DISTRIBUTED COLLABORATIVE DESIGN TO ADDRESS TOTAL OWNERSHIP COST

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ABSTRACT

Conceptual design impacts over 70% of the life-cycle cost of a product. Over 60% of a product's cost can be attributed to its supply chain, and it has been shown that supplier involvement during design can significantly reduce overall costs including logistics costs. This implies that a big portion of the overall cost is impacted by how well we do conceptual design across a product's distributed supply chain. Distributed Collaborative Design (DCD) is the ability to do conceptual design of a product in a distributed manner by involving the supply chain members. Although this represents a major area of opportunity very little work has been done to attack the problem of doing distributed conceptual design (DCD). Also lacking are the COTS tools to enable distributed conceptual design. The focus of current tools has largely been in the area of design change management during detailed design and handoff to manufacturing. In this paper we discuss the business drivers that are driving the need to support distributed conceptual design. We then discuss the requirements for supporting DCD.

The paper describes an application where a COTS PDM system is being used to support distributed conceptual design. We present a prototype implementation of the distributed conceptual design paradigm and discuss the importance of technologies such as the CORBA, integrated analysis and Simulation Tools, and OMG PDM Enablers.

KEY WORDS

Distributed Collaborative Design, Information Technology, Supply Chains, Design Tradeoffs, Product Data Management, CORBA.

INTRODUCTION

Lockheed Martin, a leading defense contractor for military systems in an era of declining defense budgets, clearly recognizes the need to reduce total ownership cost of systems on all new procurements. This is essential to maintain or improve competitiveness, and hence integral to the overall corporate strategy. DoD and the entire defense industry are also faced with the same situation, hence share similar cost improvement objectives.

Approaches to address cost include intelligent application of new design and manufacturing technologies, new materials, leverage of modern computing and communication approaches, and analysis/optimization of process for individual processes and the total life cycle process. Decisions which affect cost in all life cycle phases should be addressed to the maximum extent feasible during the front end design phases, at a point when perturbations in design or strategy are practical. Decisions made at this phase of the process have the greatest effect on life-cycle cost – hence expansion of the set of life cycle phases and associated trade studies issues to be addressed at this level has the most dramatic effect on overall cost optimization. Figure 1, which indicates the cost impact of design decisions at various project phases, highlights the high importance of concept phase decisions relative to other phases. Decisions in the first 10% of a project control 80 – 90 percent of the total system cost.

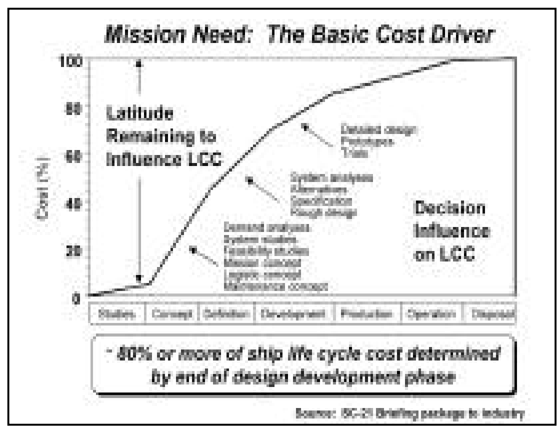

Figure 1. Decisions in early design phases have most significant cost implications.

Distributed Collaborative Design is the required strategy to enable teams of designers to address total life cycle issues at early design phases. Multi-tier teams, with complex supply chain relationships have the most challenging situation relative to collaboration at early development phases, however also stand to gain the most benefit. The effectiveness of teams in implementing DCD will translate directly to improved cost savings and hence competitiveness.

Computing technologies, networks, and information management products are some of the key ingredients to implementation of DCD. Lockheed Martin ATL is a leader in information system research with an emphasis on Artificial Intelligence, Distributed Processing, Embedded Signal Processing, and Enterprise Technologies. ATL has direct experience with multiple leading commercial Product Data Management products, and coupling of these systems as required for support of teams in collaborations. This paper discusses some of the unique requirements for addressing logistics management during conceptual design, and presents a DCD prototype implemented with a commercial PDM system.

PROBLEM

Decisions made during conceptual design have an enormous impact (70%) on total ownership cost of a system. This leverage drops sharply in moving forward through the life-cycle phases of a program. As we strive to significantly reduce logistics and other ownership costs, we have to seriously look at this important phase and ensure that total ownership issues are addressed. One key problem the design teams face is that for a large program, design is performed at multiple sites by many sub-contractors. Due to design complexity and lack of collaborative tools, these design teams don't interact continuously, but only at pre-set milestones. At these milestones specifications or designs are exchanged "over the wall". Due to the complexity and lack of integrated tool sets, downstream functions are largely ignored.

These problems are compounded by the use of different tools by different organizations involved, and the fact that different programs require a different mix of team members. It is difficult to maintain multiple tools and train users on multiple systems. All of these impact the overall cost of the solution. Better architectures are needed to overcome these problems, since a completely integrated architecture is not realistic. During early stages the design is changing and evolving rapidly. This causes work to be done in an ad-hoc fashion. It is therefore difficult to manage the design process and information without over burdening the designers. The tools generally encode the behavior while the information resides in files or databases. When information is exchanged, behavior and business rules are typically left behind. This leads to inconsistent application of the same information through the life-cycle, leading to many inefficiencies.

One of the most difficult problems to overcome is that of different design representations used by different disciplines and functions. These representations have evolved largely independently of each other, and generally tend to avoid the non-linearities that result from the interaction across discipline boundaries. These representations then drive the tools and practices of a discipline. Consistent and cross-discipline representations are needed to start approaching design from a systems perspective.

APPROACH

The approach to implement DCD is guided by several principles that have been found useful in information technology and other domains:

- Provide Information (and Resources) only when needed.
- Provide only the needed information (no more, no less).
- Do not carry Information "defects" to the next step.
- Put in place a process that discourages generation of defects.
- Information should be owned by the entity that is most suited to keep it current/accurate.
- Information accessible by all those who have a need or who may have a need.
- Take soft/qualitative factors into account.

The efforts of the commercial vendors must be leveraged to ensure that the results are quickly deployable throughout the industry without disruption of the existing and planned information technology strategies of the primes and their suppliers. The solutions need to be developed in an IPPD fashion with key vendors as part of the team. This is key to achieving a solution that is affordable.

Plan for technology change and upgrade for your information systems. A major weapon program is likely to see many major technology advances that can be leveraged to lower the total cost of ownership.

Major technology breakthroughs in the computer industry, which have rendered many advanced information systems obsolete are illustrated in Figure 2. The lifetime of military systems extends across multiple generations of computing technology – hence flexibility to accommodate change is essential for a long term architecture.

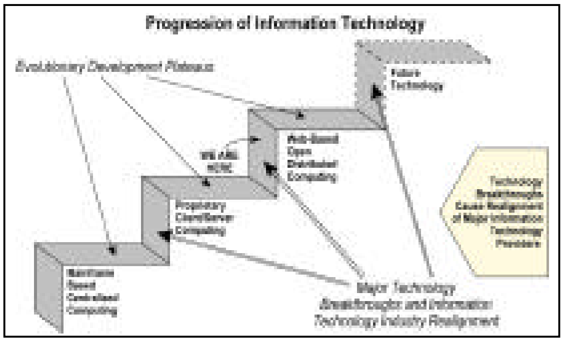

Figure 2. Major Computing Technology Break-throughs require flexible strategies

Information models need to be captured in a standard fashion. These models should contain the intellectual property of an organization where it adds value. Try to avoid capturing generic concepts and patterns that are best leveraged from the vendor implementations. For example, don't reinvent how to manage documents or workflow. Using a standard such as UML [1] will help ease technology and tool migration/upgrade.

Build the systems incrementally. Identify components of the system that provide the highest value and start building these components. These components should be small enough to be developed in less than six months. This however requires a robust and evolvable architecture. These efforts need to be guided by a requirements engineering approach [2].

The biggest challenges come from organizational and cultural issues in large multi-organization teams. Do not ignore these issues. Make sure that the architecture development takes these factors into account in addition to all the technical issues. For example, coming to consensus on a common object model is impractical for a large multi-organizational team even though it is very attractive from a technical standpoint. Hence the architecture should be able to support multiple schemas.

Federated architectures [3] lend themselves to these requirements. Our preferred approach therefore is based on a federated architecture, as illustrated in Figure 3. This approach accommodates independent schema at each organization, with each site supporting interaction with a federation manager. The federation manager implements the sharing mechanisms between the organizations, which could include a common schema which maps to each of the others. Federation managers would be implemented to support each unique team relationship.

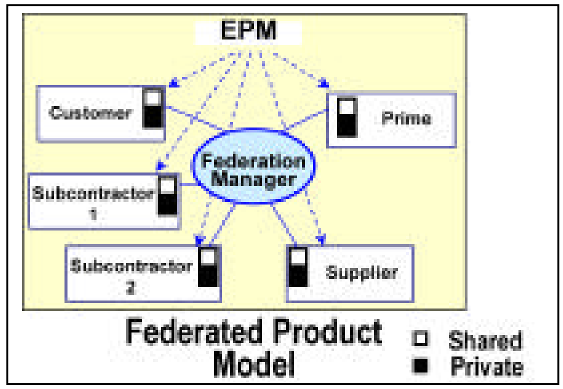

Figure 3. Federated Architectures support flexible teaming relationships.

REQUIREMENTS TO SUPPORT DCD

The enterprise architecture needs to support the distributed collaborative design across the supply chain. This will be a key enabler to achieve the aggressive total ownership cost goals for the programs. The new requirements that emerge for a DCD enterprise architecture are:

- Ability to federate enterprise (PDM, ERP, etc.) systems.
- Internet based enterprise architecture.
- Manage/track concurrent changes in a non-obtrusive manner.
- Ability to manage product configuration across multiple organizations.
- Ability to find and retrieve managed objects across multiple organizations.
- Ability to rapidly define, create, and manage design objects and processes.
- Ability to rapidly integrate legacy tools.
- Conceptual design tradeoffs at system level.
- Ability to support multiple design representations and views.

- Ability to capture a product's behavior as well as its properties.
- Ability to share objects over the internet.
- Ability to put constraints and rules on the objects.
- Ability to capture design rationale.
- Ability to capture requirements and Ilities of a design.
- Support for Interoperability standards such as PDM enablers and CORBA.

CASE STUDIES

EXTENDED PRODUCT MODEL (1)

Lockheed Martin is developing new product development support technologies which extends commercial product data management products by association of behavior, decision rules, and other characteristics with the classes that are relevant to the product. This extended product model capability enables close coordination of multiple tradeoff studies performed at the conceptual design phases, and ensures that the results of the analyses and design decisions are maintained with the relevant product data through the design and life cycle phases. The product model, implemented in a collection of business systems, therefore represents all aspects of the design (mission models, mechanical models, logistics support models, etc.), and is developed, maintained, and enhanced by a distributed collaborative team. The long term vision, indicating support of multiple life cycle domains as applied to the ship development is shown in Figure 4. This extended product model approach is being applied at Lockheed Martin to support the development of major systems including satellites, ships, and aircraft.

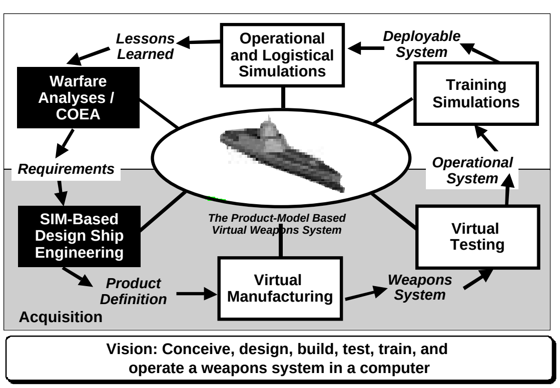

Figure 4. Extended Product Model Vision

The primary tradeoff analyses in new systems design are oriented to manage cost. An example which benefits from the application of the extended product model involves analysis of the manning situation on a ship platform. Effectiveness of the platform in a mission is related to optimum operation of a collection of sensor and weapon systems. Each of these systems includes manning requirements. Addition or enhancement of sensors/weapons improves mission performance, however addition of personnel impacts factors such as space utilization on the ship, support personnel requirements, supplies, and the development program for trained personnel. Use of the extended product model enables the manning requirements with each subsystem to be related to the development of the personnel support infrastructure of the ship, and hence accessed by the design and analysis models used in manning studies. The cost impact of addition of a system to the ship can be more readily assessed taking into account the manning impact of the change.

In addition to the manning impact, addition of a weapon system to a ship needs to deal with the logistics issues for munitions and regular maintenance. Design of the onboard storage spaces, handling equipment, and logistics supply network for each weapon can be effectively addressed at the conceptual design phases using these extended product modeling approaches, in conjunction with distributed collaborative design.

COLLABORATIVE ENTERPRISE ENVIRONMENT (2)

Lockheed Martin, in conjunction with the Air Force and team members is developing a Collaborative Enterprise Environment for implementation of DCD internally for the Air Force, for government/industry cooperative programs. The goal of the CEE program is to develop a decision support and resource management system that inter-connects computational resources and users, provides the communication infrastructure to enable geographically distinct resources and users to seamlessly collaborate and solve a problem. Examples of computational resources include requirements tools, CAD tools, design tools, and project management tools. By linking these tools together within the infrastructure of CEE, they become available to the users, regardless of where the tools and/or users are located.

A prototype implementation of CEE was developed and demonstrated in 1998 using the USAF's proprietary Lethality Analysis toolset as shared computational resources. Lockheed Martin ATL provided an extended product model capability for supporting CEE (Figure 5) focused on management of simulation runs and experiments associated with the Lethality Analysis toolset. This EPM was implemented by extending the base product model capabilities of the Metaphase PDM system.

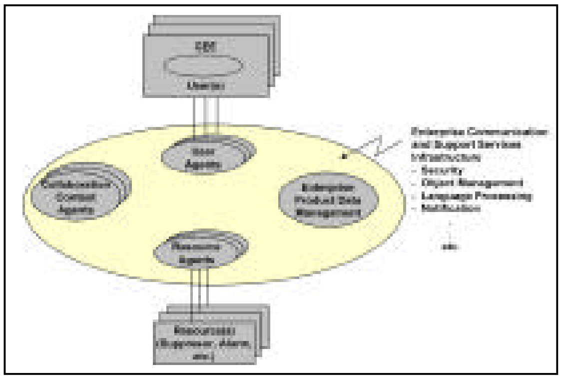

Figure 5. Lethality Analysis Toolset with Extended Product Model Support

The Lethality Analysis toolset consists of the Suppressor and ALARM simulators. Suppressor is a mission level simulation model used for analyzing military operations. A typical Suppressor simulation represents a military operation such as aircraft attacking targets defended by an integrated air defense. A Suppressor simulation is defined by the Scenario Database, Environment Database, and the Type Database input files. Output from a Suppressor simulation is a time ordered list of the important events from the simulation run [4]. ALARM (Advanced Low Altitude Radar Model) is a simulation model designed to evaluate the performance of a ground based radar system attempting to detect low altitude aircraft. The primary mission of ALARM is to provide areas of detectability by a single radar and to aid the radar analyst in the understanding of detectability phenomenon. ALARM input data consists of several data blocks that correspond to the components being modeled. Output from ALARM is a flight path sequence file that specifies whether or not the target aircraft was detected [5].

The EPM capability provides configuration management support for the datasets produced and consumed by the Lethality Analysis toolset. The Metaphase PDM system has an object-oriented internal data model which was customized for this type of simulation support. These extension include new classes for simulation runs, and experiments. Subclasses for the Lethality Analysis toolset include the specific organization of input & output files required. A custom interface for direct interaction with these classes was created using the Metaphase JAVA API capabilities. When used in CEE, the Lethality Analysis user selects the appropriate datasets for the run and checks them out into his work location using the custom interface to the PDM. After the Lethality Analysis toolset is run, the results are checked back into the Metaphase PDM system along with the original input files that created those results.

This EPM prototype significantly improves the productivity of engineers in execution and analysis of this toolset, and enables access and sharing of results across the CEE.

SUMMARY

New innovative strategies are required to effect substantial life cycle cost savings for new systems. Analysis of a robust set of cost factors relevant to the total life cycle during the conceptual design phase enables improved decision making at this critical phase. Distributed Collaborative Design, leveraging emerging internet communication and information management mechanisms, will provide the necessary tools and methodology to effectively implement improved decision processes, and hence reap the benefits. Lockheed Martin is committed to implementing DCD and realized many successes as a result of DCD technology programs or internally funded initiatives. ATL has demonstrated that a foundation of COTS product data management tools with extensions relevant to the specific application domains enables DCD and resulting productivity gains for these domains. This strategy is being extended to additional application domain associated with several major programs.

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