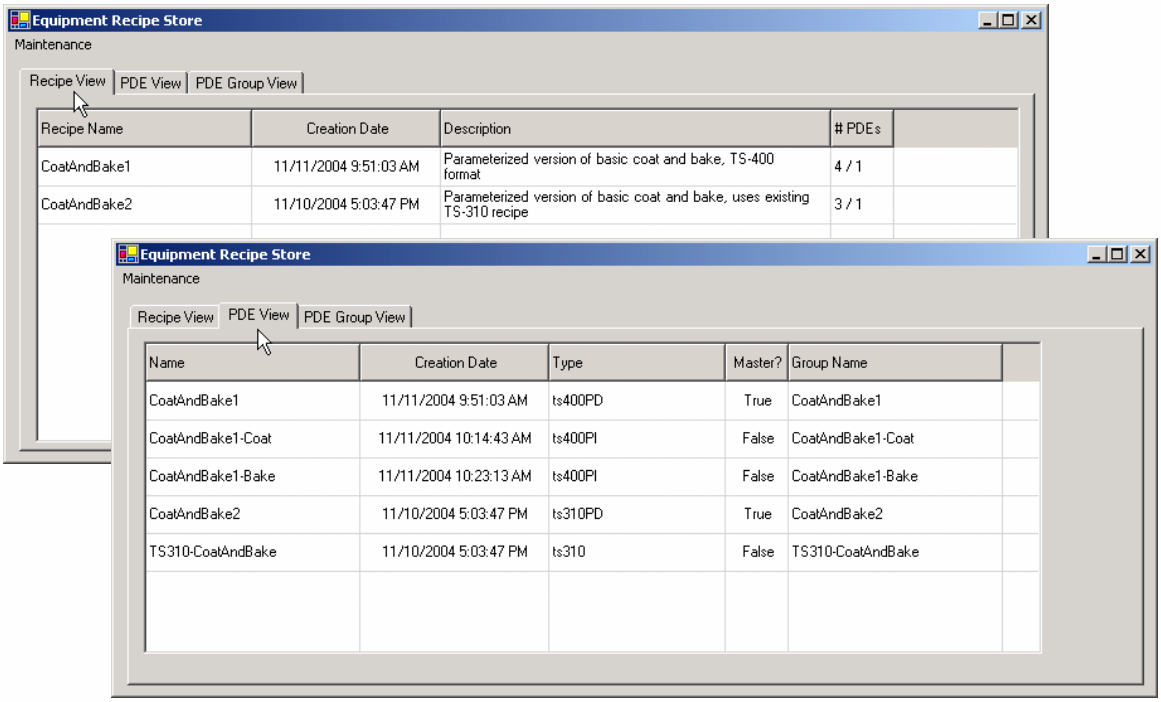
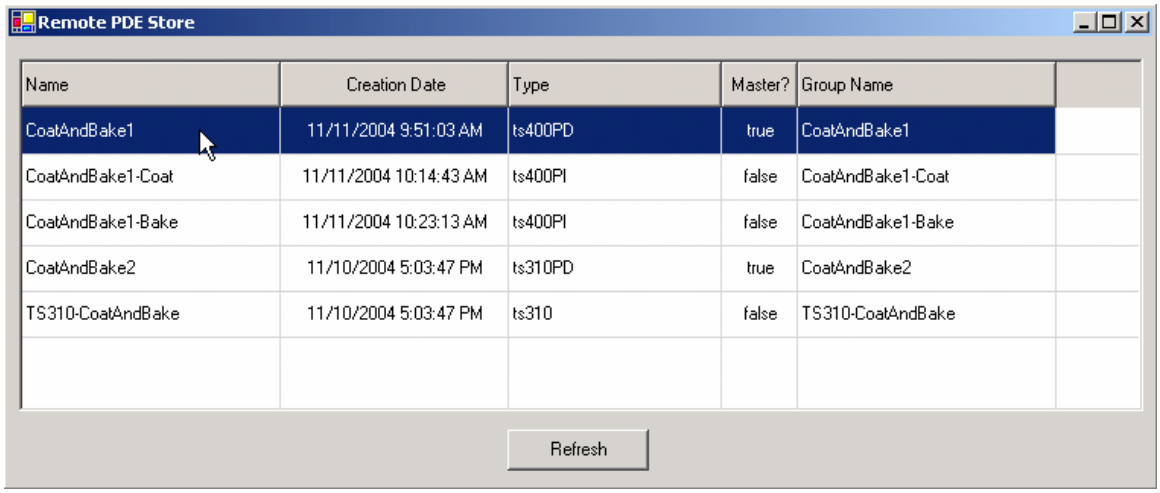
Equipment Simulator



Multiple views of local recipe store contents

Equipment Simulator



View of remote recipe store contents. Needed to support getPDE (download) service.

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Design And Implementation Issues

- **Calculating checksums over XML documents**
  - **XML supports multiple (byte-level) representations for the same document content, so:**
    - **XML must be fully canonicalized before checksum calculations**
    - **The "original" XML must be accurately reproduced from recipe storage in order to verify checksum**
- **Recipe storage must be carefully designed to avoid having to open/read every stored recipe component (PDE) when:**
  - **Servicing a getPDEdirectory request**
  - **Traversing PDE dependencies within a recipe**
  - **Determining PDE group membership**

Very Large Recipes (> 4 GB)

- **Difficulties due to large recipes**
  - HSMS limits total message size to 4GB; SECS-II limits single data item size to 16MB*
    - RaP SECS mapping must work around these constraints
      - Probably using multi-message transfer of recipe
    - Implementation of this mapping will be more complex than for a single request-response message pair
  - RaP implementer must be careful not to instantiate entire recipe in memory
    - RaP Prototype makes makes heavy use of Streams to pass recipe data from one sub-system to another
      - Streams are read or written as infrequently as possible
    - Must be sure that helper utilities avoid in-memory instantiation as well

*** These constraints don't apply to the RaP WebService (SOAP/XML) mapping.**

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Very Large Recipes (> 4 GB)

- **Large recipes lead to long processing times**
  - Recipe transmission time
  - Local and remote recipe processing time
    - XML parsing, XML canonicalization
    - Checksum calculation and recipe content validation
    - Data compression/decompression
    - File I/O
  - As a result, any of these operations can take a long time:
    - Local generation of a RaP request and/or processing of the RaP response
    - Remote request processing; remote response generation
    - Message transmission to and from remote node

Very Large Recipes (> 4 GB)

- Large recipes lead to long processing times
  - It may not be feasible to block other host or equipment operations
    - First and foremost, wafer processing must not be affected
    - Process or metrology data still needs to be collected
    - User interfaces need to stay responsive
  - The solution is asynchronous (multi-threaded) programming
    - Multi-threaded programming can be complex and error-prone
    - It's hard to think in parallel

Prototype Deliverables Summary

- Reports from each phase of the activity
  - Identifying issues with the RaP document and content
  - Identifying design and implementation issues
- RaP support requirements
  - For a sample process tool: TrackSys TS-400
  - Lots of detail, 57 pages
- A prototype RaP implementation
  - Factory System Simulator
  - Tool Simulator

Prototype Activity Assessment

- This effort was effective in identifying a large number of potential RaP improvements
  - Many of these have already been incorporated into the specification
- The Requirements Phase was most effective in identifying document and content issues
  - Use of SW requirements assessment criteria could be adopted by other standards teams
- The Design and Implementation Phases were necessary to identify implementation difficulties
  - Fewer issues, difficult to uncover before implementation

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Conclusions

- Prototyping is particularly effective when
  - The main (concepts) document is near approval
  - The implementation standards are in early draft
- Stable commercial implementations possible up to two years earlier
  - Changes detected by early prototyping would ordinarily be
    - Found during commercial implementation ~6-12 months later
    - …and corrected ~6-12 months after that (12-24 months total)
- The industry would benefit from a process that encourages/requires early prototyping
  - A model is needed for how to fund and execute such prototyping activity
  - ISMI may do this for select priority issues, but the industry needs it done consistently for all cases