RASSP Enterprise Technologies for Signal Processor Life-Cycle Support

by

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Abstract

Enterprise integration technologies are a key contributor to improving time-to-market, cost, and design quality by a factor, which is the goal of the DARPA Rapid Prototyping of Application-Specific Signal Processors (RASSP) program [1]. The Lockheed Martin Advanced Technology Laboratories (ATL) RASSP team developed a productivity improvement model, shown in Figure 1, that indicates the relative contributions of various RASSP technologies to the overall improvement. Enterprise technologies address the entire 17% enterprise partition, and more than half of the 30% reuse and model-year architecture partition, thus accounting for at least 35% of the overall RASSP productivity improvement.

The ATL RASSP approach to implement enterprise systems is to extend commercial technologies so the results are available to a broad base of potential users. Unlike current automation concepts which start at later stages of the development cycle, the RASSP enterprise system supports the entire signal processor life cycle. Core concepts of the enterprise system include:

- Tools and tool frameworks integrated into an enterprise environment
- Program execution control through workflows
- Integrated data management functions
- Design reuse
- Concurrent engineering team support
- Integrated design engineering and manufacturing.

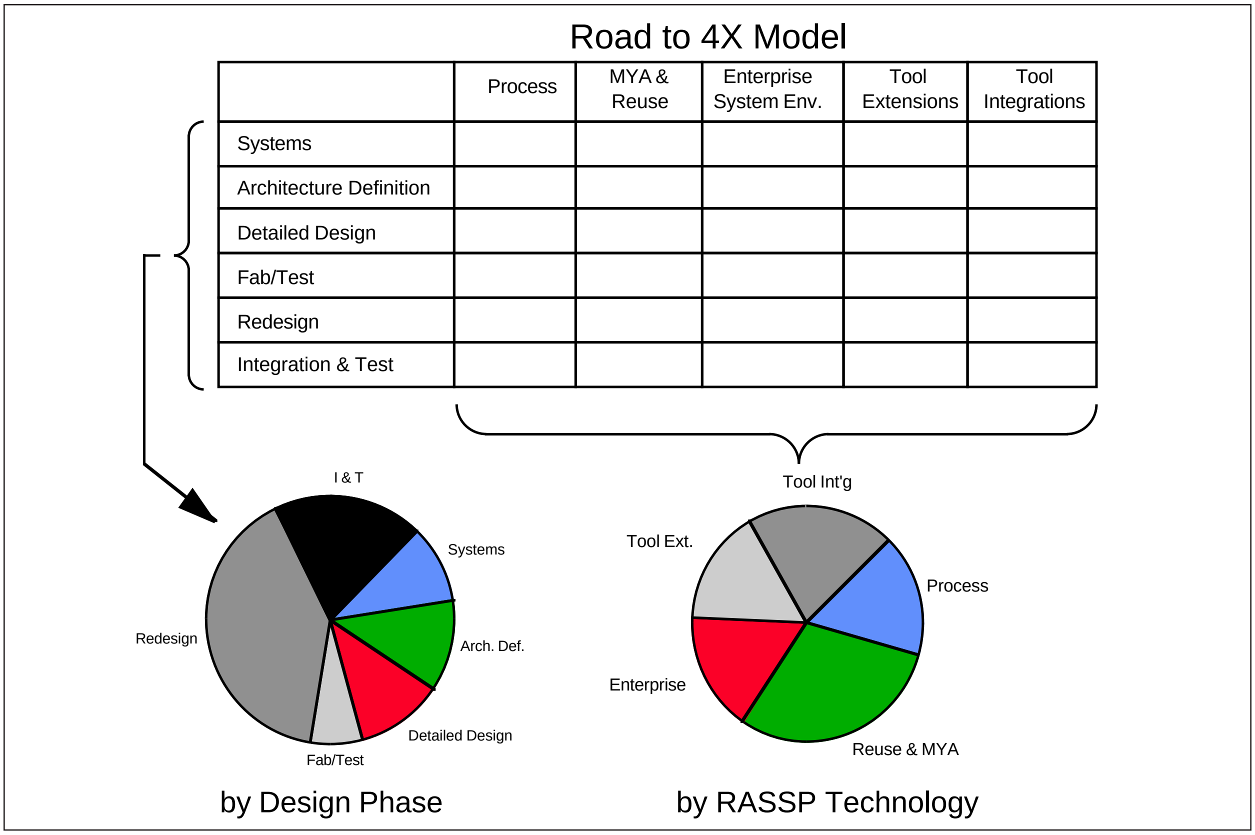

Fig. 1. *Two views of cycle-time reduction contributors.*

The model-year architecture, which enables users to rapidly, efficiently upgrade systems with new technology, is supported in the enterprise system by a robust reuse management system. Manufacturing interface and communication services elements of the enterprise system provide improved concurrent engineering support for distributed product teams. The enterprise system will be provided to commercial and aerospace users as products, including a reusable set of workflows for electronics design, commercial tools supporting the enterprise system environment, and utilities to enable users to customize the RASSP enterprise system for a particular organization or project.

The enterprise system development cycle includes four build cycles with increasing capabilities. The ATL team completed the Build 2 implementation in May '96. This implementation supports the processes associated with detailed hardware/software design, architecture design, and trade-off analyses. It is being used at Lockheed Martin and multiple government sites for benchmarking and evaluation. Results to date indicate >5:1 productivity improvements in the manufacturing interface, and 5-10% improvements in design engineering, which is growing with increasing level of utilization.

Biography

John Welsh

Mr. Welsh is the currently Deputy Program Manager for the Lockheed Martin Advanced Technology Laboratories RASSP progam, with specific technical responsibility for the enterprise system development activities on the program. Mr. Welsh has over 20 years technical and managerial experience on aerospace engineering programs, with partucular focus on systems and electrical engineering. Development projects include CAD software, submarine environment simulation, radar systems and signal processors, and advanced processor architectures. Mr Welsh has a Bachelors degree in Electrical Engineering from Villanova University and a masters degree in Systems Engineering from the University of Pennsylvania. Mr Welsh can be contacted at jwelsh@atl.lmco.com.

Bipin Chadha

Dr. Bipin Chadha is currently Lead Member of the Engineering Staff at Lockheed Martin Advanced Technology Laboratories. Dr. Chadha is the Technical Lead for the information management strategy on the RASSP program, as well as the principal investigator on multiple process improvement initiatives within Lockheed Martin. Prior to Lockheed Martin, Dr. Chadha was an information systems and process improvement consultant for Intergraph Corporation, and a manufacturing information system developer for AT&T. Key areas of technical expertise include large scale data management, workflow and document management, expert systems, and business process reengineering. Dr. Chadha received his Ph.D. in Mechanical Engineering from Georgia Institute of Technology in 1992, a Masters degree in Mechanical Engineering from Southern Illinois University in 1987, and a Bachelors degree in Mechanical Engineering from the University of Roorkee, India.

Biju Kalathil

Biju Kalathil is a Senior Member of EPngineering Staff at Lockheed Martin Advanced Technology Laboratories, Camden, New Jersey. His research interests include application of information systems for design and manufacturing process improvement, database systems, and electronic commerce. He has developed enterprise information environment concepts and models for the RASSP program, and is currently developing and validating enterprise information environment concepts for the Affordable Multi-Missile Manufacturing (AM3) program. Kalathil received a Ph.D in Computer Science, and an M.S. in Civil Engineering from the University of Illinois; and a B.S in Civil Engineering from the University of Kerala, India.

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Mr. Holmes is currently a Lead Member of the Engineering Staff at Lockheed Martin Advanced Technology Laboratories in Camden, New Jersey. He is currently specializing in the Internet and finding network solutions to a variety of engineering problems associated with the Rapid Prototyping of Applications Specific Signal Processors (RASSP) and Affordable Multi-Missile Manufacturing (AM3) programs. Specific development areas include development of secure Internet communications and collaboration. Before that, Mr. Holmes was involved in the design and development of the International Space Station Alpha communications system.

Mary Catherine Tuck

Ms. Mary Catherine Tuck, formerly with Intergraph Corporation, is a Senior Software Analyst with Premier Professional Services Inc. in Huntsville AL. Recent accomplishments include product data management implementation with workflow integration for the RASSP enterprise system, as well consulting support for PDM customizations. Ms. Tuck's expertise is in object oriented anaysis and design, and software development for commercial and military systems. Ms. Tuck has a Bachelors Degree Magna Cum Laude in Computer Science from University of North Alabama in 1988.

William Selvidge
Mr. William Selvidge is a Senior Systems Consultant with Intergraph Corporation. Mr. Selvidge is the Program Manager and Technical Lead for the RASSP enterprise system development at Intergraph. Mr. Selvidge has over 15 years of experience in electronics hardware and software development for commercial applications. Technical expertise includes process engineering, electronics CAD, and product data management, software development, and manufacturing processes.

Elisa G. Finnie
Ms. Finnie is currently President and CEO of Sandpiper Software Inc., a new start organization specializing in reuse management technology. Ms. Finnie has over 17 years professional experience in software design, development, and engineering management. Her primary area of interest is in application of knowledge representation and interoperability technologies to problems of complex data management on an enterprise scale. Her background includes over 14 years experience as a real-time software designer, architect, applications engineer, and project lead for Lockheed Martin Missiles and Space Company, 3 1/2 years as software development, quality assurance, and customer support manager for Aspect Development, and most recently, over a year as an independent consultant to Lockheed Martin, driving the design reuse strategy for the RASSP program. Ms. Finnie has an MA in Linguistics from Stanford University in 1989, and a BS in Mathematics and Computer Science from UCLA in 1979.

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1.0 Introduction

The competitive business climate and decline in the defense budget have forced defense contractors toward agile design and manufacturing approaches supported by agile, enterprise-wide infrastructures. The RASSP Enterprise System provides key automation support for teams of signal-processing engineers in execution of complex development projects, thereby facilitating, efficient program control, and orderly management of design configurations, resulting in greatly improved productivity. Core concepts of the RASSP enterprise system include integration of tools and tool frameworks into an enterprise environment, program execution control through workflows, integrated product information management functions, concurrent engineering team support, a reuse system, and integration of design engineering and manufacturing. Figure 2 illustrates how the enterprise system supports the RASSP objectives.

The enterprise system is the integrated set of tools and facilities required to support the development of a signal processor prototype — requirements, design, manufacturing, test, management, procurement, etc. ATL's RASSP enterprise system provides users with a workflow management tool and an enterprise-wide product data manager to integrate the tools used in the various stages of signal processor development. It supports integrated product development by providing an infrastructure for concurrent engineering in a distributed environ-

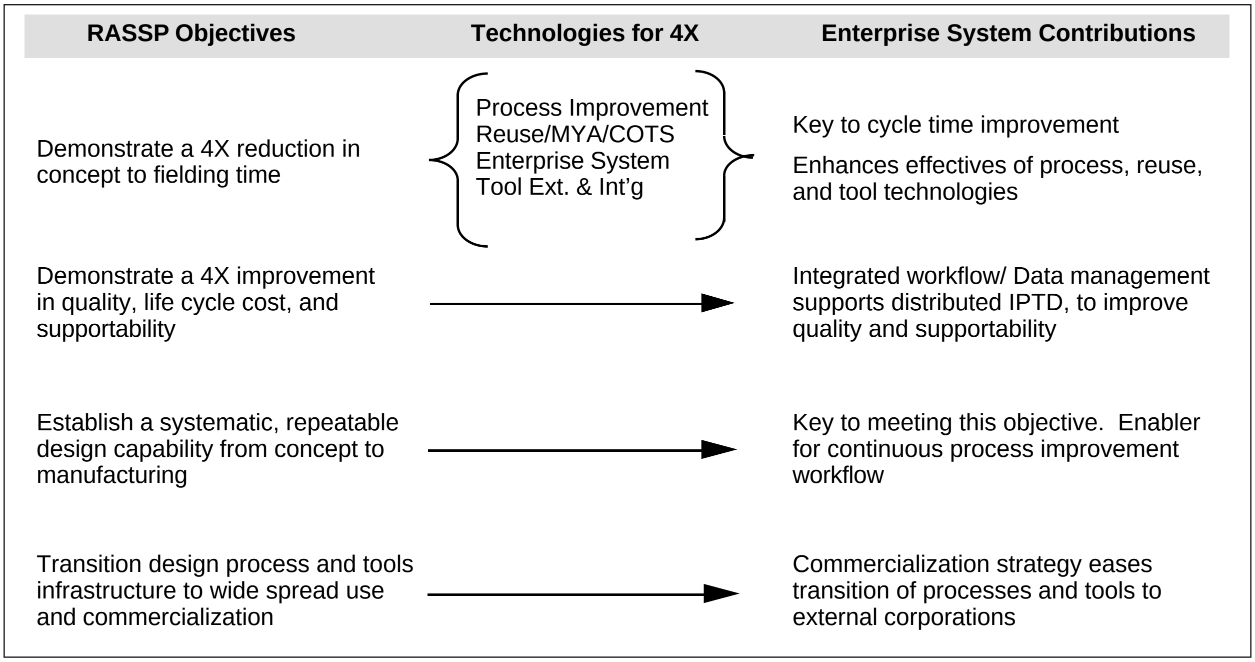

Fig. 2. *The enterprise system is key to satisfying RASSP objectives.*

ment. The enterprise system enables users to interact with other users on common internal networks, and it enables users to interact with external system users, such as team member organizations, manufacturing centers, and external suppliers who are members of the concurrent engineering development team. The focus of the enterprise system is on the entire signal processor life-cycle, as opposed to any particular function (requirements, design, etc.). Related industry efforts in product data management focus on management of "released" information; ATL's RASSP enterprise system addresses released data and "in-process" information associated with front end processes.

2.0 Concept of Operation

The core concept of operation for the enterprise system is to enable teams of engineers to concurrently execute project plans that are expressed as workflows. In addition to the workflows, the plans also include a project management tool (such as MS Project) that is closely coupled with the workflow. When a member of a design team executes a workflow, as shown in Figure 3, execution initiates control commands to a CAD/CAE tool, as relevant for the particular workflow step; it also initiates data transactions with the enterprise product data management system, local data management systems, and library systems, as relevant for the particular workflow step. Project management tools are coupled with the enterprise environment. These tools receive regular status updates as workflow steps are executed, which provides effective, non-interfering project management and concurrent task execution.

To support this execution concept, the workflow management tools link to design tools, data access mechanisms, and other services that remove these functions from the responsibility of the design engineer, which allows the engineer to focus on design tasks. Process engineers design and implement workflows with support from design engineers. These workflows repre-

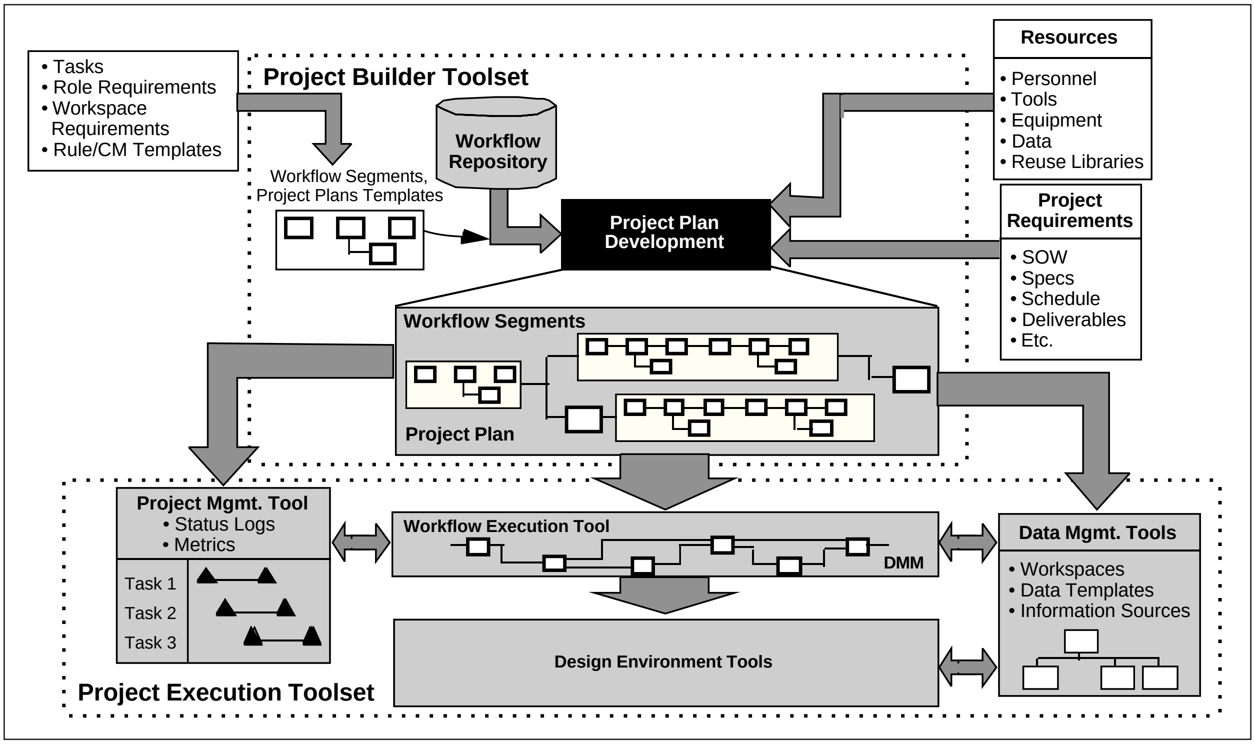

Fig. 3. *Project plan improvements with workflows.*

sent the detailed implementation of the RASSP concurrent engineering methodologies. Program managers, working with design engineers, develop project plans using workflow segments as building blocks. Design engineers use enterprise desktop tools to execute particular workflow segments that represent their specific project assignments. They then execute the appropriate steps identified in the workflow, which then link to the appropriate design tools and data files/elements. Engineers perform the detailed design tasks using specific CAD/CAE/documentation tools. The engineers return to the enterprise system/design methodology management level on completion of tasks, where they perform the necessary information management and process management functions under control of the workflow manager.

In addition to supporting workflow use, the enterprise system provides multiple workspace views for the design environment:
• Tool and application workspaces
• Data workspaces for product information and reuse information
• Project/workflow workspaces as described.
The resources, data objects, and applications available to engineers are defined by their identity and role in an authorization hierarchy implemented in the enterprise system.

This concept of operation improves coordination of the project, and enables configuration management of design information early in the process, with minimal setup or utilization overhead on the part of the development organization. The enterprise system reduces lost work, and eliminates duplicate or redundant functions. These are key the contributors to the productivity gains realizable with the enterprise system.

3.0 Enterprise Architecture

The core enterprise system architecture, shown in Figure 4, is hierarchical, integrating design tool frameworks and individual design tools with workflow and data management systems. The enterprise system supports purchasing, manufacturing, and other business functions. It includes a distributed reuse system with an object-oriented repository at the enterprise level, and local framework/tool libraries coordinated with enterprise-level functions. The individual CAD tools are either integrated directly with the enterprise system or within sub-frameworks tailored to specific design disciplines, such as Mentor Graphics' Falcon Framework for hardware design tasks.

Intergraph's Design Methodology Manager (DMM) provides the primary tool and sub-framework integration/encapsulation support functions, and methodology/ workflow management. The Intergraph product data manager, DM2.0, provides the core distributed product data management function of the enterprise system. Metadata, based on RASSP-specific information models and workflows, organizes the information in the DM2.0 system. The Aspect Component Information System provides the reuse data management capability. This system, with specific object-oriented enhancements, enables reuse of high-level system and subsystem design objects, in addition to components.

The enterprise system provides manufacturing interface support functions, enabling users to generate STEP-compliant representations of electrical designs. [2] Mentor Graphics' Falcon Framework is integrated with the enterprise system, which enables users to launch tools from the enterprise level, and to manage Falcon design objects at the enterprise level.

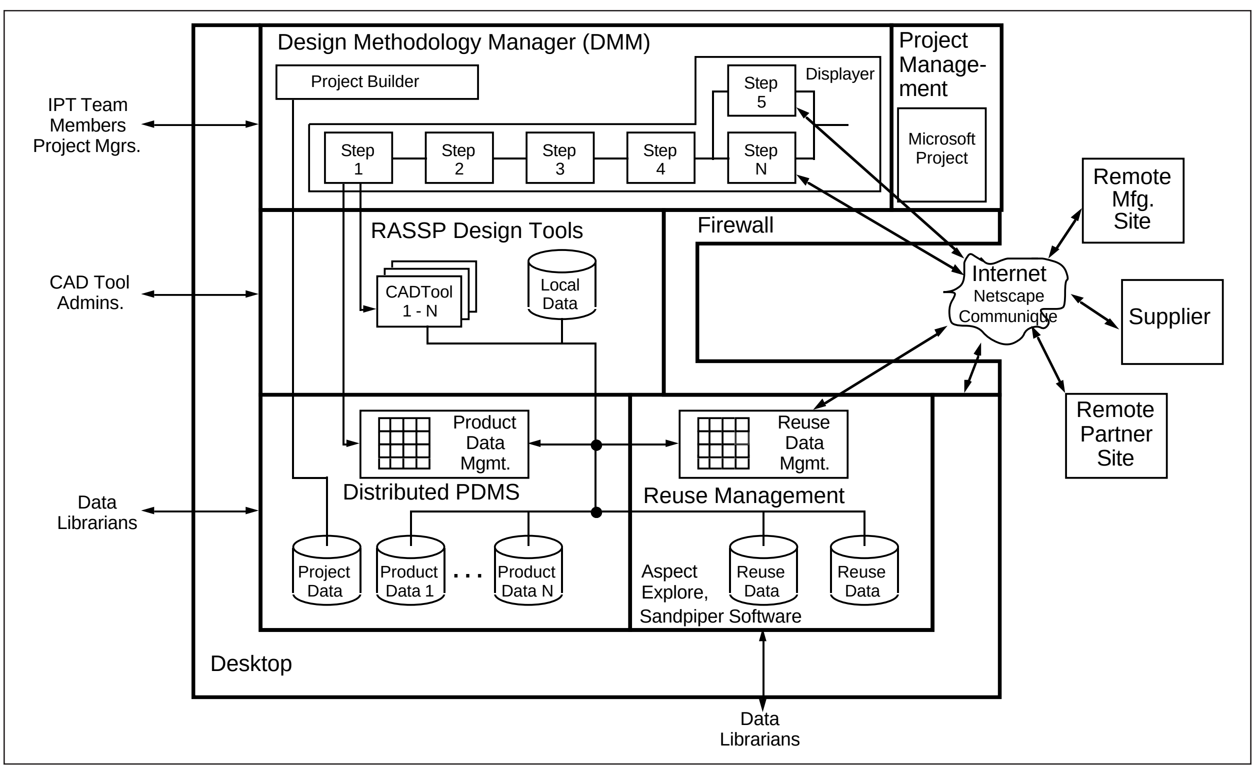

Fig. 4. *Enterprise system architecture.*

4.0 Enterprise System Development Approach

Implementing the RASSP enterprise system involves process engineering, process implementation using workflows tools, and information management supporting the improved processes. Secure communications technology and manufacturing interface capabilities are also included for integrated product team support.

4.1 Process Engineering

Process engineering is a methodology that supports the evolutionary and revolutionary change that is required to achieve an organization's strategic goals through more effective, efficient, and agile business processes. [3] It involves not only process changes, but also organizational changes to support the new processes. There is a significant impact on the policies and procedures of an organization, because teams are organized around processes rather than around organizational functions. Teams are empowered to make more decisions as checks and controls are reduced. Process engineering leverages technology to make old processes better and to break the old paradigms. Once program goals have been set and a strategy devised to achieve those goals, the process team, including domain experts, model the domain "AS-IS" processes using IDEF (Integrated computer-aided manufacturing DEFinition language) and simulates them to understand the AS-IS environment.

Users then reengineer the processes using breakthrough enablers, such as the RASSP model-year architecture, enterprise infrastructure, distributed control business practices, innovative organizational strategies, etc. Users then simulate the reengineered "TO-BE" processes *what-if* analysis and determine the benefits of the new processes.

The process models developed on RASSP are focused on signal processor development, and they address systems definition, architecture design, and detailed hardware and software design. These models include over 350 individual activity definitions. An example process model for "module design" is shown in Figure 5. [4]

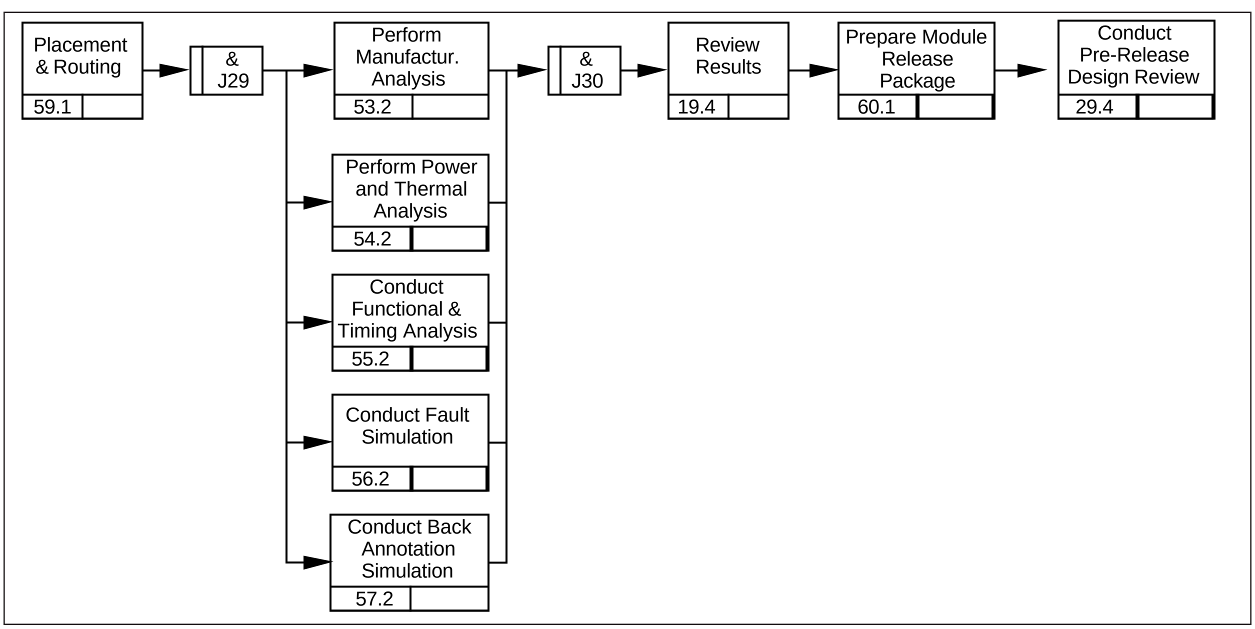

Fig. 5. *Module design process model.*

To implement the "TO-BE" models, users map them to workflow models in the workflow management tool. Execution-specific information, such as CAD tool control scripts, precedence control codes, environment variable setups, etc. is added to these workflows to enable their enactment. Users then store the workflow models in an enterprise repository for configuration management.

To support the process-model-to-workflow-mapping, the ATL team prototyped and demonstrated a Process Modeling Language (PML) and supporting toolset for analysis and mappings. This toolset provides a language representation of the processes for more direct mapping to the form needed by the workflow tools. A PML example is provided in Figure 6. The PML description of a process model consists of a PML model file and a PML glossary. The model file defines the connectivity information about the process model: the activities, junctions, and inputs, outputs, controls, and mechanisms (ICOMs). The glossary contains text definitions of all activities and ICOMs. The ATL team plans to further develop PML and its associated toolsets, and to leverage related process ontology efforts, such as the Marvel [5] environment developed at Columbia University, to provide a more complete process interpretability package.

In addition to identifying the activities and precedence relationships, the IDEF3 models also include logical identifiers on the ICOMs. which enable users to manage the product data relevant to the process. The logical identifier for the information objects in the workflow is ultimately implemented as a "business item" in the product data management system. The logical identifier or business item name represents the place holder for instances of objects that will flow through the workflow. For product data and reusable element information objects that are managed in the system, RASSP information models represented in EXPRESS and EXPRESS-G [5, 6, 7] (graphical form) describe the file configuration metadata about the product and domain-specific metadata class hierarchies. [2] The information model includes configuration management constructs derived from the STEP [8] models, constructs specific to PDM system implementations, and manufacturing-interface-specific constructs. To develop the RASSP information model, the team analyzed several standard models relative to RASSP-specific requirements: the Product Data Control Model developed by Rockwell on the USAF Integrated Data Strategy program, the STEP parts and protocols AP203, and Part 44. [9, 10,

```
DIAGRAM    "2.2.3.2 Perform Wirewrap"
    ACTIVITY  2.2.3.2.2  "Generate Wirewrap Backplane Manufacturing Tools"
    INPUT
        Generated*Wirewrap Connection List
    END
    CONTROL
    END
    MECHANISM
        Released*WISDOM
        Qualified*Backplane Design Engineer
    END
    OUTPUT
        Generated*Hand Wire Report
        Generated*Wirewrap Tooling File
        Generated*Wirewrap Test File
    END
END
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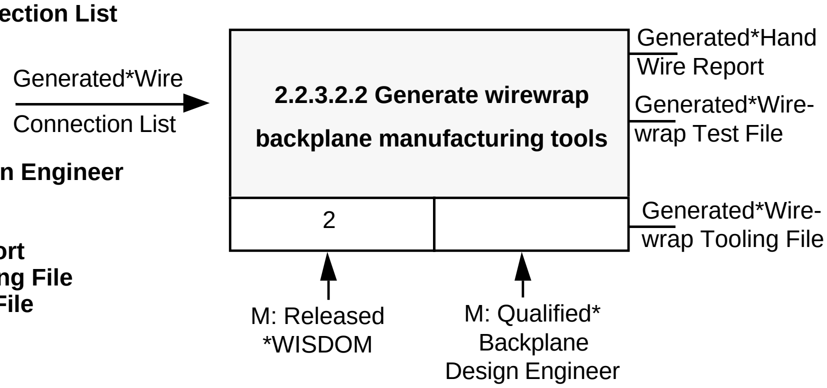

Fig. 6. *Process modeling language example.*

11]. Users store the information model entities in the repository for configuration management. In the enterprise system, the information models are implemented in both the product data manager and the reuse data manager.

4.2 Process Implementation as Workflows

Users execute the implemented workflows using enterprise workflow management tools, which link to tools, data-access mechanisms, and other services. This approach removes these functions as required responsibilities for the design engineer, which enables them to significantly improve productivity because they are focused on design tasks. Project engineers or supervisors typically design and implement project plans based on workflows using the system.

The information expressed in an executable workflow includes:
- Process steps
- The precedence relationships between the process steps
- The personnel roles authorized/required to perform work
- The information objects involved (created, used, modified, destroyed, etc.) in the process step
- The tools to be launched or controlled at each step.

The RASSP workflows are hierarchical; they represent the various disciplines associated with electronic design. The workflows consist of reusable workflow segments that users can combine in various configurations to address specific project needs. These segments consist of multiple process steps, each of which are also reusable. Users can either use the RASSP workflows in current form or develop process plans based on reusing RASSP workflow segments, individual process steps, and possible custom user steps.

The workflow manager tool in the ATL RASSP system is Intergraph's Design Methodology Manager (DMM), which graphically represents the workflows of a project, and enforces the execution sequence and tracks the status of the workflows. Each activity in a workflow can be associated with multiple tools. Figure 7 shows a DMM representation of a RASSP workflow, with the hierarchy visible in different windows. Users start an activity by clicking on the box representing the activity in a workflow; when they exit, the activity informs DMM of the activity status. DMM decides whether an activity may be launched or not, based on the status of the activities that precede it in the workflow. DMM also provides pre-condition and post-condition scripts of the activities in a workflow. Examples of these activities include functions such as checking for the existence of data objects, or translating data objects to the appropriate formats.

The ATL RASSP team developed multiple extensions to the DMM tool:
- Multi-level access control for task execution based on job classification
- Hierarchical workflow modeling capability
- Status tracking and project history
- Interfaces to project management tools
- Integration with the enterprise product data manager for check out/in of business items on task start and completion.

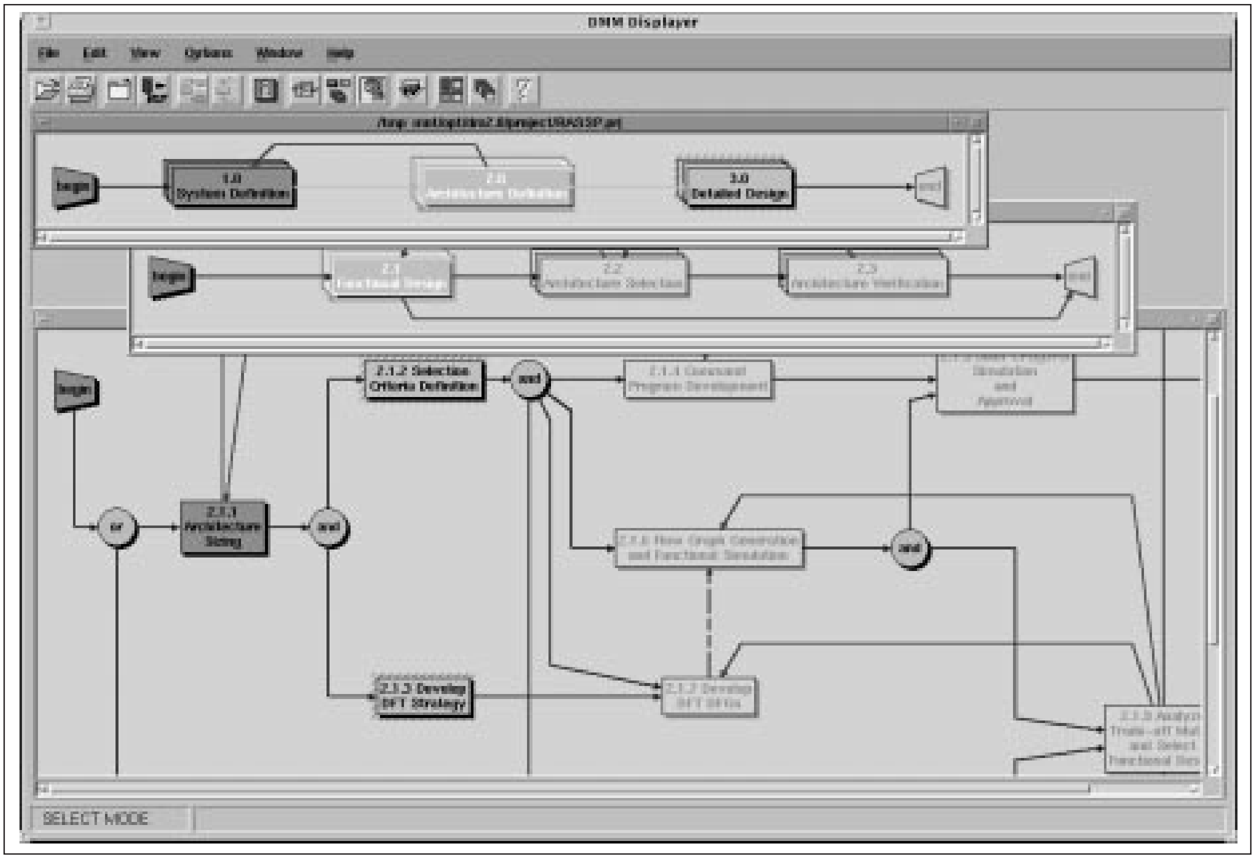

Fig. 7. *Workflow implementation in DMM.*

The team is working on more enhancements to accommodate RASSP-specific, concurrent engineering workflows. These workflows support a high degree of process flexibility, which is needed for front-end signal processor design where users need to develop many alternative design approaches in parallel to achieve an optimal approach. Examples of these special case concurrent workflows include:

- Multiple concurrent tasks using parallel copies of data sets
- Multiple design alternatives developed concurrently
- Pipeline of data sets through a workflow
- Failback paths
- Multiple iterations in a workflow.

The business items used in workflows represent collections of information that are managed in the enterprise system and assembled under a logical identifier (business item name). Business items are managed by the enterprise data management system during project execution. Business items are either copied out or checked out of the data management system on user execution of particular workflow steps, and returned (updated) to the data management system on completion of the steps. The specific approaches to handle the business items on task start and task completion are included with the definition of each step. In the simplest case, a business item is checked out at the start of a task, and returned on completion of the task.

Since each workflow segment identifies a set of business items which are relevant to the workflow segment, when a user selects a group of workflow segments to build a project plan, the business items defined with the segments are associated with the project plan. The workflow segments are then instantiated for the particular application task on the project. In instantiating the workflow segment, both the tasks and business items are instantiated for each specific case of the workflow.

The workflow manager also helps capture useful metrics for projects. The metrics currently being collected on the RASSP program include:
- Time spent in a step
- Number of iterations through a path/step
- Tool usage
- Person(s) performing the step
- Notes per process step.

4.3 Information Management
Enterprise information is a key corporate asset and requires a well planned management strategy. The ATL RASSP team developed an information model for enterprise data that specifies the metadata the design engineers and project/system administrators need to track the product and reuse information in the system. The team analyzed several standard models to develop this information model. The RASSP enterprise system enables users to manage product information and reuse information, and it uses separate but related strategies for each.

4.3.1 Product Information Management (PIM)
The RASSP product information management system supplies the correct data set for each process step. This function is transparently performed by the product information management system in conjunction with the workflow manager. The data manager also enables users to access data independent of the process step or workflow. Users have access to the data manager interface to perform any functions necessary to get the job done.

The PIM provides the ability for project teams to define users and their access authorizations, workspaces, configuration management rules and functions, business items that flow through the processes and their corresponding data items, and the ability to manage all the information related to a project as a data set.

The PIM addresses configuration management with a hierarchy of workspaces implemented in the data management system, coupled with a flexible data object versioning scheme. This capability provides a solid baseline approach that users can easily customize for specific projects or organizational needs. On project creation, the PIM defines shared workspaces for the project. The PIM creates the business items associated with the workflow segments comprising the project plan in the shared workspace; this provides a data template at the start of the project.

Workspaces are partitions of the design object space that allow designers working on the various parts of a project to selectively make their design objects visible to others in the project [12]. In the RASSP configuration management model, three types of workspaces exist: private, shared, and global. Workspaces are organized hierarchically, as shown in Figure 8. Each node in the hierarchy represents a workspace. Branches in the hierarchy represent a parent-child relationship between workspaces. The *global workspace* is at the root of the hierarchy. *Shared workspaces* are the intermediate nodes in the hierarchy. *Private workspaces* are the leaves in the hierarchy. [2]

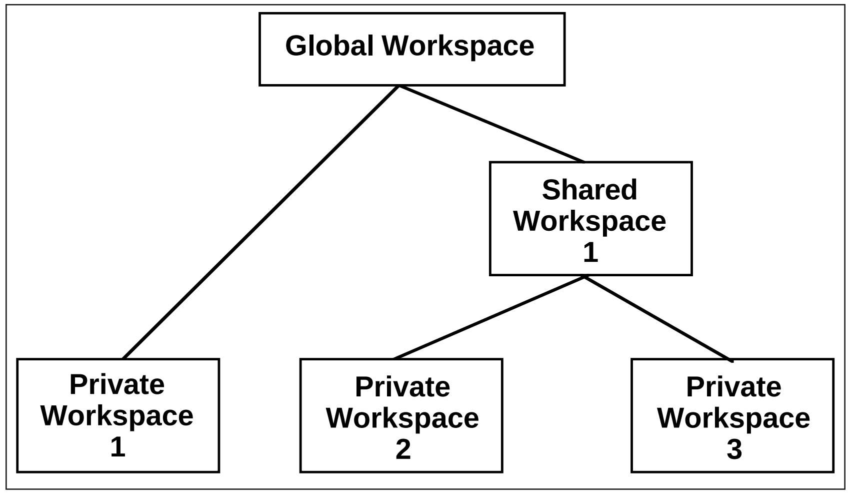

Fig. 8. *Workspace hierarchy.*

Users implement this workspace hierarchy in DM2.0 using the features of *users* and *vaults,* which is a logical collection of shared objects. Relationships between workspaces may be enforced for a project team by defining *groups,* which contain related users, and limiting the access of these groups through the use of *rules.* The rules specify the privileges for each class of user to access shared locations or perform operations.

In DM2.0, each user has a private workspace. That is, there is a one-to-one mapping between a user and a private workspace. Rules are used by the PIM to enforce the privacy of individual workspaces. Users implement shared workspaces through the vaults. Rules are used to control access to a vault. The global workspace consists of selected data from all shared workspaces (vaults), obtained through the DM2.0 *query* capability.

The ATL RASSP configuration management model uses a data object versioning scheme where related data objects that evolve simultaneously are grouped as a *configuration,* as shown in Figure 9. At any point in its life cycle, a configuration can exist in one of three states: *transient, working,* or *released.* Upon creation, a configuration is transient and is associated with a private workspace. Users can update a transient version of a configuration or delete it. Users can promote a transient version to a working version when the configuration reaches a level of maturity where it can be shared with other users. Working versions reside in shared workspaces. At this state, users cannot update the configuration, but they can delete it. Note: Users can update a working version by creating a new working version of the configuration with an updated sequence number. A configuration is in the released state when users promote a working version of that configuration to the global workspace. Users cannot update or delete released configurations.

Users can create a transient version of a configuration from a previous version regardless of its state. The source configuration remains unchanged if it is a working or released version. Creating a transient version from an already existing transient configuration causes the source configuration to be promoted to the working version level. Users can delete a configuration if it is at the transient or working version level and is at the lowest level in a workspace hierarchy.

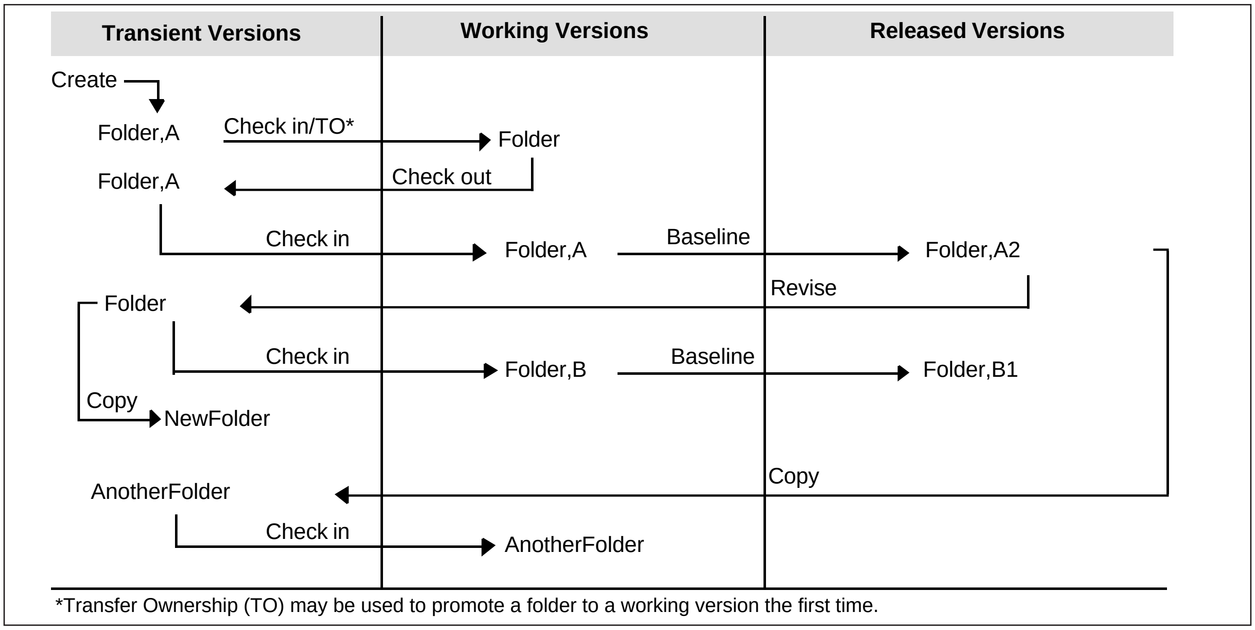

Fig. 9. *DM 2.0 implementation of data items states.*

Users implement the RASSP scheme for version control in the product data management system by using the concept of a *folder.* A folder enables users to group a set of objects for a specific purpose. The objects may be of different classes and may be added or removed as required. A folder is transient if it is created by a user. At this point, users can update or delete the folder may be. When users transfer ownership of a folder from an individual user to a vault, they promote the folder to a working version. Users can check out, baseline or delete a working version of a folder. A released version of a folder will result from *baselining* a working version. Users cannot update or delete a released folder. *Revising* a folder generates a new copy of the folder that users can manipulate. The global workspace consists of all baselined objects (including folders) and users can access it by a predefined query. All users can exercise this query.

4.3.2 Reuse Data Management

Reusing design and product information is one of the key enabling strategies to improve productivity by a factor of four. Reuse implementation is also key to reducing time-to-market and life-cycle cost, while improving quality and manufacturability. To achieve this objective, users need processes and a supporting infrastructure to address both design for reuse, and design with reuse.

To support the RASSP approach to reuse implementation, ATL developed a library management model that defines initial processes and a comprehensive management approach to integrate the relevant sources of reusable design objects. The model provides a single-source capability to search and for enterprise-wide sharing of reuse data. [2] Users searching for a particular reuse element can either traverse the classification hierarchy and/or specify particular parameters and characteristics that constrain the search. The user interface displays various options for users to specify additional parameters based on the relevant point in the search. Users can also query multiple destination reuse managers either with a single request or with multiple related queries.

The ATL RASSP team developed a Reuse Design Object Class Hierarchy (RDOCH) as a basis for organizing the reusable design data. Developing the RDOCH involved identifying and using existing standards for data organization where they exist (e.g., IEC 1360-1 for electrical component information), augmenting these standards, and creating new classification schemes where no standards exist. [13] The overarching goal for the reuse management implementation is to develop a classification scheme that characterizes all classes of reusable design data for the RASSP domain, and can be implemented in the library management system to provide a single source for searching for reuse information, and that is intuitive from a user perspective. This scheme must:

- Be general enough so that users can adapt it to fit most corporate environments
- Provide complete, consistent, and correct classification of design data, normalized across tools and data suppliers
- Be rigorously defined and reviewed by a large enough audience so that it can become the basis for an industry standard.

The methodology ATL adopted to develop the RDOCH includes rigorous definition of preliminary and final classification trees and complete data dictionaries for each class, with review by the ATL RASSP team, appropriate RASSP team members, and external organizations at various phases of the development process. The highest level of the classification hierarchy in the current RASSP implementation is shown in Figure 10.

The RDOCH represents the metadata used by the RASSP Reuse Data Manager (RRDM). The design for reuse processes have users design to specific quality and documentation standards for candidate reuse elements, cataloging the elements according to the specification in the reuse classification hierarchy, then releasing them for incorporation in the reuse system. The methodology to maintain or extend the reuse classification hierarchy is included in the design for reuse processes.

The RRDM stores the complete classification hierarchy, including metadata describing all reusable design objects available in the RASSP environment. In the design with reuse processes, designers locate reusable design objects by querying the metadata; they may view a particular design object using a standard viewer or a viewer specific to the tool that created it. If relevant, users can import the selected objects into the design environment or use them in the design. Reusable design objects are stored in native design tool formats or in standard interchange formats where possible. Sources for reusable design objects in the RASSP environment include:

- Native CAD tool libraries
- Standalone, tool-independent libraries
- Vendor product information
- Specifications and standards
- Design objects created within a design organization.

Users can store physical design objects within the tool environment, in the RRDM design data repository, or in a file system within the virtual enterprise network, while the metadata describing the reusable design data is stored within the RRDM descriptive data repository.

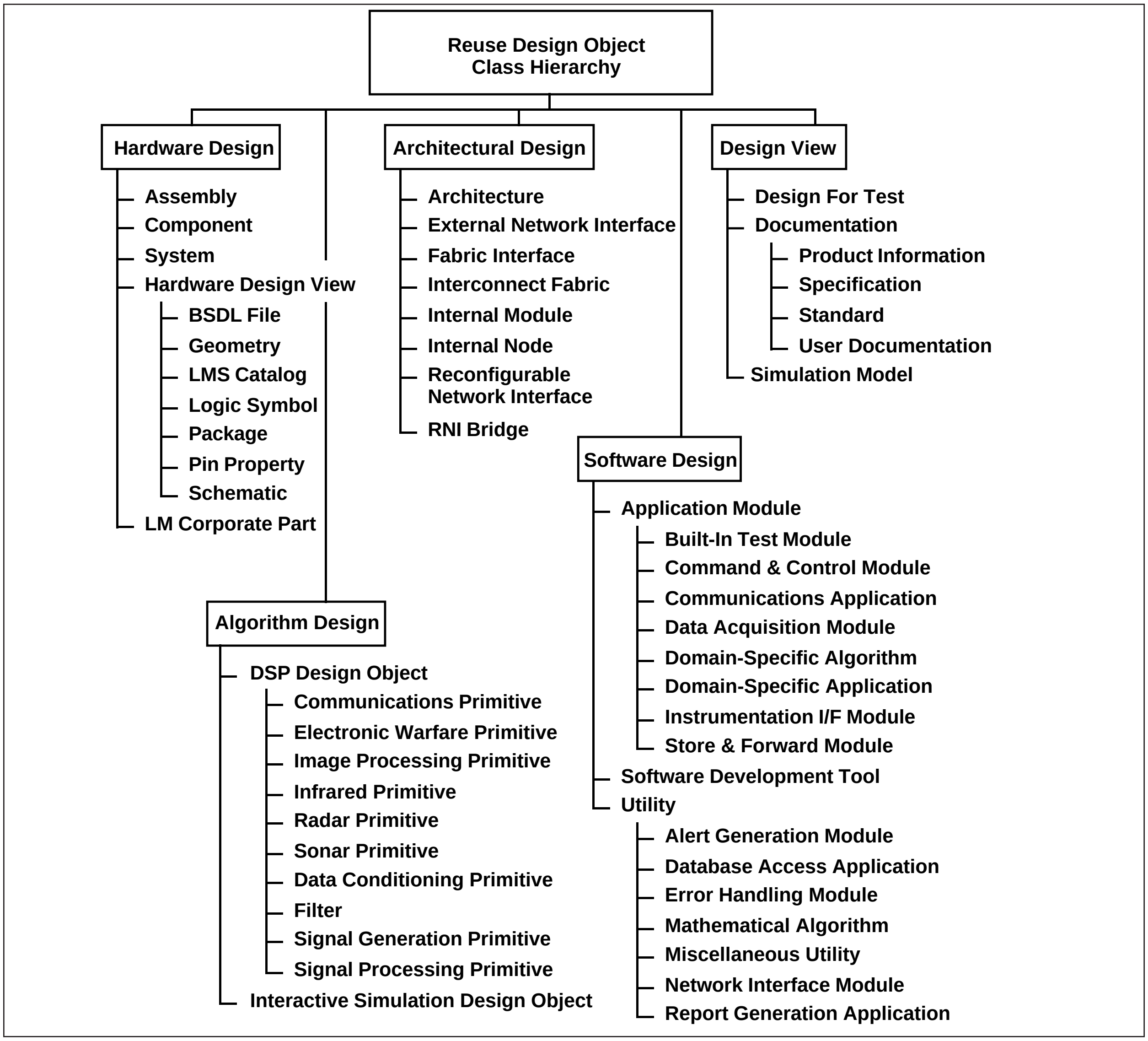

Fig. 10. *The Reuse design object class hierarchy (preliminary).*

The ATL team implemented a prototype of the RRDM with the Aspect *Explore* Component Information System. *Explore,* a RASSP-supported development over the past two years, includes object-oriented enhancements to the original Aspect Component Information System (CIS) product to create class browser, metadata viewing, metadata editing, and data model modification capabilities. This system is being used by a Lockheed Martin design team, implementing a Navy signal processor upgrade, for process improvement benchmarking.

4.4 Manufacturing Interface

To rapidly prototype application-specific signal processors, a standards-based, information-sharing infrastructure is needed. The information-sharing standards must enable users to exchange design information and design intent; this exchange enables users to effectively and efficiently transform prototype information into information for production.

A critical component of the enterprise system for supporting this information exchange is the standards-based manufacturing interface [14] being developed by SCRA (Figure 11). The objective of the manufacturing interface is to enable first-pass producibility success by providing seamless integration of design and manufacturing and an Integrated Product/Process Development (IPPD) environment. By providing an IPPD capability, the manufacturing interface allows rapidly prototyped designs to be rapidly produced. The standards-based manufacturing interface supports virtual partnering between design and manufacturing organizations. The RASSP manufacturing interface effort is effectively using existing projects, such as the industry-funded PDES, Inc. Electrical project, the ATP-funded PreAmp program, the TRP-funded CommerceNet program, the DARPA-funded TIGER effort, and the Navy-funded RAMP effort. Leveraging this existing work wherever possible is enabling SCRA to develop a highly flexible, cost-effective solution to the manufacturing interface problems of inefficiency, high cost, and incomplete information exchange.

At the heart of the manufacturing interface is a novel concurrent engineering capability to enable users to effectively design for producibility by creating an IPPD environment. This concurrent engineering environment is distinguished from other concurrent engineering environments in two respects. First, it uses the STEP methodology to create the information-sharing

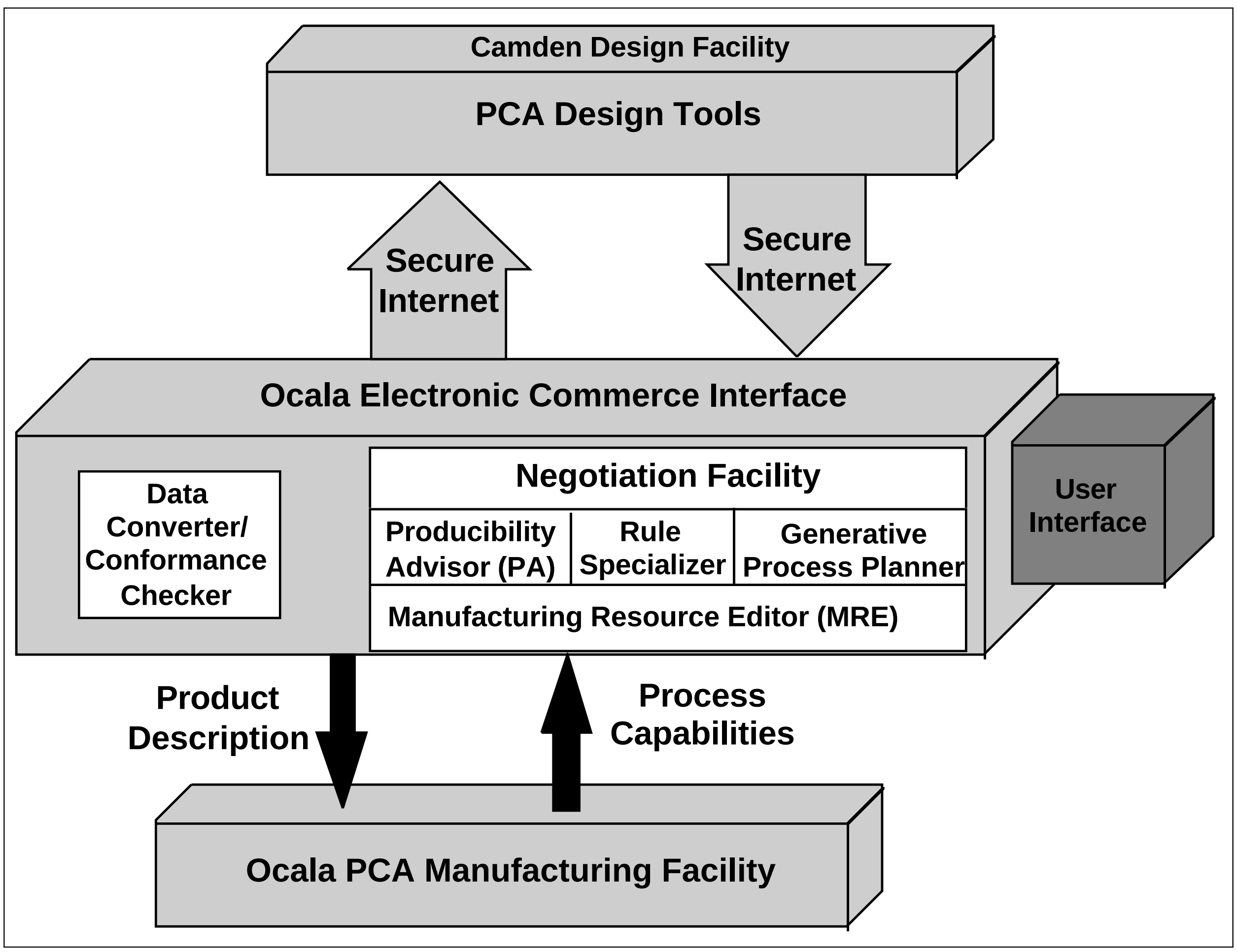

Fig. 11. *RASSP manufacturing interface architecture.*

infrastructure necessary for IPPD. Second, it provides a unique, knowledge-centered approach to concurrent engineering. The ATL RASSP team accomplished this by integrating an inference engine into the STEP-based information-sharing environment. The result is an automated concurrent engineering capability that enables engineers from different disciplines to capture their experience in an executable form to detect potential producibility issues early in the product development process.

The team installed the initial implementation of the manufacturing interface in the Lockheed Martin Ocala PCA manufacturing facility. This implementation includes producibility analysis capabilities for concurrent engineering support, and functions to automatically generate the information to drive the Ocala manufacturing equipment from a Mentor Board Station design database. The information exchange is accomplished by first converting the Mentor data into a STEP-standard form known as Application Protocol (AP) 210 using the RASSP Mentor-to-AP210 Data Converter [15]. This standard representation of the design data then drives all down-stream tools. The outputs of these tools drive Ocala's production equipment.

Ocala used this enhanced capability to significantly reduce from days or weeks to hours, their setup time for new designs on several missile production programs. Ocala processed more than 15 PCAs with the RASSP manufacturing interface. The required manufacturing data was produced in less than an hour with the RASSP manufacturing interface versus two weeks using typical methods. Comparisons with other manufacturing facilities indicate that the time from design to manufacturing setup can be consistently reduced by more than 10X over current methods. In 1995, the Navy Best Practice survey team identified the RASSP manufacturing interface as a best practice as a result of the dramatic productivity improvements demonstrated to date. [12]

4.5 Communications Services

The ATL RASSP team formulated the communications services' requirements by identifying specific capabilities the services would provide in support of the overall enterprise functions. The team plans to use public networks as the primary interconnection medium to support agility in partnerships and virtual corporations. The high-level objectives the team identified for this effort include:

- Secure data exchange and toolset access
- Low-cost implementation using available network infrastructure products
- Collaboration tools to make it easier for physically distributed team members
- Recognition of possible application of emerging technologies.

A model of communications services is shown in Figure 12.

To support secure data exchange with the RASSP enterprise system, inter-site communication uses secure channels that support text, graphics, and data file transfers. To achieve low cost and high flexibility, the enterprise relies on prerequisite Internet-based communications services, as opposed to establishing a Value-Added Network (VAN). The ubiquitous nature of the Internet suggested its use as the communications services backbone. A focus application of communications services on the RASSP program is associated with the manufacturing interface functions, since design generation and manufacturing are most often performed at physically separated geographic locations.

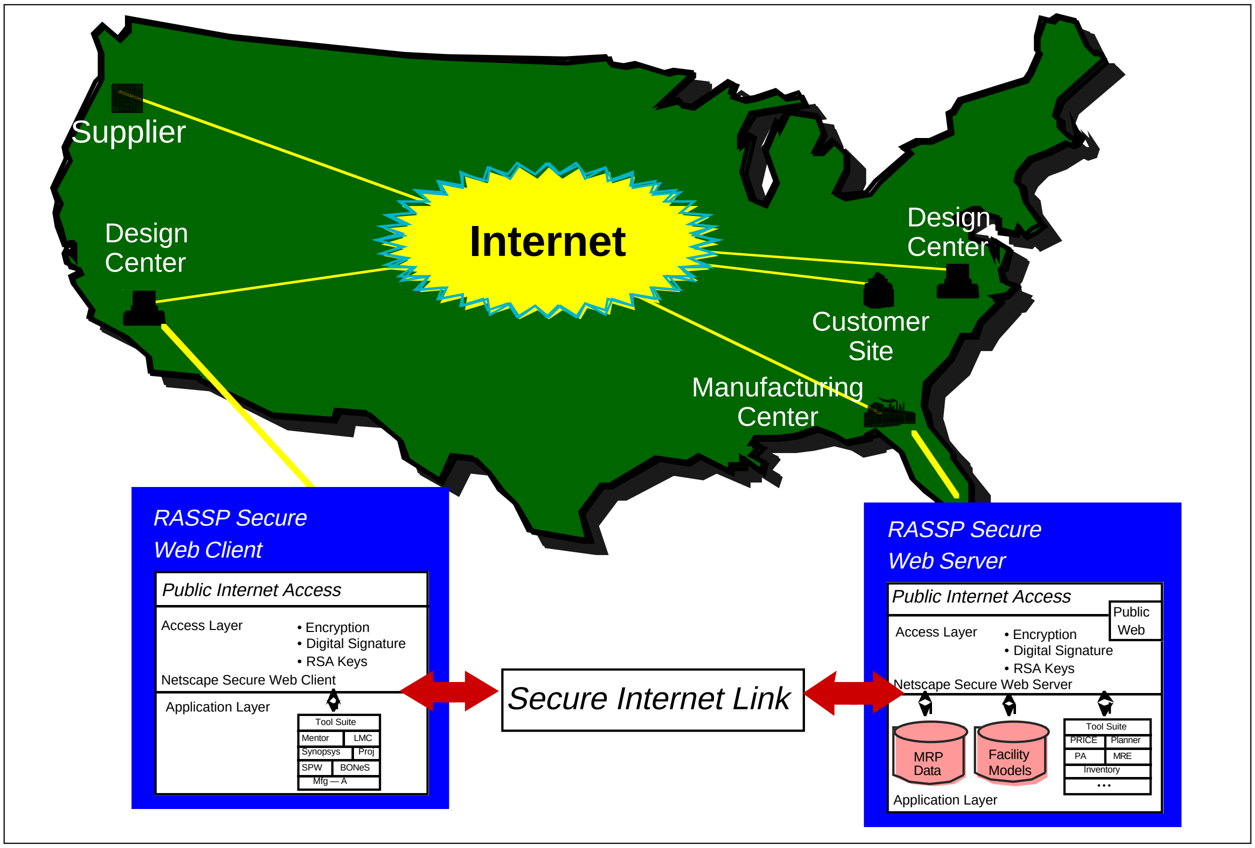

Fig. 12. *Communication services model.*

Two candidate secure Web technologies are available that are suitable for staging on RASSP: the Secure Sockets Layer (SSL) and Secure Hypertext Transfer (SHTTP) protocols. The team adopted the SSL approach due to the cross-platform availability of Netscape's SSL-compliant browser, although SHTTP is considered more robust as a security mechanism. Netscape's SSL Commerce Servers are installed at two Lockheed Martin locations: ATL in Camden, NJ, and the Ocala, FL manufacturing facility. The ATL site is used primarily for staging, prototyping, and document access; the Ocala site is used to implement the real-world, on-line Web manufacturing interface developed by SCRA. The secure servers allow users to establish secure, encrypted, authenticated communications links between client and server machines using the Internet as the base communication layer.

In this approach, the secure client/server tools provide secure, encrypted sessions. Each client/server session uses the same encryption key pair along with a unique, randomly-generated session key that is used only once. These sessions, however, are transparent to users and are simply the result of users identifying the uniform resource locator (URL) of the secure server. Any SSL-enabled client can access the server. To ensure that only authorized accesses are allowed, existing HyperText Markup Language (HTML) capabilities require clients to authenticate themselves through a username/password scheme. Since the client and the server session communications are encrypted, the usernames and passwords cannot be snooped. It is important to note that a username/password database must be established and used with secure communications for the links to be effective and confidential.

Unfortunately, toolset access is a more difficult technical problem to solve. The existing security features are Web-based; the RASSP CAD tools used are predominantly Unix and X-Window-based. Although it is possible to use X clients and servers with the Internet backbone, they do not meet the secure data exchange requirement. The team is investigating other mechanisms that allow X applications to work securely over the Internet. Another approach being investigated for tool access is Web middleware functions that don't use X Windows. Common Gateway Interface (CGI) Web-based scripts for example, generate real-time images which can, in turn, be transferred securely from servers to clients.

In addition to supporting data transfer and tool access functions, the team is using the Internet to support collaboration between design engineers, manufacturers, suppliers, and other life-cycle development team members. Collaboration functions include real-time audio, video, and shared whiteboard applications. These functions can significantly impact cost and schedule because participants can interact efficiently and iteratively by sharing design and product details. When these functions are coupled with the secure access and encryption mechanisms, communication privacy can be achieved with these tools. Collaboration tools in the RASSP enterprise system include Communique and Multimedia Engineering Collaborative Environment (MECE). Communique provides shared whiteboard, audio, and video conferencing capabilities, while MECE provides design teams with an electronic engineering notebook capability. Once users establish a database of engineering notebook components, these can be accessed and shared using Web browsers.

In addition to the middleware functions and collaboration tools, the newly emerging Java technology being developed by Sun Microsystems shows particular promise for applicability to the RASSP enterprise system. This technology involves partitioning more functions of the client-server model to the client. Since many of RASSP tools follow the client-server paradigm, the application is fertile for the use of this technology.

5.0 Status

The RASSP enterprise system provides significant capability for enabling large productivity gains for signal processing teams — from 1.2-2X or up to 4X in conjunction with other RASSP tools and processes. The development plan for the RASSP enterprise system includes four prototype build cycles. The team demonstrated the initial prototype system in February 1995; it focused on support for electronic hardware design. The team completed an enhanced implementation specifically focused on the requirements of a signal processor upgrade program for the Navy UYS-2 system in December 1995. This system supported signal processor architecture development tasks, and the detailed hardware and software development phases. The program plan for the UYS-2 upgrade uses the following RASSP workflow segments:
- Functional design
- Architecture selection
- Architecture verification
- ASIC (FPGA) design
- Module preliminary design
- Module final design
- Hierarchical simulation.

The team demonstrated the Build 2 RASSP system in 2Q96. The system supported all design phases, and it enabled users to rapidly generate new workflows and implement program plans using workflow segments with corresponding data management templates. The team installed the system at the Army Research Laboratories in Ft. Monmouth NJ, and the Army Night Vision Electronics Systems Division in Ft. Belvoir, VA for evaluation. Beta Site installations are planned for 3Q96.

6.0 Summary

Key benefits of the RASSP enterprise system include a practical approach to apply process technology in an engineering environment; capability for users to plan and manage complex products; improvements in reuse implementation through an integrated, distributed strategy; and 5-10X productivity improvements in the design/manufacturing interface through secure communication services.

Acknowledgements

This work was funded under the DARPA RASSP program (Contract Number DAAL01-93-C-3380). We are thankful to our customer team members R. Harr (DARPA), R. Reitmeyer (Army ARL), A. Bard (Army ARL), and L. Carmichael (Army ARL) for continued guidance and support.

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Road to 4X Model

	Process	MYA & Reuse	Enterprise System Env.	Tool Extensions	Tool Integrations
Systems					
Architecture Definition					
Detailed Design					
Fab/Test					
Redesign					
Integration & Test					

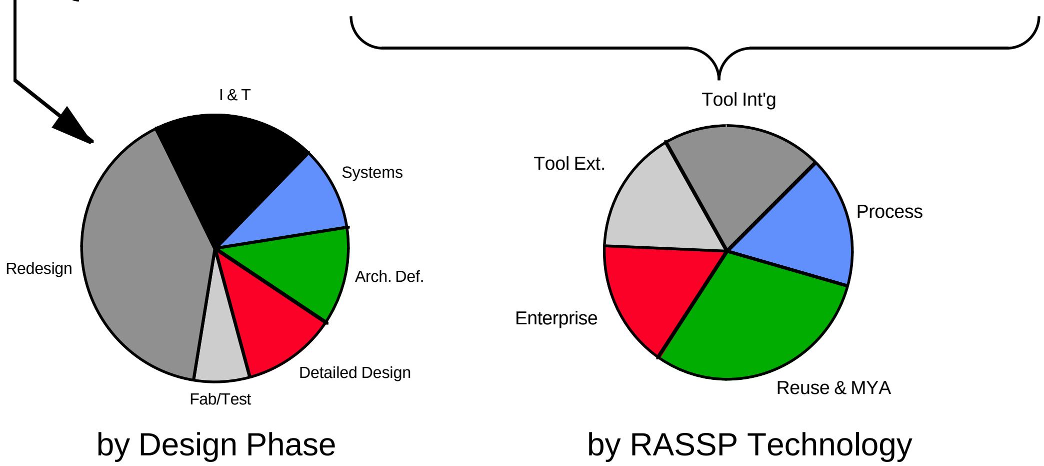


Fig. 1. *Two views of cycle-time reduction contributors.*

RASSP Objectives	Technologies for 4X	Enterprise System Contributions
Demonstrate a 4X reduction in concept to fielding time	Process Improvement Reuse/MYA/COTS Enterprise System Tool Ext. & Int'g	Key to cycle time improvement Enhances effectives of process, reuse, and tool technologies
Demonstrate a 4X improvement in quality, life cycle cost, and supportability	→	Integrated workflow/ Data management supports distributed IPTD, to improve quality and supportability
Establish a systematic, repeatable design capability from concept to manufacturing	→	Key to meeting this objective. Enabler for continuous process improvement workflow
Transition design process and tools infrastructure to wide spread use and commercialization	→	Commercialization strategy eases transition of processes and tools to external corporations

Fig. 2. *The enterprise system is key to satisfying RASSP objectives.*

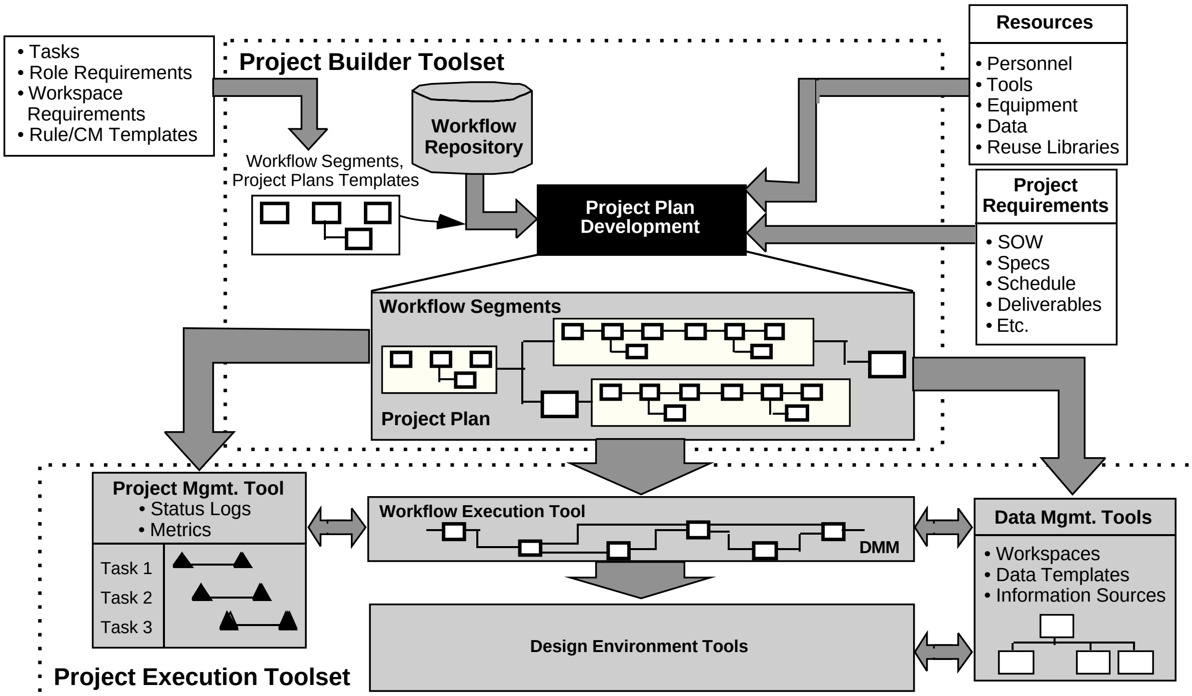


Fig. 3. *Project plan improvements with workflows.*

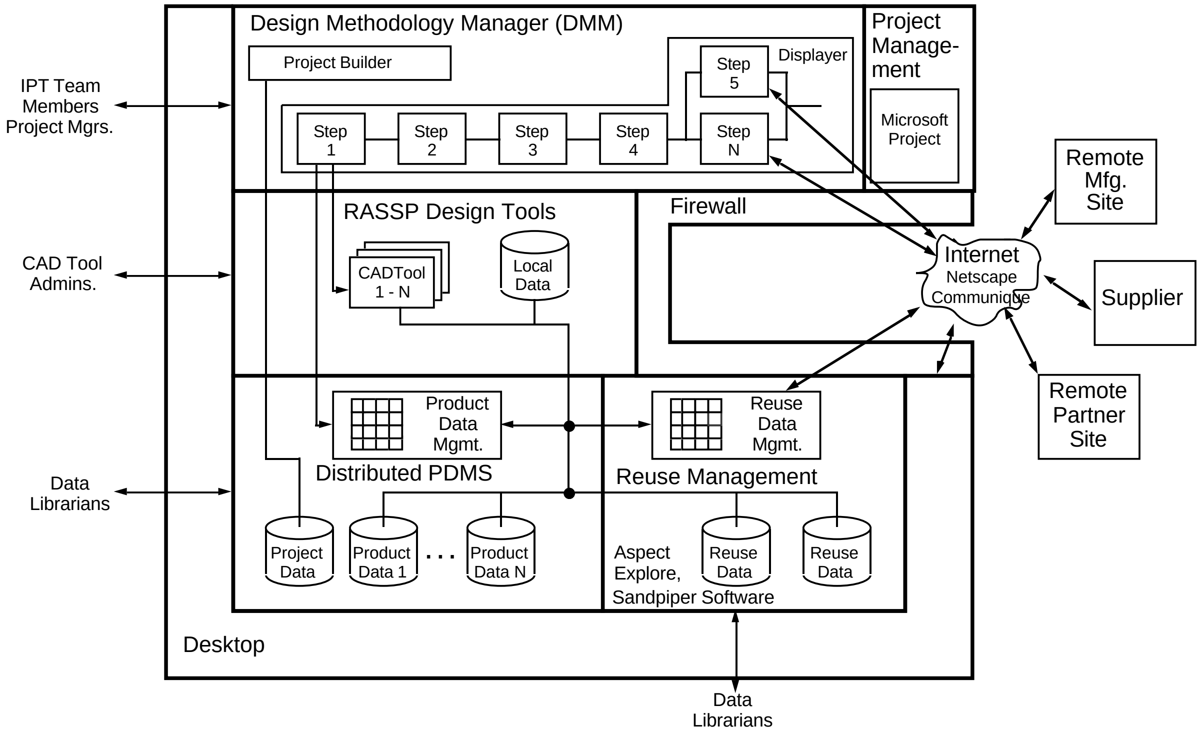


Fig. 4. *Enterprise system architecture.*

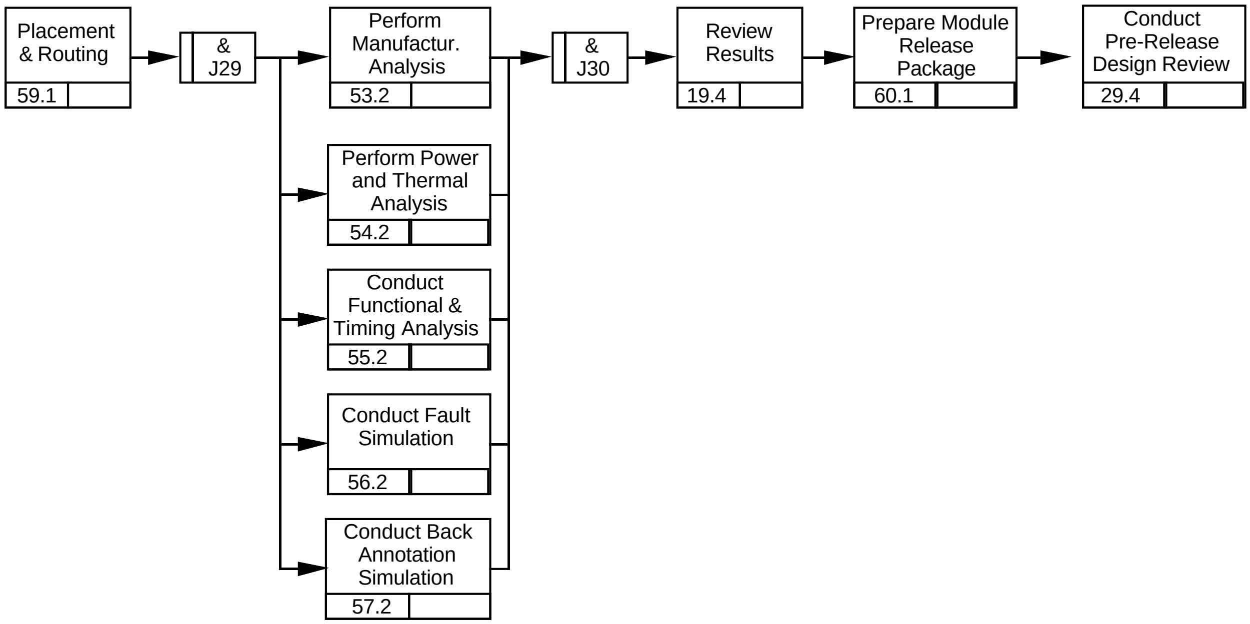


Fig. 5. *Module design process model.*

```
DIAGRAM    "2.2.3.2 Perform Wirewrap"
    ACTIVITY  2.2.3.2.2  “Generate Wirewrap Backplane Manufacturing Tools”
    INPUT
        Generated*Wirewrap Connection List
    END
    CONTROL
    END
    MECHANISM
        Released*WISDOM
        Qualified*Backplane Design Engineer
    END
    OUTPUT
        Generated*Hand Wire Report
        Generated*Wirewrap Tooling File
        Generated*Wirewrap Test File
    END
    END
```

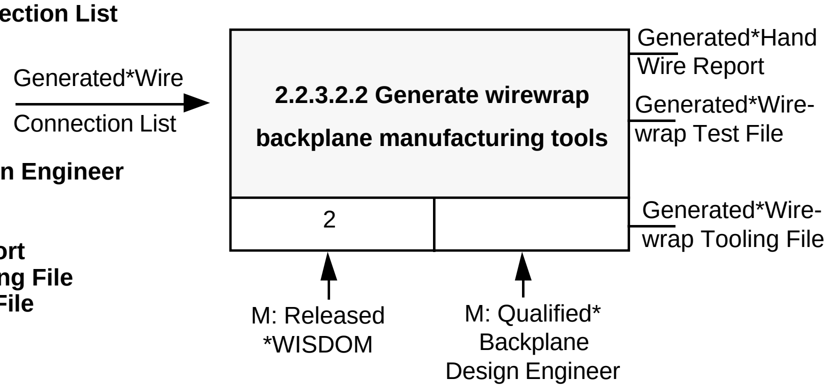


Fig. *6.* *Process modeling language example.*

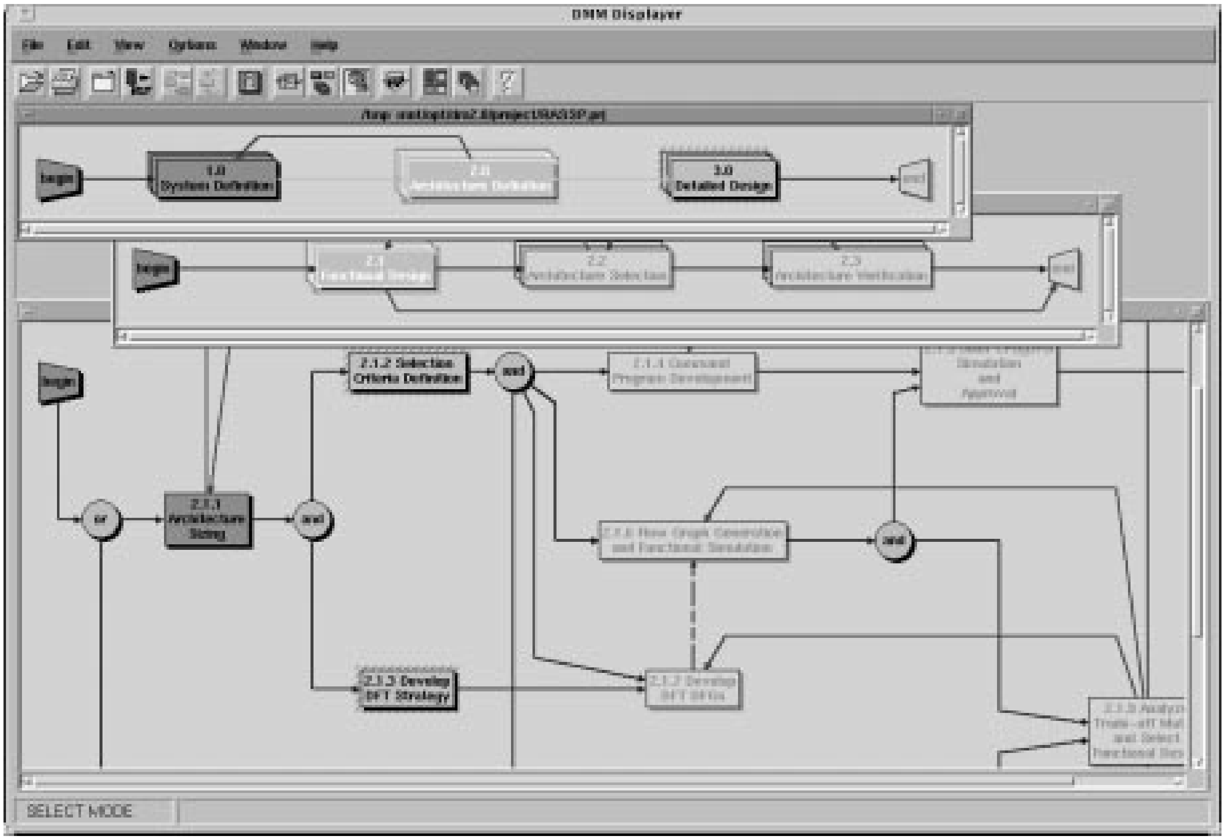


Fig. 7. *Workflow implementation in DMM.*

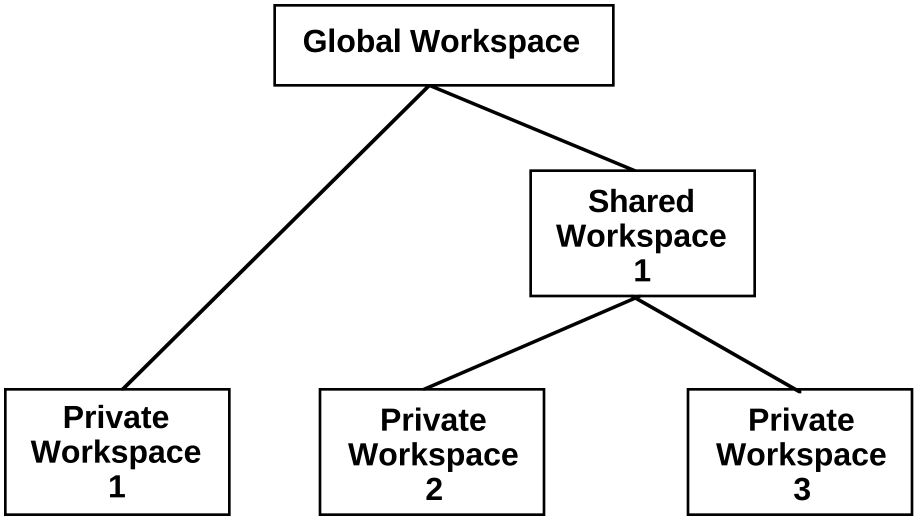


Fig. 8. *Workspace hierarchy.*

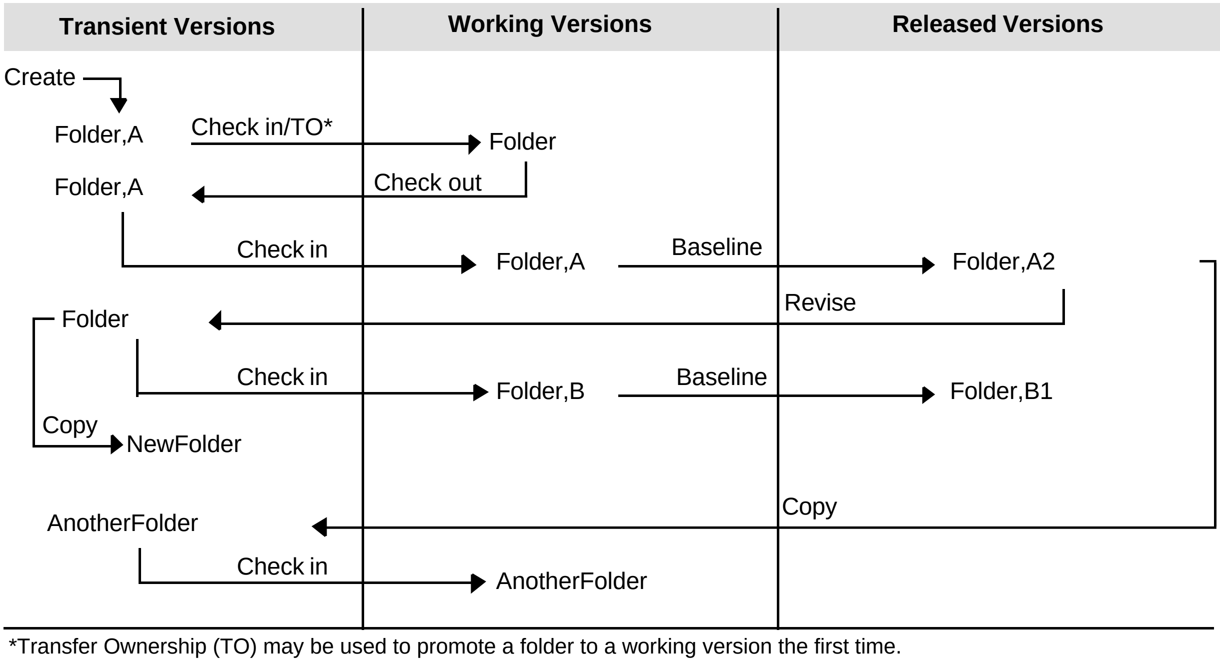


Fig. 9. *DM 2.0 implementation of data items states.*

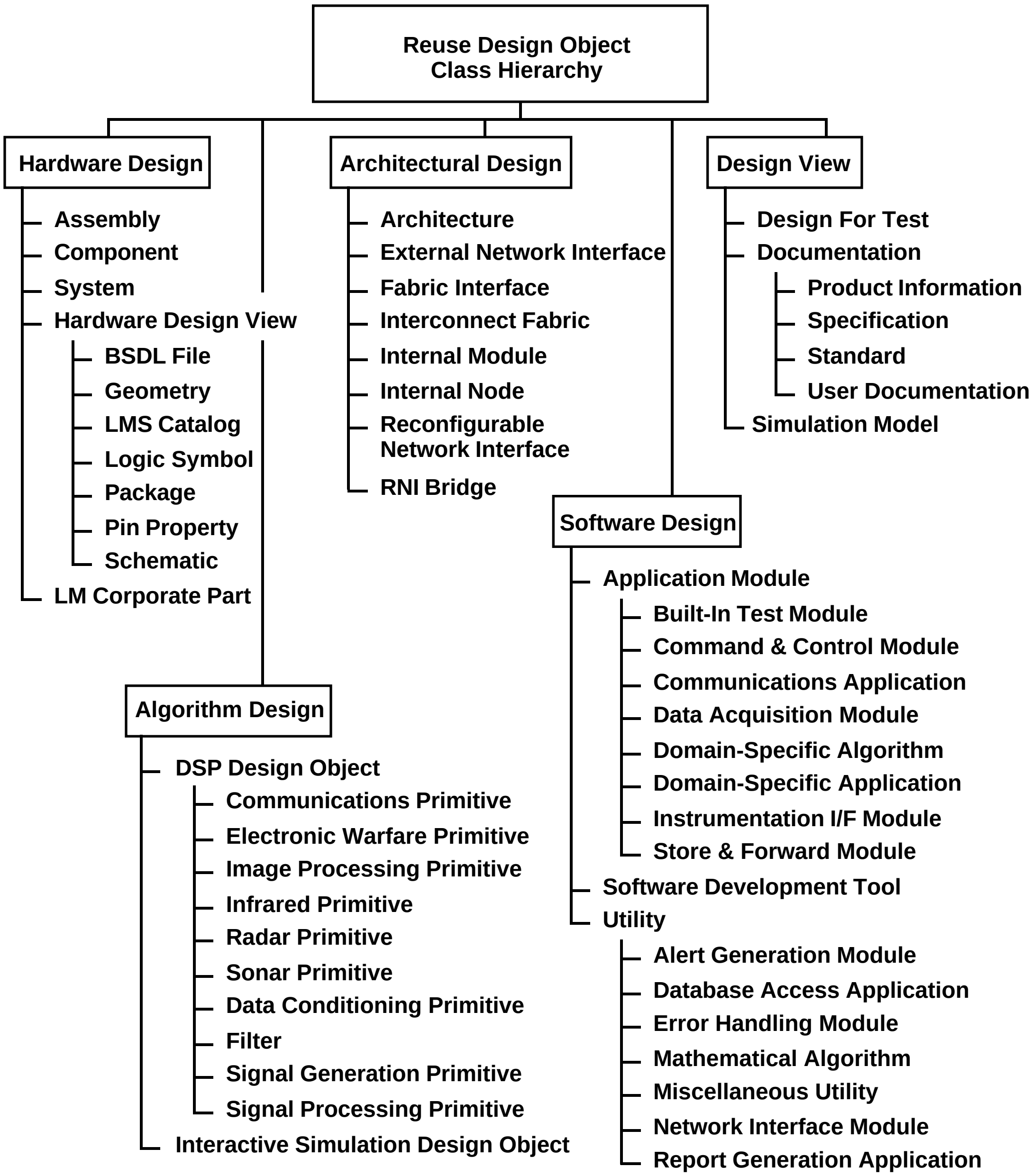


Fig. 10. *The Reuse design object class hierarchy (preliminary).*

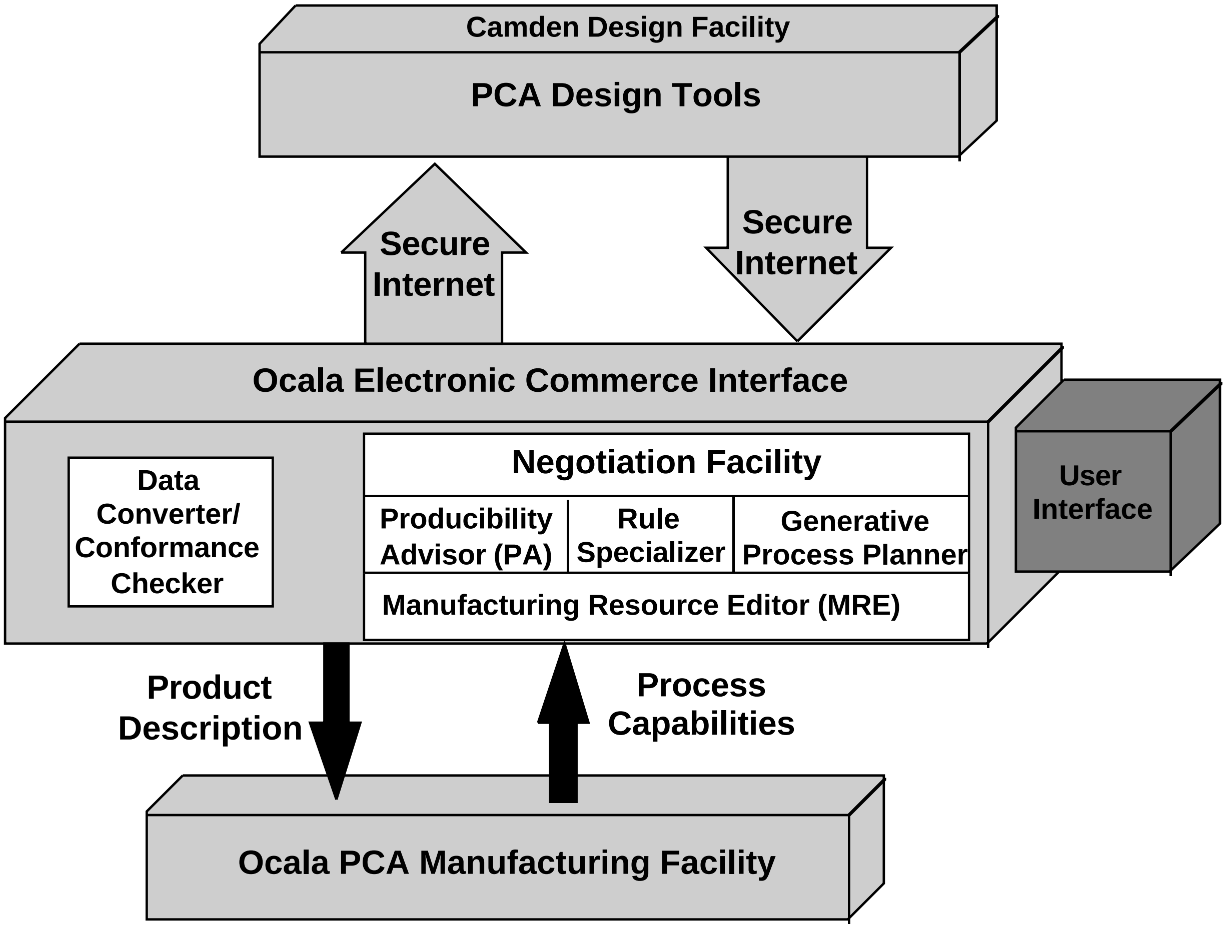
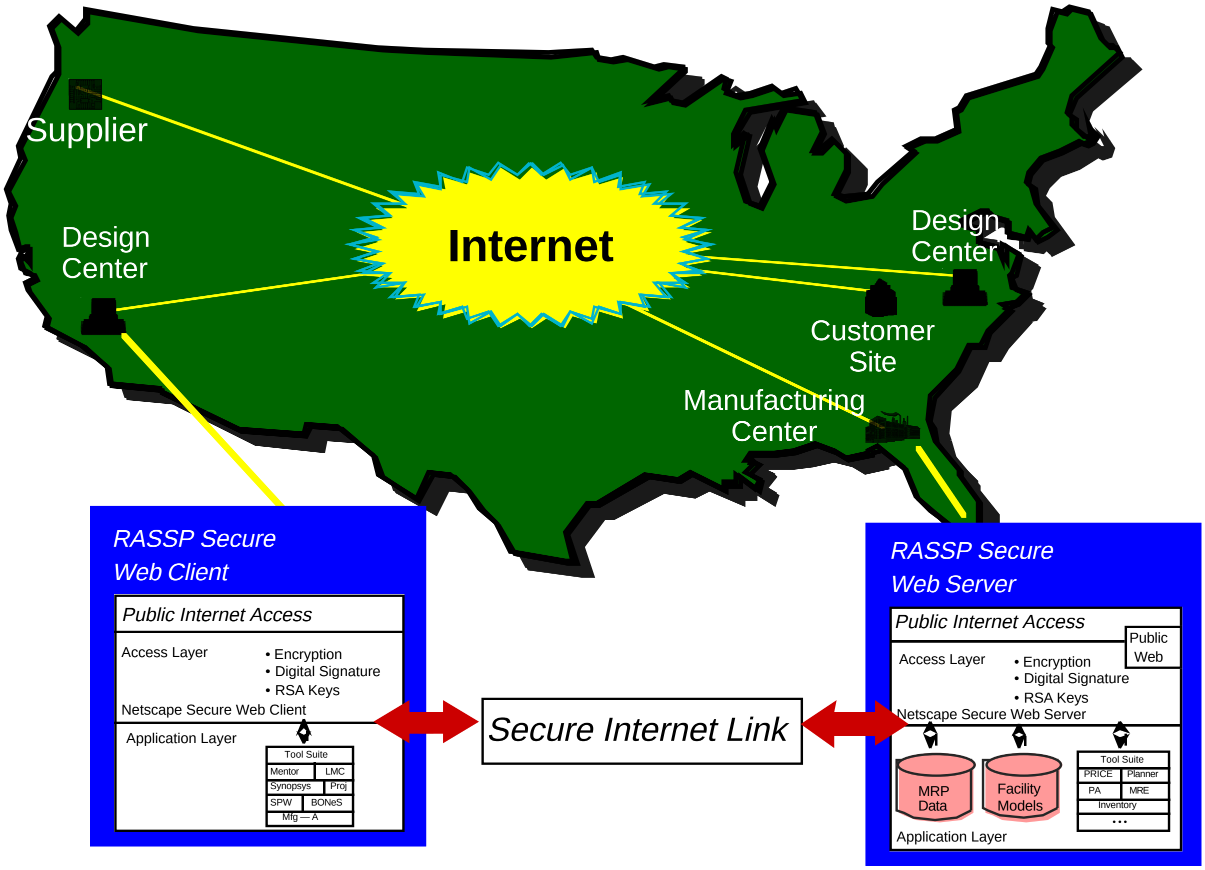


Fig. 11. *RASSP manufacturing interface architecture.*



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