A Family of Systems Collaborative Engineering Environment

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Abstract. This paper describes the Naval Collaborative Engineering Environment (CEE) being developed to facilitate data/information exchange and collaboration among engineers, scientists, users, and managers at multiple distributed geographic locations for the purpose of family-of-systems interoperability engineering. A description of the envisioned open systems, standards based infrastructure of communications, data processing and resource management services is included, as well as how the Naval CEE will be used within the US Naval Force Systems Engineering Process.

Background

The US Naval acquisition community has the responsibility to provide battle force systems that are not just mobile, responsive and effective but when employed as a joint coalition force is integrated and interoperable. To accomplish this the US Navy invests in developing and deploying warfighting capabilities that are state of the practice and in modernizing legacy forces with the latest technologies to ensure a survivable and mission capable battle force, regardless of the enemy and/or environment. However, basic collaborative capabilities and an adequate base of higher-level knowledge and information to resolve force level interoperability and integration problems do not presently exist to support the current acquisition process.

The Office of the Chief Engineer (CHENG) under the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN, RDA) has been chartered to provide a technical architecture for Naval force systems integration and interoperability. The CHENG charter includes implementation of engineering processes within the Naval system acquisition community to assure force systems interoperability, and definition of the technical measures of effectiveness (MOEs) and measures of performance (MOPs) which support the measurement of operational performance for interoperability.

In a separate action the Naval Sea Systems Command (NAVSEA) has established a Distributed Engineering Plant (DEP) to provide capabilities to perform land-based testing and certification of Battle Group systems interoperability. The DEP concept encompasses support for the full system acquisition life cycle, including requirements definition, concept development, engineering and manufacturing development, test and evaluation, and operational support. However, the current DEP implementation focuses on T&E requirements and is based on hardware-in-the-loop (HWIL) and real-time simulation capabilities. This requires a dedicated, wide-bandwidth capability communications backbone. The recent Office of the Secretary of Defense (OSD) Joint DEP Task Force has extended the Navy DEP concept to postulate a framework for integration and testing between the services for Joint systems interoperability.

For the Navy to achieve integration and interoperability goals the various engineering and management tools of acquisition will need to be applied in a collaborative-integrated environment. This need has been identified in a number of recent Office of the Secretary of Defense (OSD) initiatives including Simulation Based

Acquisition (SBA), Integrated Manufacturing Technology Roadmap (IMTR), the Integrated Digital Environment (IDE), and the Integrated Program Management Initiative (IPMI). Considerable progress has been made over the past few years in establishing the communications and computing infrastructure necessary to support such an environment. Projects such as the DARPA Simulation Based Design (SBD) and the ONR SC21 Manning Affordability Initiative sponsored Human Centered Design Environment (HCDE) have demonstrated the feasibility of realizing an advanced distributed collaborative environment using commercially available building blocks.

CHENG will leverage the insights gained and capabilities developed in on going projects such as identified above and those found in the commercial sector to create a full scale CEE for use by the Naval acquisition community in support of complex systems development and system interoperability management. The CEE will be implemented fully consistent with the Department of the Navy Chief Information Officer instructions and guidelines for data integration and interoperability. It will also comply with and leverage the Navy/Marine Corps Intranet (NMCI) architecture and infrastructure.

Naval CEE Elements

The Naval CEE will consist of three principal and synergistic elements shown in Figure 1.

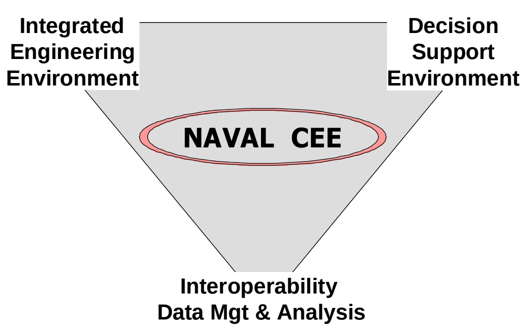

Figure 1 – Naval CEE elements

The Decision Support Environment (DSE) will provide web-based capabilities to interact and share information. This will be based on Microsoft Exchange 2000™, Windows 2000™, Office 2000™, and Outlook. Livelink™ will be used to provide data management, document sharing, and workflow management. Desktop VTC, white board, chat room and application-sharing capabilities will be based on Microsoft NetMeeting. Group facilitation software will be utilized to support team decision-making activities.

The Integrated Engineering Environment (IEE) provides the second key element of the Naval CEE. It will feature an integrated set of government and commercial-off-the-shelf system architecting and engineering tools. These will be integrated via a central, object-oriented data repository that will maintain a force systems data base schema that is common to all platforms and systems within the Naval force. The IEE will support distributed engineering teams engaged in requirements analysis, functional analysis, system synthesis, and assessment of force system architectures. It will generate Architecture Framework views of the force system architectures (operational, system, technical). The IEE will support multiple levels of data and information management, including force systems, mission capability packages, and platforms/systems. The initial implementation of the IEE will be based on DOORS™, CORE™, and Interchange™. Additional capabilities will include architecting tools such as the Joint Mission Architecture Analysis Tool (JMAAT).

The components and interrelationships of the IEE are shown in Figure 2.

The third key element of the Naval CEE is the Interoperability Data Management and Analysis (IDMA) capability. This element will establish a force systems interoperability database and visualization capability. It will be the repository for the force system architectures views generated by the IEE and provide force-systems data evaluation and assessment capability.

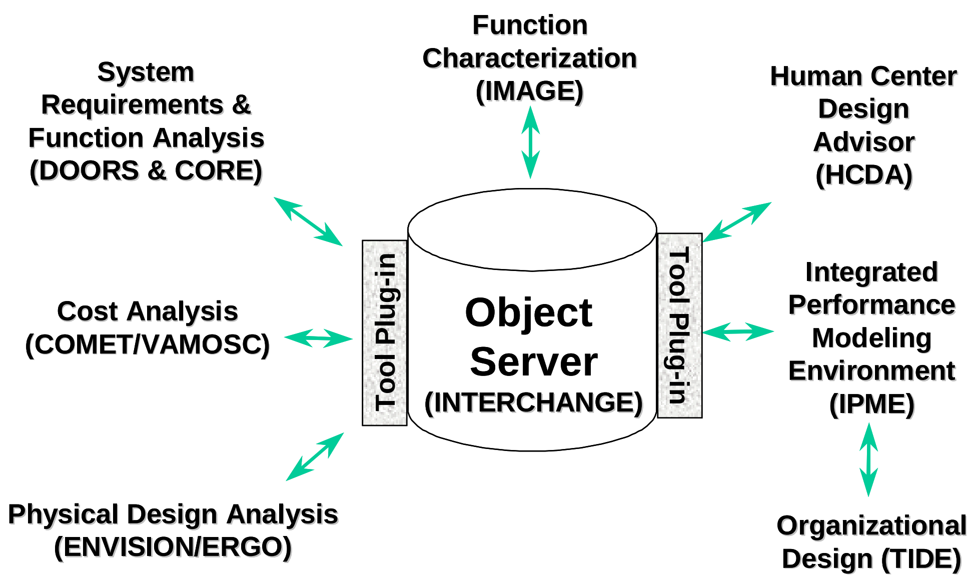

Figure 2 – The IEE Element

CEE Purpose

The purpose of the Naval CEE is to provide an integrated digital environment that 1) enhances the cooperation and exchange of data, information, and knowledge among Naval stakeholders and 2) enables the integration and interoperability of systems across the spectrum of the Naval acquisition process.

Stakeholders

The Naval CEE stakeholders include those people and organizations that interact directly with the CEE as a user or operator; could be materially affected, either positively or negatively, by the implementation of the Naval CEE; have a specific purpose involving the Naval CEE, such as managing or performing acquisition, or helping accomplish a task, project or program associated with that specific purpose; have a role in providing inputs to the requirements for a Naval CEE or in fulfilling functionality or services related to the Naval CEE; and provide resources to enable a person or organization to become a Naval CEE user.

Specific CEE Needs

There are five areas of need that are the focus of the Naval CEE—Family-of-Systems[1], System/Platform Acquisition, Technology Development, Operations, and Evaluation and Assessment.

Family-of-Systems. The need at the family-of-systems level is to enable multiple, diverse acquisition entities to collaborate for rapidly solving complex acquisition problems across a mix of platforms and systems aligned to achieve various mission capabilities. Lack of such a collaborative capability continues the multidimensional communication problems

[1] There is a distinction between "Family-of-Systems" vs "System-of-Systems" according to Joint Chiefs instruction (CJCSI 3170.01A, 10 August 1999). Family-of-Systems is defined as "A set or arrangement of independent systems that can be arranged or interconnected in various ways to provide different capabilities. The mix of systems can be tailored to provide desired capabilities dependent on the situation (e.g., Space Control, Theater Missile Defense, etc.). Systems-of-Systems is defined as "A set or arrangement of systems that are related or connected to provide a given capability. The loss of any part of the system will degrade the performance capabilities of the whole (e.g., National Missile Defense)." A Navy Battle Force fits the Family-of-Systems definition and this is the level at which the Naval CEE is chartered.

that exist today. These problems exist because of the distribution of information sources, information users, information suppliers and the diverse talents needed for developing and implementing the integrated and interoperable complex systems required for warfighting excellence. Additionally, no single acquisition entity has the resources or authority for acquisition of a mission capability that ensures battle force integration and interoperability. Multiple acquisition managers are required to be involved in family of systems requirement formulation, design decisions and implementations, and in assessing the impacts of these formulations, decisions and implementations.

System/Platform Acquisition. The need at the system and platform levels for collaborative information sharing is to develop concept definitions to meet family-of-systems allocated capstone requirements and to support multiple developers involved with implementing systems engineering processes. Lack of this collaborative capability exacerbates current problems in sharing business and technical information. These problems exist due to political, business and cultural influences and constraints on the diverse working groups from industry, the Navy and other entities involved in business activities and technical activities related to developing system concepts and validating that the concepts satisfy required mission capabilities. Additionally, teaming arrangements among service, industrial, academic and international partners must overcome the constraints associated with sharing technical data and doing collaborative simulations, testing and analyses.

Technology Development. The need for collaboration between the technology development community and the system development community is to ensure that: 1) emerging technologies are brought together with the implementation of system of systems interoperability requirements in the required time frame and with required life cycle functionalities; 2) platform and system requirements are satisfied with state-of-the-art solutions; and 3) that the technologies are seamlessly integrated across systems and platforms. The lack of such collaborative capabilities to exchange emerging technology information creates technology renewal and insertion problems in keeping the Fleet at state-of-the art readiness. The exchange of information on technology developments and their readiness status for insertion into new and legacy systems for modernization is complicated because of different priorities between technology and system acquisition stakeholders and the lack of use of available channels for information exchange across the technology-system development boundary.

Operations. The need for collaborative information sharing is to develop objectives and solutions for new concepts of operation, changed battle doctrine, real-time at-sea maintenance, inserting time-critical technologies, and capturing up-to-date platform warfighting status. The lack of such collaborative capabilities creates potential war fighting and maintenance problems. These problems result from lack of capability to recognize and plan for dynamic changes in political, economic, sociological, and operational environments in which systems with 25-50 year lives will have to be responsive.

Evaluation and Assessment. The need for collaborative methods, tools and simulations is to evaluate and assess architectures, specific application domains, and the force systems integration and interoperability body of knowledge. The lack of such collaborative capabilities creates problems in assuring integrated and interoperable Naval force systems; assuring that commonality, standardization and information sharing are optimal within the constraints of the specificity of the application; and enabling comprehensive force system investment decision making, individual program reviews and program and force level risk assessments.

Concept of Operation

The concept of operations (CONOPS) describes the Naval CEE operations as well as the intended virtual enterprise (VE) environment that will help ensure the interoperability of systems across all acquisition stages. The CONOPS describes what this virtual enterprise does for a user or stakeholder and what the user will do with the Naval CEE tools. In keeping with the purpose of describing envisioned Naval CEE operations by functional requirements, life cycle capabilities and projected use cases.

Naval CEE Functional Requirements

At all phases of the systems acquisition life cycle, the Naval CEE will need to satisfy functional requirements for increased efficiency, resource coordination, and streamlined data exchange.

For increased efficiency of engineers working together in a distributed environment, the Naval CEE will provide the following functionality:

a. Accessibility to electronic versions of all documentation for authorized members on a demand-pull basis. Documents include proposals, reviews, calendars, specifications, requirements, schedules, meeting minutes, e-mail, action items, CAD drawings, visualizations, databases, reports, and briefings.
b. Information by authorized members from any site at any time.
c. Maintenance of documentation and software under configuration control, with traceability and archiving of changes.
d. Support for authorized personnel to view, discuss, and generate documents with each other using desktop capabilities such as video teleconferencing and whiteboarding.

For resource coordination, the Naval CEE will provide the following functionality:

a. Give authorized members of the team the capability to create plans of action and milestones, funding estimates, and progress assessment on a continuing real-time basis.
b. Monitor the progress of tasking and alert managers and engineers to assess the impacts of variances in tasking and changes in plans, schedules, and configurations.
c. Accommodate remote activation of applications, such as simulation models or remote compiling / patching of software and data extraction.

For streamlined data exchange to ensure compatibility, the Naval CEE functionality includes:

a. Adoption or, if necessary, definition of standards for data interfaces between the systems used by the distributed engineers.
b. Rapid distribution of data for analysis and problem resolution.
c. Synchronized environmental and scenario data among remote sites.
d. Common data definitions across the acquisition life cycle.

Life Cycle Capabilities

The Naval CEE is envisioned to have systems engineering capabilities that will enable support of the total system acquisition life cycle. This includes notional application of the Naval CEE-enabled systems engineering approach to requirements, design, development, testing, and fleet support.

Requirements Definition Activities. During the requirements phase of the acquisition cycle, the Naval CEE will have the capability to enable development of concepts of operations and notional prototypes for new and modified systems and platforms in a family-of-systems context. Capabilities will include demonstration and prioritization of operational requirements via the use of modeling and simulation (M&S) tools. Battle-force-level interface definitions with interface requirements and data flows will be able to be developed and made available to the design agents and the government. In addition the Naval CEE will be able to support collaborative analysis for planning, programming, and budgeting system (PPBS) decision-making.

Design Activities. In the design phase, top-level software and system design issues will be able to be addressed. Inter-system and inter-function communication methods among different combat systems can be defined to ensure that the battle-force interoperability requirements are implemented. Design-level models, as well as models of the communications methods, can be integrated at different government and contractor sites to examine battle-force interoperability issues early in the design.

The Naval CEE will enable collaborative doctrine development and threat, mission analysis, system capability analysis, and interoperability analysis.

Development Activities. In the integration phase, the common environment supports the transition of the functionality of the combat and C4I systems, previously represented by models, to the developed software units and elements. Multi-site integration of units/elements can be performed with the capability of remote execution. The CEE developmental support tools will provide the ability to delineate the system to be acquired in a variety of fidelities, from top-level conceptual representations to highly detailed engineering models. Specifically, the Naval CEE will support the following types of data capture, representation, analysis, and communication 1) Systems Engineering Representations of the System Under Development, 2) Subsystem Interface Specification and Integration, 3) Interfaces to Tools, 4) Platform Integration and Battle Force Interoperability Assessment, and 5) Risk Assessments.

Test and Evaluation Activities. For the test and evaluation (T&E) activities, the Naval CEE supports the Navy DEP and Fleet exercises in providing an integrated approach, from system standalone tests to multi-system battle-force tests, that are needed to ensure battle-group/battle-force interoperability. These activities will be able to be conducted across the life cycle, in realistic environments, and considering human factor ergonomics,

Production and Development Activities. The CEE will provide the ability to support activities conducted during production and deployment. Issues related to Limited Factory Test and Evaluation (LFTE), Initial Operational Test and Evaluation (IOT&E), and Low Rate Initial Production (LRIP) will be supported.

Support Activities. The Naval CEE will provide support for both headquarter activities and fleet activities. For headquarter support activities the capability to establish and support configuration control of battle group baselines, the Naval CEE database will be available as well as the capability of accessing Cost As an Independent Variable (CAIV) and life cycle costs from an affordability point of view. For fleet support activities the capability will be provided to capture the experience data from the fleet in terms of trouble reports (TRs), casualty reports (CASREPs) and other experience reporting from operations and training functions that occur as well as root cause analysis of interoperability problems and correction of system and interoperability problems.

Naval CEE Use Cases

The concept of operations for the Naval CEE is built on four use cases—Acquisition, Technical, Science and Technology, and Warfighter. Use cases provide like scenarios for analyzing and evaluating the capability of the Naval CEE as it is being defined and implemented.

Acquisition Use Case. This use case deals with the acquisition of a mission capability for the battle forces. No single acquisition entity has the resources or authority to accomplish the acquisition in isolation from the others. All the effected organizations must cooperate and collaborate in order to deploy the new battle force capability. An example of these capabilities would be Time Critical Strike (TCS) or the Single Integrated Air Picture (SIAP); thus, the context of Acquisition Case focuses on the problem of acquiring TCS or SIAP, and involves the cooperation of multiple, diverse acquisition entities.

Development Use Case. This case enables the Naval CEE to provide a capability for multiple persons from multiple organizations to effectively work together to perform various engineering activities. It is assumed that at least some of the people are geographically separated. The CEE will contain tools, computer databases, models, simulations, etc. to support general engineering activities. Many of these are generic in that they support groups of people working in a cooperative fashion; such as electronic mail, document repositories, and conferencing. Others are tailored to support a specific engineering task. This use case describes how the CEE would be used to develop battle force engineering capabilities. Its primary function is to help describe CEE requirements that support battle force engineering.

S&T Transition Use Case. The Science and Technology use case will support transition and insertion of new technologies supporting interoperable battle force systems to achieve new performance or mission capability. This case will draw on the current context of advanced technology prototypes to demonstrate new capabilities in complex test operation. This use case will highlight live and simulation and modeling integrated environments supporting evolution and revolution of battle force mission capabilities.

Warfighter Use Case. The warfighter use case will support development of objectives for initiatives for new CONOPS and Battle Doctrine. The Naval CEE will provide capability to the acquisition and development community to define and support warfighter technical objectives and to accelerate transition of fleet initiatives.

Plan of Action

Implementation of CEE capabilities will be achieved incrementally by integrating selected, available government and commercial engineering environment resources in three phases. A pilot testbed will be established to test and evaluate potential technology capabilities and tools in accordance with the CONOPS and SRD. Selected infrastructure and applications with proven capabilities will be assembled, tested, configuration managed, and installed at multiple sites. Training will be conducted for system administrators and users. The CEE capabilities will be implemented in the following phases:

a. The first phase will provide the initial DSE information sharing capabilities for the RDA CHENG core staff, Council of Chief Engineers, and Technical Advisory Group. It will include email, calendar, and action item tracking based on Microsoft Windows 2000, Office 2000 and Outlook. It will also include document sharing based on Livelink™. In addition the first phase will include an IEE capability pilot supporting requirements engineering and functional design and analysis at 3 - 5 sites. The initial implementation of the IEE will be based on DOORS™ for requirements analysis and management. CORE™ will be used for functional analysis and architecture development. JMAAT™ will be used for capturing C4ISR Architecture Framework views. Interchange™ will be used as the central system data repository and will serve the distributed users need for maintaining data consistency between engineering tools and configuration management of the integrated environment.
b. The second phase will expand the core collaboration framework to the entire RDA CHENG technical team. SIPRNET connectivity will be established. The engineering collaboration capability pilot will initially have the capacity for a potential total of 10 sites. Engineering tools for virtual design and assessment will be integrated and a distributed repository will be implemented to support the growing force systems interoperability design repository. This phase will demonstrate Naval CEE functionality, secure operations, expanded systems analysis, expanded common database, expanded collaboration, and product and process workflow.
c. The third phase will expand both the core collaboration and distributed engineering capabilities to additional sites and users as required. Additional engineering tools will be integrated to support specialty engineering domains and interoperability engineering activities. An integration framework will be implemented to link to the Navy DEP and provide a coordination layer for the fully integrated Navy CEE. Naval CEE utility for aiding the analysis of interoperability cases, including 1) systems analysis tools for interface requirements and functional architecture definition; 2) common database interchange using a force systems engineering model; 3) interoperability analysis using force system connectivity; and 4) middleware validation.

d. Follow-on phases will include demonstration of 1) fully functional Naval CEE that demonstrates collaboration capabilities across mission and warfare areas and can be tailored to focus on event-driven needs; 2) fully functional Naval CEE that incorporates unique features required by CINCs, Services and Agencies; 3) a broadly available Naval (Joint) CEE with interfaces in place to be used universally throughout the US Navy for interoperability testing in the battlegroup, to discover problems early on in platform and system programs and to promote integration and interoperability in other CINCs, Services and Agencies. The long range goal is to have a Naval CEE re-engineered for changes in doctrine, tactics, techniques and procedures (TT&P), and the political/economic situation.

Summary

The Naval CEE is being deployed by the Office of the Chief Engineer (CHENG) under the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN, RDA) to facilitate data/information exchange and collaboration among engineers, scientists, users, and managers at multiple distributed geographic locations for the purpose of family-of-systems interoperability engineering. It also will provide an open systems, standards based infrastructure of communications, data processing and resource management services.

The Naval CEE will provide to planners, developers, assessors, technologists, and warfighters a collaborative capability for engineering new and legacy systems/platforms to satisfy integration and interoperability family-of-systems requirements.

Biographies

Dr. Jerome (Jerry) G. Lake is an internationally recognized instructor, consultant and speaker in systems engineering. He is co-founder and president of Systems Management international (SMi) established in 1993 and past president of the International Council on Systems Engineering (INCOSE). Dr. Lake was a principal writer of both EIA/IS-632 and IEEE 1220-1994. He served on the Electronic Industries Alliance's systems engineering working group that prepared the ANSI/EIA 632 standard *Processes for Engineering of Systems* and he currently is serving with the US TAG for ISO/IEC JTC1 SC7 preparing a standard on *System Life Cycle Processes*. He has authored numerous articles on systems engineering, project management, and related topics. Dr. Lake is an aerospace engineer with earned advanced degrees from the University of Michigan (Master of Science) and University of Oklahoma (Doctor of Philosophy). He is a graduate of the US Military Academy. Dr. Lake is a Fellow of the American Society for Engineering Management and recognized in Men of Achievement and Who's Who in the World, East (US), and Southeast (US), and American Education. In 1996, he was honored with the second INCOSE Founders Award.

Dr. Harry E. Crisp is Director for Special Projects in the office of the Chief Engineer for the Assistant Secretary of the Navy (Research, Development and Acquisition). He holds a Ph. D. in Electrical Engineering from Auburn University. He has been with the Navy since September 1971. Dr. Crisp has performed research in Navy combat and weapons systems technologies and has authored several papers on engineering complex systems, human centered design, and technology management. He has been a member of INCOSE since 1994 and currently is the Director-at-Large on the Board of Directors and serves on the editorial board for the INCOSE technical journal. He has also served two terms as the Government/Academic Director for INCOSE Region V and has been the Board of Directors representative to the INCOSE Technical Board. Dr. Crisp is also a member of the Institute of Electrical and Electronics Engineers and the American Society of Naval Engineers.

Previous Menu/Document