Using a structured framework for manufacturing semiconductors provides valuable business lessons.

SEMATECH's Experiences with the CIM Framework

SEMATECH, the semiconductor manufacturing technology consortium, has worked since 1991 with the major U.S. semiconductor companies to develop a semiconductor industry standard for a software framework for Computer Integrated Manufacturing (CIM). This experience and the results SEMATECH and its member companies[1] achieved offer practical lessons on standardizing object-oriented frameworks for specific business domains.

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The CIM Framework [4] defines a component-based architecture for the next generation of agile Manufacturing Execution System (MES) systems. For the first time, suppliers of semiconductor MES systems and users of those systems have collaborated to specify the standard partitioning and capabilities for a marketplace of commercial MES solutions.

The need for rapid information systems changes has resulted in a requirement for applications to be broken into smaller pieces for manageability and implemented across distributed networks for cost and performance reasons. Interoperability between individual applications in this environment has also become of paramount importance. Independent applications that each perform separate enterprise information system functions must cooperate to be effective because most have complex dependencies and relationships with each other.

The requirements for rapid change and interoperability in the face of increased applications complexity led SEMATECH to conclude that a CIM framework architecture is a necessity. A framework architecture will become an essential part of using information systems for competitive advantage in the semiconductor industry.

SEMATECH initiated the CIM Framework project in 1991 anticipating the following future manufacturing needs:

- Commercial alternatives to proprietary internal software.
- Solutions assembled from multiple suppliers' offerings.
- Use of existing systems while evolving new capabilities.

SEMATECH first partnered with Texas Instruments to build upon the object-oriented foundation provided by the Microelectronics Manufacturing Science and Technology project (MMST) [1, 7]. SEMATECH member companies helped validate, evolve and broaden support for the CIM Framework specification. CIM software suppliers, including the Texas Instruments WORKS project, the IBM SuperPOSEIDON project, and the Promis Encore! group provided key improvements based on implementation experience.

[1]SEMATECH member companies are AMD, Digital, HP, IBM, Intel, Lucent, Motorola, National Semiconductor, Rockwell, and Texas Instruments.

SEMATECH uses the term *framework* to refer to a collection of specifications of interacting software components that comprise a solution for a particular domain. A framework embodies generalized expertise in the domain based on analysis and synthesis of a wide range of specific solutions. Framework technology also supports the assembly of these solutions from multiple supplier offerings.

The CIM Framework is an instance of a callable framework [6]. A callable framework allows the application to retain the thread of control and provides services when the application calls the framework. By contrast, a calling framework provides a control loop that calls application-provided code at appropriate times.

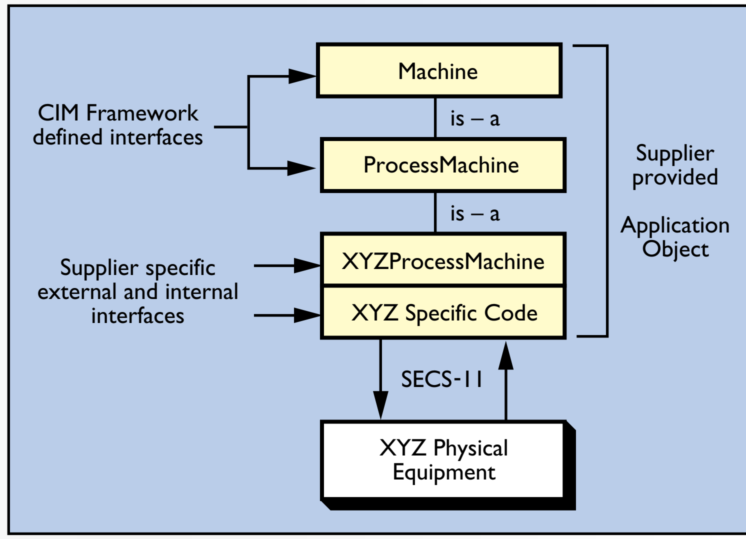

Figure 1. Example Application Object

CIM Framework Specification Structure

The CIM Framework is based on the Object Management Group's Object Management Architecture (OMG OMA) [2, 3, 5]. OMG's OMA enables distributed location transparent and language-independent communication between objects. It also supplies a set of common services needed by distributed object applications. Interfaces between service requesters and service providers are specified using OMG Interface Definition Language (IDL). Clients are isolated from implementation details of servers such as internal data representations and algorithms.

Behavior specifications supplement interfaces through an object-oriented analysis of the CIM domain [1]. Interfaces representing object types map real-world semiconductor manufacturing objects and concepts to their software equivalents. Components package these interfaces and behavior specifications as the building blocks of the framework. CIM suppliers develop executable code called Application Objects based on one or more of the CIM Framework Components. Suppliers have flexibility on grouping Component implementations into product packages and provide added value through extensions or optimizations. Components that have an open specification

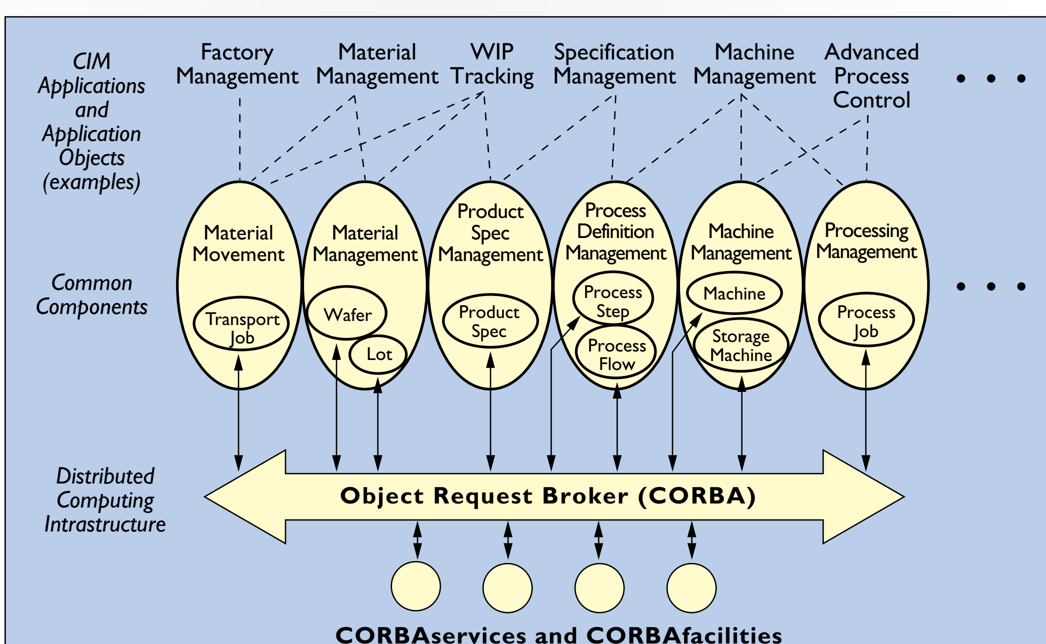

Figure 2. CIM Framework Architecture context

support integration of Application Objects from multiple suppliers.

Figure 1 shows a sample Application Object implementing a specialized software ProcessMachine interface to a specific type of equipment. The executable code contains the CIM Framework-specified interfaces, supplier-defined interfaces, and translation layer code to convert the CIM-level instructions into instructions executed by the tool control software. The executable code would then be registered as the interface module to the XYZ equipment.

Figure 2 represents the scope of the CIM Framework and illustrates its context. Note that Application Objects can use one or more CIM Framework Components, as illustrated by the broken lines.

Lessons from Framework Specification and Development

SEMATECH's experience with the CIM Framework highlighted several challenges that face developers of domain framework specifications.

Implementation Experience is Essential. A stable framework specification must be based on experience from several different implementations. Industry acceptance is enhanced when key suppliers influence the specification based on product development experience.

Frameworks Increase Initial Cost. Specifying a framework involves significant cost beyond that needed for single-use software development. The initial cost of specification and implementation is further increased by costly framework skills, added education, validation and conformance testing. Generalizing and refining the specification multiplies cost with iterations through the development process.

Infrastructure Coupling is Difficult to Avoid. The framework specification tends to become coupled to the architecture of the underlying infrastructure. Separating domain and technology concerns and keeping implementation details out of the framework specifications requires great diligence.

Frameworks Overlap. As domain frameworks become more common, the specifications of multiple frameworks will need to be integrated. Independent frameworks will overlap and intersect in ways that require reconciliation and alignment.

Technology is Immature. The CIM Framework is based on technology that is still maturing in fundamental ways. The OMA does not yet provide all of the capabilities needed for framework specification and component-based development. Stronger specification techniques like pre- and post-conditions are needed to ensure semantic interoperability. Additional object model features such as operation overloading and multiple interfaces will be required for larger scale integration of components.

Future Directions

The future of the CIM Framework lies in broadening the marketplace of compliant implementations and achieving formal standardization. Standardization of the CIM Framework was started by the Semiconductor Materials and Equipment International (SEMI) organization in early 1997. The SEMI CIM Framework Task Force is initiating a roadmap for international standardization through a series of adoption ballots for CIM Framework Components.

Other groups have started to evolve the CIM Framework and apply it to other manufacturing industries. The National Institute for Standards and Technology (NIST) has launched projects based on the CIM Framework. The OMG Manufacturing Domain Task Force is also expected to address CIM in future technology adoptions.

SEMATECH provided an extendable framework specification designed to meet the semiconductor industry's need for flexible, cost-effective applications. CIM suppliers are learning to use the CIM Framework Specification and are exploring the implications of open, framework-based products. The CIM Framework will achieve its goals as these compliant commercial solutions become available.

Framework technology signifies the beginning of a new era in software development that will challenge developers, and greatly benefit users of information technology solutions. C

References

1. Baudoin, C. and Hollowell, G. *Realizing the Object-Oriented Lifecycle*. Prentice Hall, 1996.
2. Object Management Group. *The Common Object Request Broker: Architecture and Specification, Revision 2.0, July 1995*. Object Management Group, Framingham, Mass., 1995.
3. Object Management Group World-Wide Web Site: http://www. omg.org
4. SEMATECH World-Wide Web Site: http://www.sematech.org/public/cim-framework/home.html
5. Siegel, J. *CORBA Fundamentals and Programming*. Wiley, NY, 1996.
6. Sparks, S., Benner, K., Faris, C. Managing object-oriented framework reuse. *IEEE Comput.* (Sept. 1996), 52–61
7. *Texas Instruments Technical J. 9*, 5 (Sept.–Oct. 1992).

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