NAVAL
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Applying Open Architecture Concepts to Mission and Ship Systems

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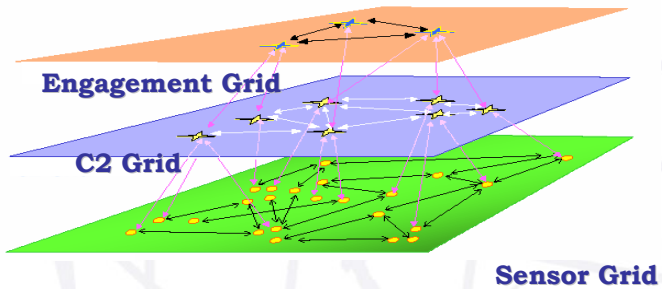
Introduction

- Purpose: *to introduce a simulation based methodology to facilitate development of a software product line architecture concept for the Navy's C5ISR systems.*

- Two key advantages to the proposed methodology:
  1. it provides a formal systems approach to the verification of the product line architecture requirements consistent with the Department of Defense Architecture Framework.
  2. it provides a medium for the iterative development of architectures that blend the operational concepts of FORCEnet with the system and technical imperatives of Open Architecture and Services-Oriented Architecture (SOA).



What I'm Going to Tell You

- Background
- Technical Approach
  - Key Concepts
  - Open Architecture
  - Domain Modeling
  - Formal Methods
  - H-P Method
  - Details of the Technical Approach
- Conclusion

Background

- The last 15 years (or thereabouts) has seen a number of interesting developments in the technologies that support C4ISR system development.
  - For example, the advent of CEC and GPS provided the impetus for the conceptual development of Network-Centric Warfare (NCW), Network-Centric Operations (NCO) and FORCEnet [Alberts, Garstka, and Stein 2000].
  - Yet, despite all that has been written about the concepts of FORCEnet and Open Architecture (OA), there has been little written on how these two concepts will come together in the naval C4ISR systems of the future.
- The main emphasis has been on technologies such as Internet Protocol version 6 (IPv6), not the architecture.
- ***As a result, there is no commonly shared or understood model of what this end state may look like.***

More Background

- There is a tendency to view the system architecture using existing paradigms that were used to develop the “stove-piped” systems that are now proving to be limited in their capability.
- This is a “paving the cow paths” approach and has made developing FORCEnet capable systems difficult.
- European firms such as Thales, Saabtech and Terma have already validated the concepts of open architecture, software product lines, and software reuse as applied to combat systems

Key Concepts

- In addition to lessons learned from European firms, the proposed Technical approach is built upon lessons learned from Lockheed Martin's Norwegian Frigate Project and a predecessor program, Taiwan's PFG-2 Class Frigate project
- Valuable lessons were also learned from the predecessor program to OA, the Common Command and Decision (Common C&D) project.
- Common C&D resulted in the development of several FORCEnet related concepts that were briefed to the Assistant Secretary of the Navy for Research and Development.

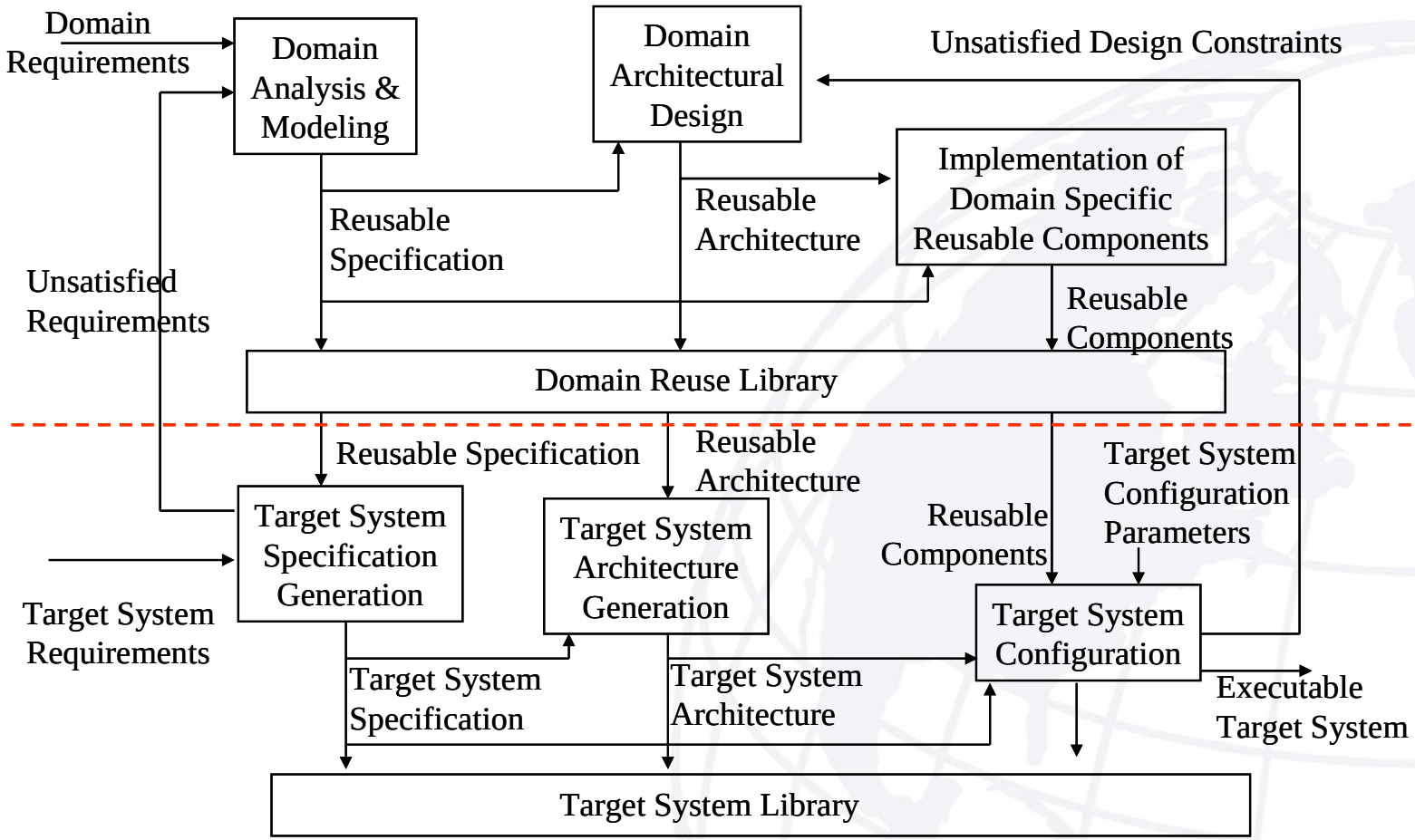
OA Principles

- The key Open Architecture principles espoused by the Navy are [Naval OA Strategy]:
  - ***Modular design and design disclosure***
  - ***Reusable application software***
  - Interoperable joint warfighting applications and secure information exchange
  - Life-cycle affordability
  - Encouraging competition and collaboration through development of alternative solutions and sources
- The first two principles are especially relevant to this paper. It is the authors' belief that proper attention to these principles will result in *software product lines* that provide *domain specific solutions*.

The Details of the Technical Approach

- The ability to make good design decisions early in the process is a significant driver in effectively lowering life-cycle cost and system development time.
- There are two key issues to be addressed with the use of the Open Architecture concept:
  - What is the structure of the various product lines required to support the various warfare domains, and
  - What is the technical approach?

Domain Modeling

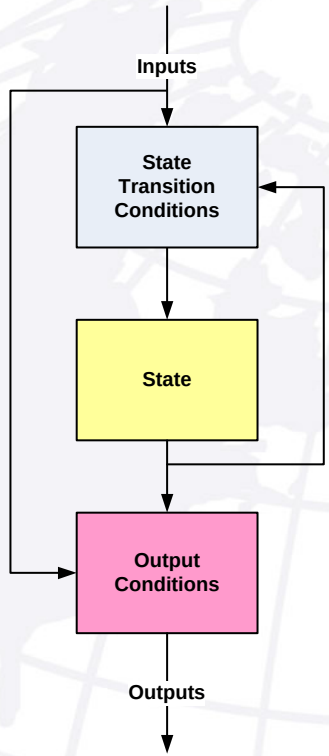


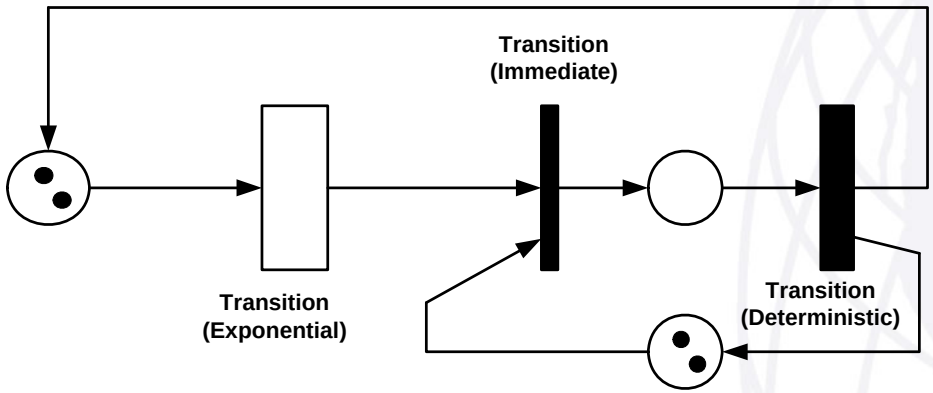
Formal Methods

- Formal methods are mathematically-based techniques for the specification, development and verification of software and hardware systems.
- *Natural language specifications tend to get out of hand as the document grows and with growth comes ambiguity.*
- The use of formal methods for software and hardware design is motivated by the expectation that, as in other engineering disciplines, performing appropriate mathematical analyses can contribute to the reliability and robustness of a design.
- *Formal methods are appropriate for the design of discrete-event real-time systems because they can be used to specify system behavior without ambiguity.*

The Approach

- The following approach uses two formal methods as a foundation:
  - *Finite State Machines (FSM)*
  - *Petri Nets*



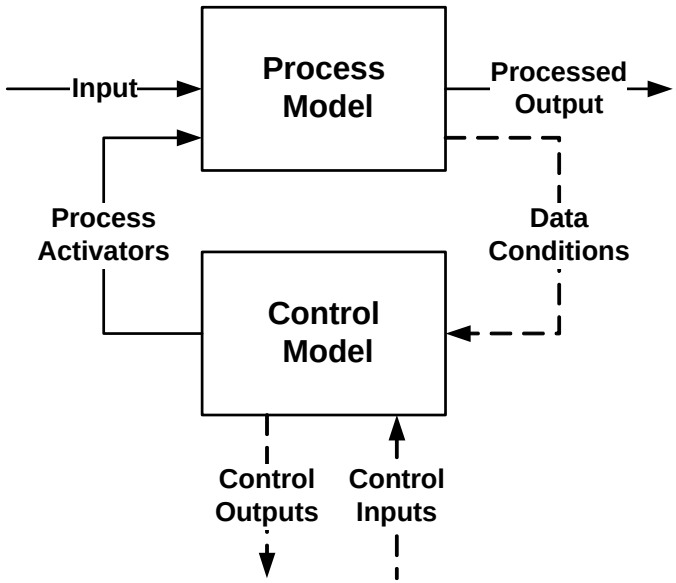


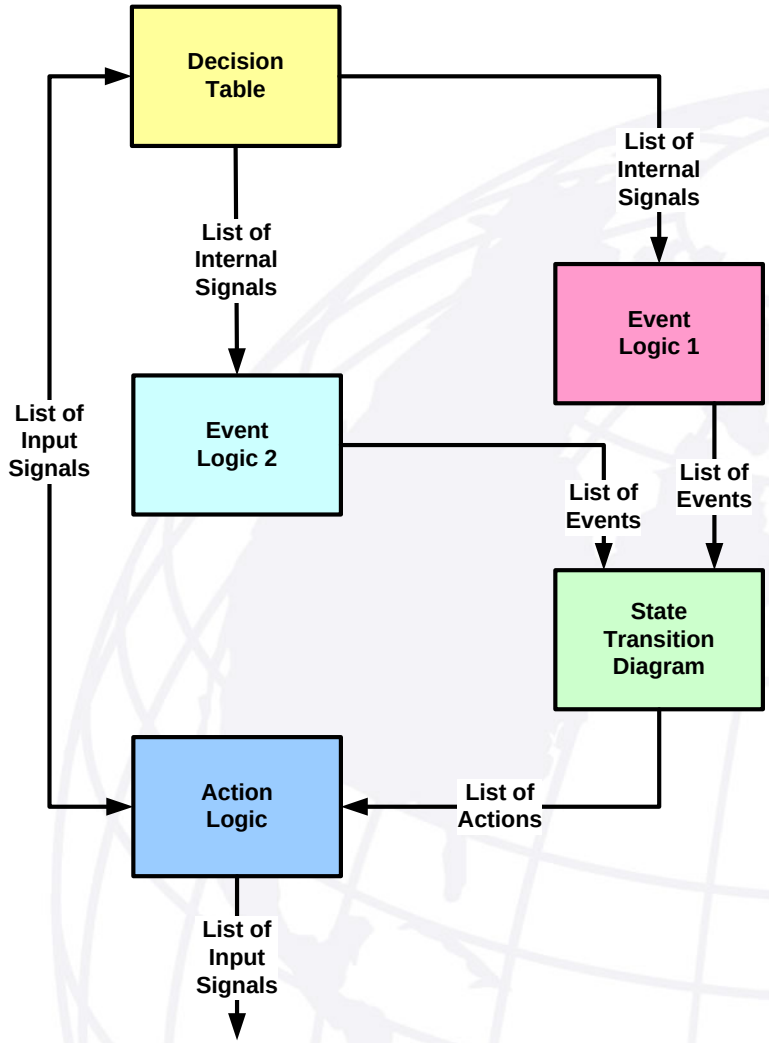
A Petri net consists of *places*, *transitions*, and directed arcs

The Methodology

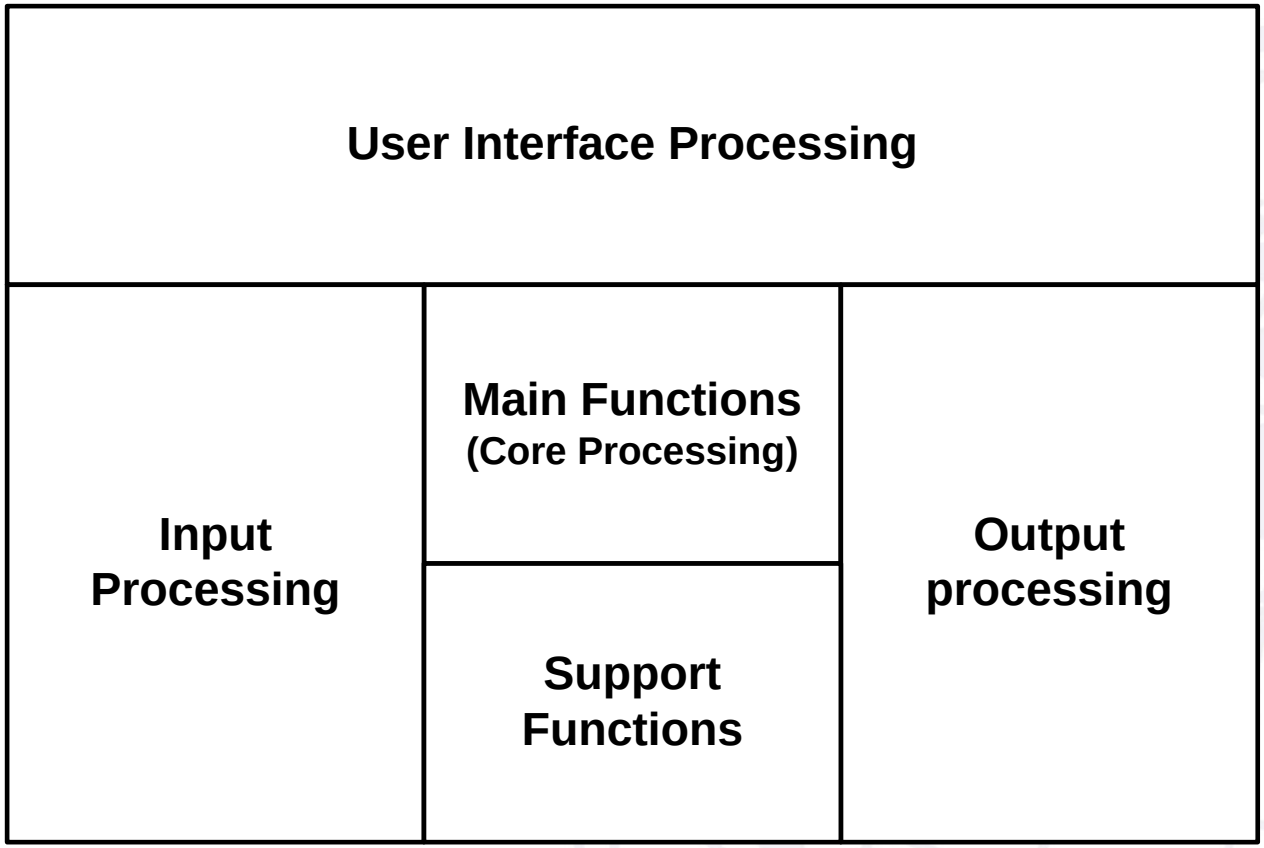
- Centered around the Hatley-Pirbhai "*Process for Systems Architecture and Requirements Engineering*" (PSARE)
  - Model-based process that uses FSM & Petri Nets
  - Accommodates HW, SW & PW
  - Can be described using SYSML/UML or EFFBD's (to name two) (not tool dependent)
  - Results in both a functional and architectural specification model
  - Can be captured with Clymer's OpEMCSS modeling approach which represents both FSM and Petri Nets
- *Core elements are the process/control model and the architecture template*

Hatley-Pirbhai Process/Control Model

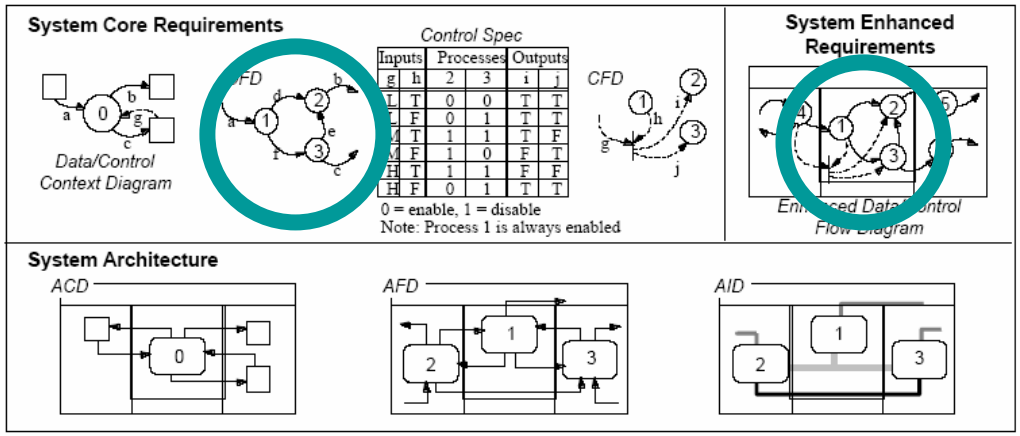




Hatley-Pirbhai Architecture Template



H-P Overview



The elements

H-P originally used Yourdon-DeMarco notation

The steps

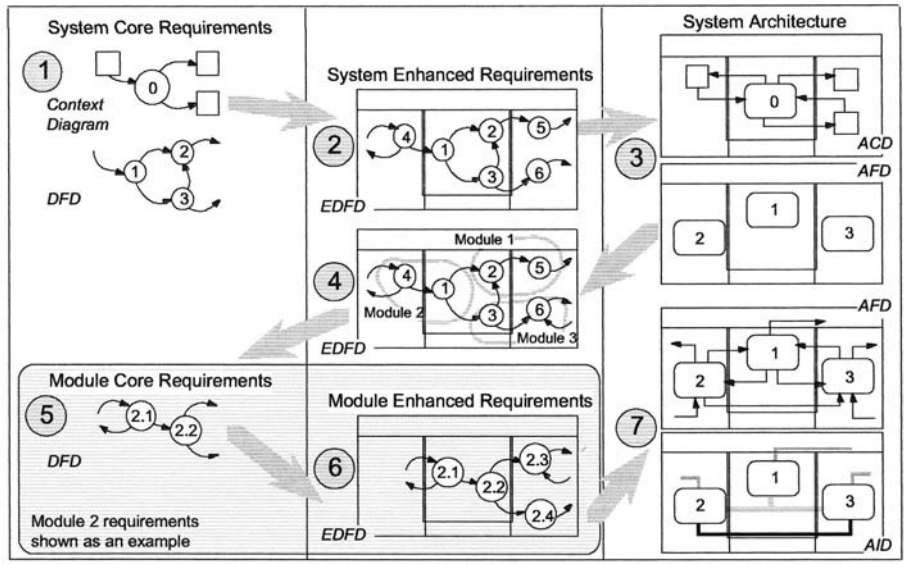


Figure 1 Model development process. Enhancing requirements models for each architecture module before drawing flows on the AFD provides consistent allocation of architecture flows to interconnects.

Figures used with permission from H&A Systems Engineering http://www.hasys.com/

Allocating to HW, SW & PW

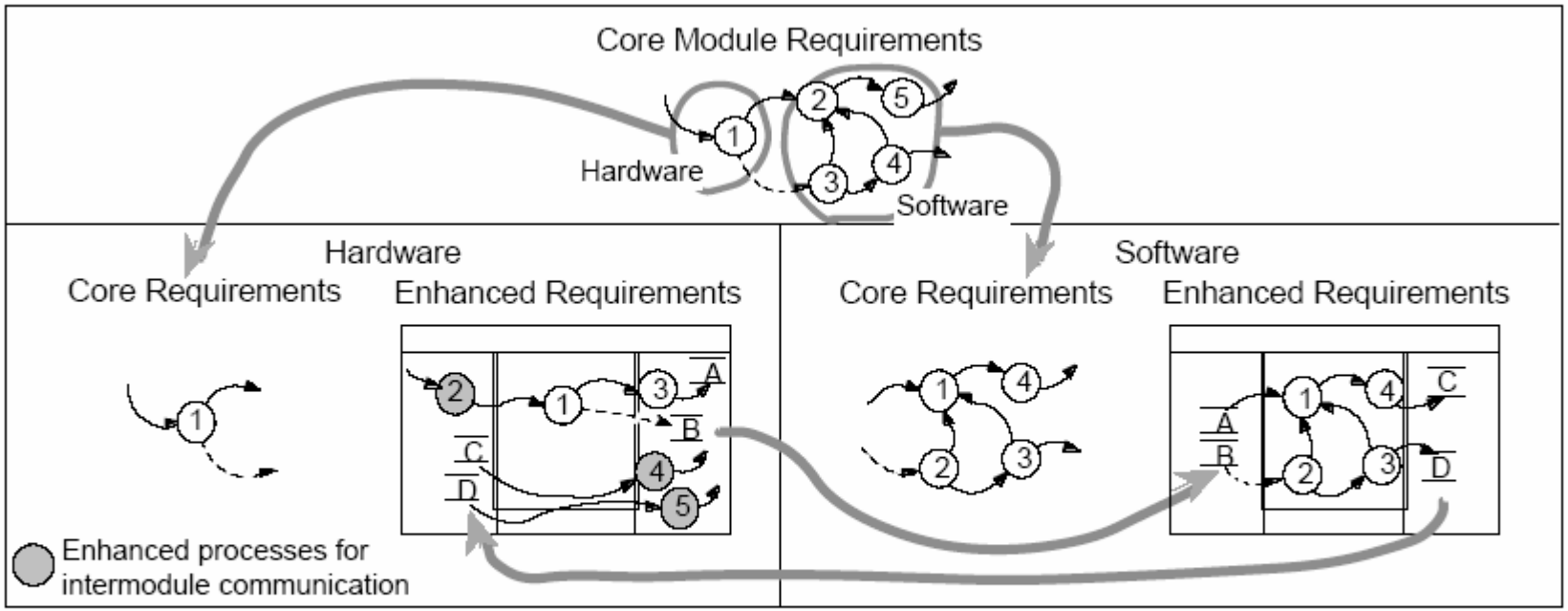


Figure 2 Hardware/software interface modeling using stores. Hardware processes produce flows into stores which are accessed by software processes. Software processes produce flows into stores which are accessed by hardware processes and transformed for intermodule communication.

Figure used with permission from H&A Systems Engineering http://www.hasys.com/

Clymer's OpEMCSS Approach

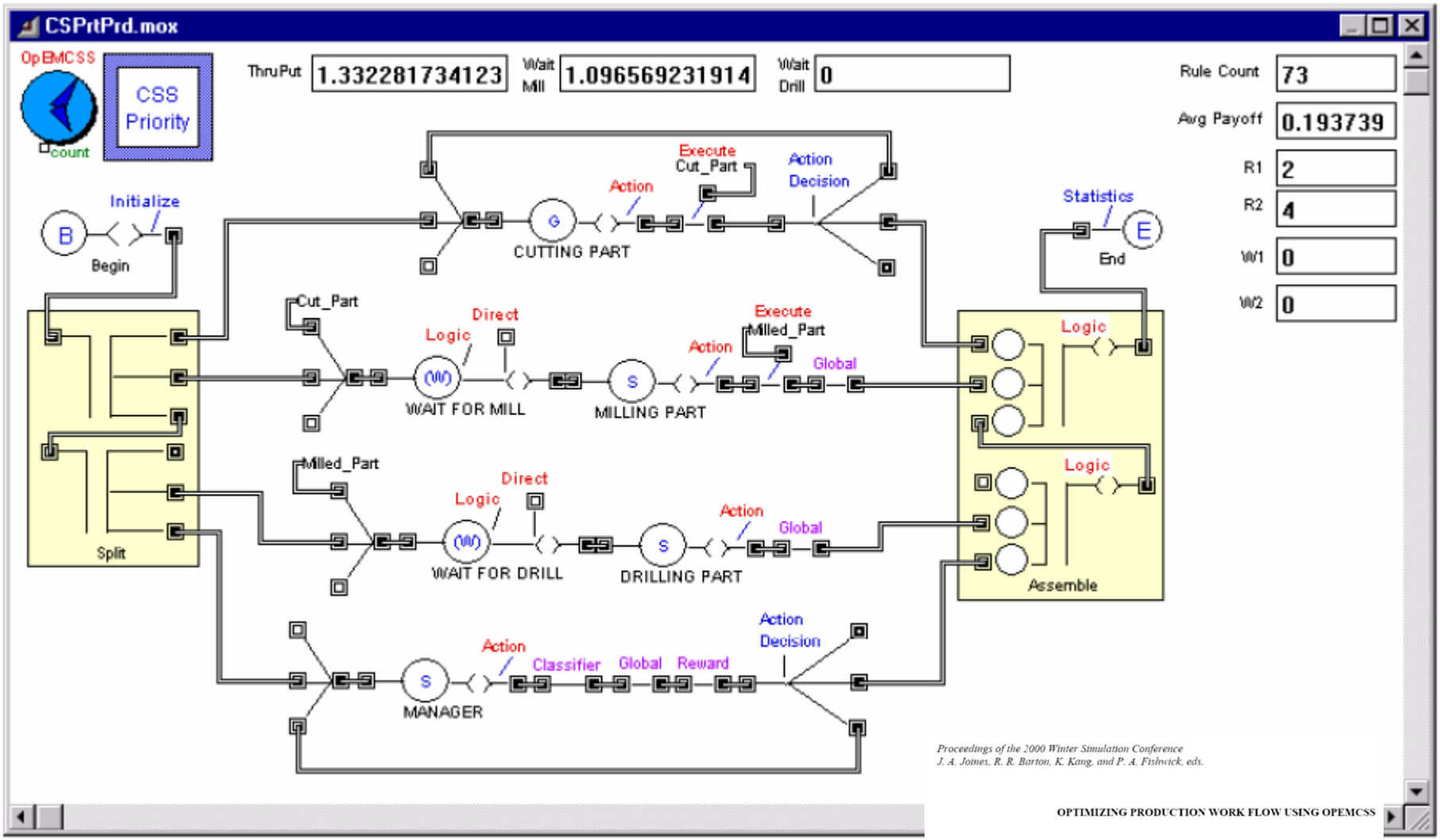


Figure 11: OpEMCSS Directed Graph Model of a Part Production System

Proceedings of the 2000 Winter Simulation Conference
J. A. Joines, R. R. Barton, K. Kang, and P. A. Fishwick, eds.

OPTIMIZING PRODUCTION WORK FLOW USING OPEMCSS

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H-P Advantages

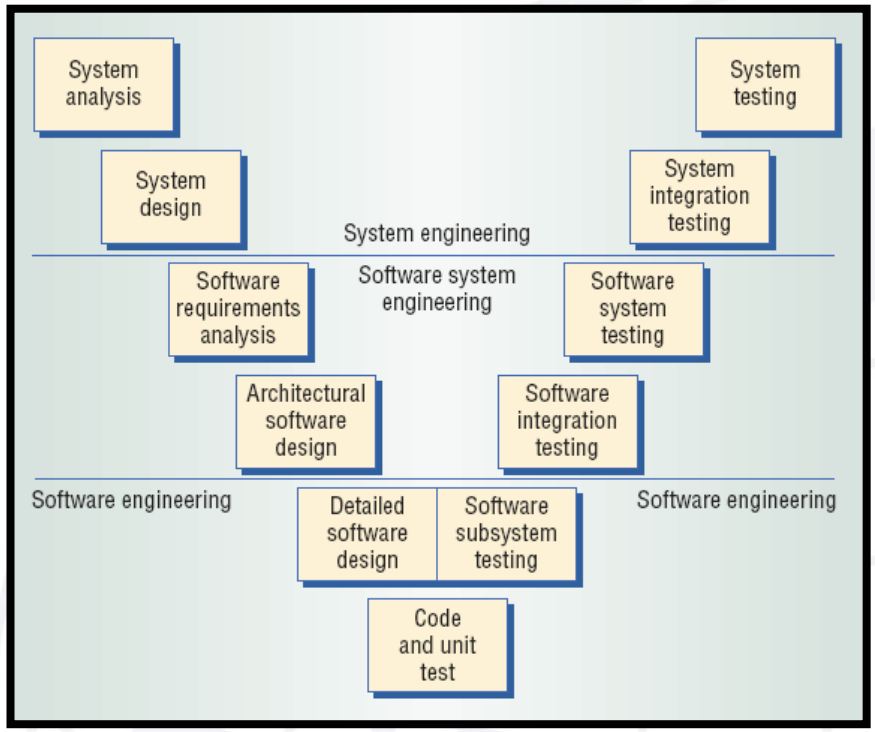
Table 1 HPM Features and Benefits. The rigor and hierarchical nature of HPM provide specific benefits.

Features	Benefits
Hierarchical model	• Specifies requirements at appropriate level • Depicts manageable amount of information at one time
Graphical and text representation of functionality	• Clearly shows interfaces (functional and physical) • Graphics depict abstract aspects of system • Text defines details
Allocation of functions to physical entities	• Greatly improved interface consistency
Rigorous method	• Promotes thorough design • Identifies gaps early

Figure used with permission from H&A Systems Engineering http://www.hasys.com/

Advantages of the Technical Approach 2

- Another advantage of a simulation-based approach using H-P can be seen by reference to the figure.
- As system development proceeds down the left side of the “Vee” the models developed provide the foundation and guidance for the steps as integration proceeds up the right side of the “Vee”.
- It should noted that the “Vee” model has been demonstrated to be consistent with spiral development



Conclusion

- The presented work gives emphasis to the value of a formal process in architecture development.
- In this case formal will mean that the architecture requirements will be validated through the use of simulation as part of a defined methodology as described.
- Specifically, the model driven architecture approach has the following advantages:
  - It is a formal method for tying the architecture requirements process to the architecture verification process.
  - It is consistent with acquisition policy
  - It provides a methodology to test Network Centric Operations concepts such as MDA, CMD, and TCT.
- The use of a simulation-based methodology will result in the requisite DODAF artifacts required for both requirements capture and the description of the system functional behavior.
- In addition, it supports the development of architectures that incorporate modular design and the identification of reusable and interoperable modules/applications.
- This approach is consistent with the development of a capability/systems-based architecture using a spiral or “Vee” approach.

Future Work

- Incorporation of the use case paradigm
- Mapping to DoDAF
- Incorporation of Clymer's work
- Merging notations/languages into a universal architecture descriptive framework