Technology Solutions for Coalition Interoperability in a C4ISR Environment

Jude Franklin, Ph.D.
Litton PRC CTO

Michael Ladwig
Litton PRC Senior Technical Fellow

Christopher Johnson
Litton PRC Senior Technical Fellow

Abstract

The motivation for this paper was derived from an invited presentation to NATO SACLANT (September 1999) describing the operational policy implications of using new technologies for the NATO of 2010. This paper describes the coalition operational environment in 2010 along with the technology implications for collaborative integration of multi-national forces. Future coalitions will have petabyte communications backbones with petaflop computing, smart sensors and Micro-Electrical-Mechanical (MEMS) devices that will be sprinkled throughout the battlespace. This will provide a huge amount of data, but it needs to be processed into information and knowledge by the coalition in order to be useful. Coalitions in 2010 will require fast, agile, empowered members, fully integrated with true collaboration, and they must be able to deal with this huge information flow. There will be a requirement for the fusion of data from sensors, message systems, and global news/political update systems to transform voluminous inputs into clear coalition understanding. In addition, there will be a need for coalition planning, situation awareness, execution, and assessment.

The collaborative needs for coalitions in 2010 include:

- Multi-national alliances
- Defensive and offensive information warfare
- All-weather operations
- Affordable access to space
- Autonomous systems and sensors
- Smart interactive robotics
- Automated information retrieval and understanding to avoid information overload
- Chemical-biological detection with pre-emptive actions
- Automated trans-national coalition supply chain management with logistics support from member countries
- Intelligence reachback to all coalition members with consistent understanding
- Accurate weather forecasting achieved by means of coalition sharing and collaboration
- High mobility
- Networked computing devices
- Access to global internet
- Distributed M&S that provides for near-real-time exploration of the decision space and that, along with automated information retrieval and understanding, enables improved planning and C2 decision-making
This paper describes the needs for ongoing research and development to achieve technology solutions for coalition collaboration. The order of this paper is:

- Background on Collaboration Problem
- Need for Coalition Intelligence and Knowledge Management
- Discussion of Four Example Solutions for Coalition Interoperability
- Summary

The paper describes several promising enabling technologies, including a description of a “loose integration” solution that will facilitate the harmonizing of different technologies for coalition interoperability and collaboration. In addition, several other programs are discussed, including the DARPA (Defense Advanced Research Projects Agency) Advanced Logistics Support, NSWC (Naval Surface Weapon Center) Collaborative Environment for Complex Systems design, and the DISA Virtual Command Center.

1.0 Background on Collaboration Problem

Cost reduction, improved efficiency, and decreased personnel are a constant theme for a successful C4ISR coalition in 2010. Downsizing, right-sizing, and competitive pressures throughout the economy force coalitions to do the same or better job at a lower cost, with fewer people, distributed over several geographic locations and nations. To achieve this, they must utilize their resources with almost perfect efficiency. Some examples of how this is being accomplished in the civilian world are illustrated below in Figure 1.

![Figure 1 – Civilian Examples of Collaboration](image)

This “organizational deconstruction” is changing the character of business and government organizations. The outsourcing of previously internal elements of an enterprise is leading to physically distributed and fractured operations. This new type of organization is struggling to unify and coordinate operations, vendors, suppliers, staff services, etc.—spread over thousands
of miles and several time zones. This driving force will quickly be the norm for coalitions as well, as they deploy around the globe.

Modern technology and increased communications capabilities have provided tools to help, but studies have demonstrated that organizations attempting efficient distance collaboration using standard tools suffer an unmistakable penalty in effectiveness. Coalitions will be faced with a difficult dilemma: they need the agility and efficiency associated with a central environment, but cost and personnel pressures are forcing their organizations to disperse.

1.1 Need for Coalition Intelligence and Knowledge Management

The coalition of 2010 must have excellent intelligence to support C4ISR activities. This means that intelligence must be gathered on a truly global basis, and it must be shared throughout the coalition. This is a technical problem that involves the timely fusion of sensors, HUMINT, open sources, and military data into a cohesive, consistent, situation awareness capability for the coalition. This, in turn, will lead to decision and information superiority. This paper will address this problem and will provide some technical solutions. A major issue must also be addressed, and this involves the human side of intelligence fusion. Specifically, there is a general reluctance to share information and data across agencies and throughout the coalition. This limitation is driven as much by culture as by a lack of available resources. Admiral Tuttle (see Selective Bibliography) states that this lack of sharing intelligence information is driven more by antediluvian laws than by capability. According to Admiral Tuttle, the architecture for decision superiority will need to be:

- Pliable and malleable
- Seamless
- Scalable
- Network centric
- Consistent with system of systems concept
- State of the art
- Highly reliable and secure
- High performance
- Compatible with collaboration tools
- Interoperable

He states that “the alchemy and door of success will hinge on the exploitation of information technology, the sharing of information and intelligence, and trust.” This trust issue must be addressed to allow coalition interoperability.

Even as we discuss these enabling technology solutions, it is important to remember the words of T. Michael Elliott, Executive Director of IEEE Computer Society, when he stated, “As we enter the next century, the most critical forces shaping the intersection of computing and culture will be social, not technical, as we come to recognize that cyberspace is not just the pop name for a METANETWORK, but a new dimension for human discourse that is effectively as real as physical space.” He points out that the rules that have been used in the past to govern the relationship of people, society, and physical space will not be able to cope with the new
fascinating interactions that will be made possible with technology. This will necessitate new rules, and as Admiral Tuttle points out, it will require a culture change and renewed trust. Unless this takes place, enabling technologies by themselves cannot provide true coalition interoperability.

The management of knowledge throughout the coalition will be very critical to its success. Knowledge, intelligence, and information must be used by the enterprise and shared by all. In order to handle knowledge effectively, there will be a need for collaborative planning and distributed collaborative planning. In this way, all of the distributed knowledge will be used to provide effective solutions for applications that include:

- Supply chain management
- Distributed design
- Crisis management
- Coordinated operations
- Emergency medicine
- Smart information retrieval and dissemination
- Effective reduction of information overload
- Distributed modeling, simulation, and wargaming
- Training on the fly

The Electronics Industry Alliance is performing a study of critical technologies that will enable information technology solutions for their government customers. In this study they are addressing the following technologies that can be used to support Collaborative Work:

- Collaborative learning
- Intuitive human machine interface
- Immersive 3D environments
- Autonomous, adaptive software agents
- Intelligent agents and avatars
- Distributed virtual environments
- Distributed knowledge management
- Collaboratories (labs without walls)
- Loose integration technology
- DARPA Advanced Logistics Program (ALP) agent technologies
- Collaborative Engineering Environment (CEE) sharing of domain-specific design tools

### 2.0 Selected Examples

This paper will not be able to address all of these enabling technology solutions, but rather it will feature a subset of the solutions in a little more detail.

Next, four examples are presented that address solutions for part of the collaborative integration problem. These are:
1. Navy DD-21 Collaboration that uses loose integration technology to satisfy the virtual ship ashore requirement

2. Defense Information Systems Agency Virtual Command Center that uses commercial off-the-shelf (COTS) solutions to provide a virtual three-dimensional world to aid the military decision makers

3. A Navy Surface Weapons Center Collaborative Environment that integrates human operators and decision makers in a human-centered design of complex systems

4. Defense Advanced Research Projects Agency Advanced Logistics Project that uses complex agent societies to facilitate supply chain management across the entire enterprise

2.1 Example 1: The Navy’s DD-21 Program and Collaborative Integration

The US Navy’s DD-21 program is a good illustration of a problem that needs collaboration. DD-21, as shown in Figure 2, is the US Navy’s next generation surface combatant, and it is under design by a team of companies. The traditional ship in this general class, DDG-51, has a crew of over 300 and operates like a small self-contained town, complete with on-board services for everything from banking to training and administrative records management. Lifecycle costs for DDG-51, driven largely by crew size, are unacceptably high and have forced the US Navy to require that DD-21’s crew be less than 100, a reduction of two-thirds.

Figure 2. DD-21 Program

To achieve this reduction, whole departments must be moved ashore, distributed across the United States, reduced in number through automation, and linked back to the ships—without sacrificing effectiveness. This concept is called Virtual Ship Ashore (VSA). The DD-21 requirement to reduce staffing levels by 66%, yet work effectively despite the distributed environment, is typical of what coalitions will require in an age of shrinking budgets and distributed coalition members. The coalition environment must not only handle the “hotel” functions shown above, but they must be able to work together to accomplish:

- Targeting
- Joint operations
- Sensor fusion
- Joint situational understanding
- Joint bomb damage assessment
- Coalition planning

These functions, in turn, cause a major need for the true integration of heterogeneous systems located throughout the coalition. This is the environment that this “loose integration” technology solution can address.

In a traditional ship, complex, multi-disciplinary tasks such as the processing of a promotion review board are relatively easy. All the needed resources are located together, and officers can work together to exchange information and solve problems. This changes in the VSA concept: once sailors and their functions leave the ship, they become part of the culture of their new home. In essence, the captain is now in charge of a “virtual corporation”—a federation of autonomous corporations trying to work together as shown in Figure 3.

![Figure 3. Virtual Ship Ashore Concept](image)

**Technical Objectives for Collaborative Integration**

Even after being “deconstructed,” the new organization still contains the information and processes needed to operate effectively. Unfortunately, these resources are fragmented by time, distance, culture, and heterogeneous information systems. Clearly, this fragmentation will be a major cause of “friction” in this new organization, and the goal of the required research and development effort will be to assemble a composite information system to overcome these problems. These same techniques are needed for coalition collaboration and integration. Note that this has a major impact on the requirements for intelligent search and retrieval as well as knowledge management. This will require an extensive set of tools to search information
throughout the organic system as well as smart intelligent agents that can browse the global Internet to find the required information. In addition, standard architecture, IT standards and common operating environments must be considered in this approach.

One R&D solution is being developed by Litton PRC and will be described next in this paper. It is called Collaborative Integration (CI), and the technical objectives are as follows:

- **Development and Demonstration Testbed Environment** – Design and implement a testbed to realistically simulate a wide range of collaboration environments with different applications including collaborative military system designs, C4ISR operations, and coalition supply chain management.

- **Design and Develop Loose Integration Toolkit (LIT)** – Develop an innovative integration technology that will make practical the integration of disparate data and human resource elements in a virtual command and control environment.

- **Apply LIT to Collaboration Problems** – Apply the Loose Integration Technology to the challenges of linking the heterogeneous elements of the distributed nations, enabling them to collaboratively perform the functions of leading and managing project tasks, making decisions, and accessing information and processes to achieve coalition-wide situational awareness and mutual understanding.

**Technical Approach for Collaborative Integration**

**Development and Demonstration Testbed Environment**

The initial Collaborative Integration testbed focuses on a specific example, the DD-21 collaboration environment, and thus must include ATM networking and realistic satellite linkages for wide area networks.

**Design and Develop Loose Integration Toolkit**

CI will confront the challenge of enabling collaboration in an environment where information, processes, and authority are all distributed and the coalition partners have heterogeneous technologies. Additionally, collaboration must take place between coalition members whose “connected” time does not overlap and who are unable to depend on continual connectivity. Within these constraints, the approach best suited to represent and facilitate integration among these collaborative entities is intelligent software agent technology.

These Collaborative Integration agents will demonstrate aspects of the following attributes required for coalition operations:

- Autonomous – manifesting proactive, goal-directed behavior
- Adaptive – learning from environmental conditions and responding appropriately
Intelligent – acting on abstract task descriptions and general goals using knowledge about available methods
Mobile – changing physical location in order to achieve goals
Collaborative – working with other entities to achieve goals

Apply Loose Integration Technology to Coalition Collaboration Problems

Two classes of collaborative integration problems are used for this approach.

The first is enabling free and easy access to relatively static, computer-based information and processes distributed throughout the virtual coalition. Organizations and individuals will expose portions of their information and processes to external access through trusted agents. A key element of the approach is the specification of enterprise description knowledge bases, enabling agents to work around unforeseen problems (such as network congestion, enemy jamming, electronic warfare, or information warfare) and to locate resources throughout the coalition that can be applied to the problem at hand. Typical coalition applications include supply chain management, C4ISR Modeling and Simulation, Coalition Planning, and C2 Decision-Making.

The second is enhancing the ability of human users to interact for “live” consultations using existing media projection tools such as Microsoft’s NetMeeting, MITRE’s Collaborative Virtual Workstation, NuVenture’s Rooms Collaborative Software Solutions, and General Dynamics’ Coalition Video Teleconferencing and Information Work Space. The goal is to focus on the creation of an artificial “shared space” occupied by the civilian, military, and coalition policy decision-makers composing a virtual workgroup. This will artificially recreate the “look and feel” of a central C2 or C4ISR environment, providing clues regarding the presence, location, and availability of others in the coalition, as well as identify available C4ISR sensors. These resources will then be assembled to provide a virtual meeting environment that will address the operational problem. The results will provide viable solutions to multi-national coalitions to address C4ISR, IW, or natural disasters.

2.2 Example 2: DISA (Defense Information Systems Agency) Virtual Command Center

The Defense Information Systems Agency is also addressing collaboration for a military cyberspace application to modernize the current C2 (Command and Control) infrastructure with their Virtual Command Center (VCC). They are using Virtual Reality (VR) technologies to facilitate the VCC. This military application has many similarities and drivers to the DD-21 VSA description. In the past, the commander’s staff have been centrally located and operating in a hierarchical manner. To achieve information and decision superiority, military commanders must maximize their presence or awareness of events across the military theatre. In addition to the modern computers and communications, DISA (Hill, Dockery and Archer) are using VR. VR allows the commander to transform human sensory operations in the real world to virtual computers generated worlds such that the decision makers feel as if they are there. For the VCC, DISA used WorldToolkit® and World2World®. This software supported distributed networked simulations and interface devices, including head-mounted displays, trackers and navigation controllers, in a client server environment.
The VCC has features that include:

- **Tactical Sandtable** – multidimensional environment that allows the military decision makers to manipulate elements such as tanks via a mouse and allows the users to get the “look and feel” of various hot spots in the battlespace.

- **River World** – Military personnel can attempt to “cross” a river as well as “fly” through the battlespace to determine terrain and the river’s water level to allow them to consider various options for fording, bridging, and ferrying.

- **Collaboration** – Users run the VCC application from their own workstations and they are immersed in the shared environment being represented by avatars that are three-dimensional representations of the users. These avatars can move about the River World and the Sand Table, interact with other avatars, and communicate back to their users.

- **Immersion** – VR allows the users to be immersed in the VCC environment and use their natural cognitive and perceptual skills.

There is still considerable controversy over the final implementation of these virtual environments. The VCC uses a Virtual Reality approach with success, but there are other less costly alternatives such as Distributed Virtual Environments (DVEs). The DVE described by Waters and Barrus allows distributed users to interact, although the environment is not immersive.

### 2.3 Example 3: Collaborative Environment for Human Centered Design of Complex Systems

The Naval Surface Weapon Center (NSWC) has addressed an integrated engineering environment to facilitate the roles of human operators and decision makers for large complex systems engineering projects for the 21st Century. Crisp, et al, have developed a prototype of a human-centered design environment that will enable the required collaborative design activities. This work is supported by the US Navy’s SC21 Manning Affordability Science and Technology Initiative. The project will provide a collaborative framework that enables multi-disciplinary teams of engineers and scientists to design on an interactive basis. They address the full range of engineering tradeoffs throughout the life cycle of the design. They are especially wary of the human systems aspects of the design and this facilitates the culture and trust issues that were mentioned earlier.

Figure 4 indicates the collaborative engineering activities that are envisioned. It uses a client server environment that allows domain specific tools to share common design data and requirements information. This allows the transition from one design activity to another. The collaborative project must support:

- Design Configuration Management and Versioning
- Schema Editor and Evaluation
- Traceability
• Integration Toolkit
• User Access Control
• Automated Metric Collection and Report Generation
• Distributed Collaborative Operation

Figure 4. HCDE Collaboration

2.4 Example 4: DARPA ALP and COUGAAR Tools

DARPA has started an Advanced Logistics Program (ALP) to support innovative approaches for military logistics. ALP is developing and demonstrating advanced information technologies to control the total logistics supply chain. These enabling technologies will support logistics and associated transportation assets to be deployed, tracked, refurbished, and re-deployed in an efficient manner. ALP was built as an end-to-end logistics (factory to foxhole) system to address materials, supplies, equipment, personnel, and transportation. It is intended to cross all levels of the military hierarchy with clear executive oversight of the process. The system is intended to be dynamic to accommodate adaptive planning and to generate plans. It has the capability to support distributed planning that was highlighted by VADM Tuttle as a major coalition need.

Figure 5 provides an overview of ALP and it shows the hierarchy of clusters, agent community, and complex agent society as well as the program objectives. The technical approach uses a distributed agent-based architecture as shown in Figure 5. This figure shows the fundamental building block of a cluster. The clusters consist of a similar set of functions and associated components, and these agents are modeled on human cognitive processes. The agent community shown in Figure 5 consists of a group of clusters that can emulate organizations and communities such as those found throughout the logistics supply chain. Finally, the communities can be formed into a society as shown in the right hand side of Figure 5. As can be seen, this complex agent society is composed of agent communities distributed throughout the US or even the world. ALP is developing this information technology infrastructure to allow and enable the military operators and their logistics teams to work together with defense agencies to develop plans that are based on real time data and facts.
The grand challenges of ALP are:

- Automated Logistics Plan
- End-to-End Movement Control
- End-to-End Rapid Supply
- Real Time Logistics Situation Assessment

The ALP technology goals are:

- Distributed agent architecture research
- Distributed information management research
- Real time information fusion research

These distributed agents work together to handle complex logistics problems. As an example, Figure 6 shows the functions of various software agents that are addressing a logistics problem associated with scheduling a business trip. The ALP program provides tools that should prove beneficial to the execution of collaborative integration for a coalition for applications beyond logistics.

The COUGAAR (Cognitive Agent Architecture) project is related to the DARPA ALP program. COUGAAR is intended to be an open source intelligent architecture that is available to the general public. It provides developers with a framework to implement the large-scale distributed agent applications such as those associated with ALP. The DARPA Web site contains additional details on ALP and COUGAAR.

Figure 5. ALP Approach – (Taken from DARPA Web Site – http://www.cougaar.org)
3.0 Summary

The paper described a technology environment that can address the coalition problems in 2010. The paper provided background and insight to the nature of the coalition collaboration problems that need to be addressed. Alternative technology solutions are introduced and are addressed, including:

- Litton PRC Collaborative Integration Program
- DISA Virtual Command Center
- NSWC Human Centered Design of Complex Systems
- DARPA Advanced Logistics Program

Future coalition solutions should be able to take advantages of these enabling technology solutions to evolve an acceptable hybrid composite system.
Selective Bibliography


Franklin, Jude E., “Enabling Technologies for IT”, EIA GEIA Technology Forecast, 1 November 2000


Franklin, Jude E., “Enabling Technologies for I.T,” GEIA Enabling Technology Conference, 21 September 1999


Krygiel, Annette J., “Behind the Wizard’s Curtain,” CCRP Publication Series, July 1999


VADM Jerry O. Tuttle, USN (Ret.), “Decision Superiority and Intelligence,” SASA Colloquy April 2000

Waltz, David and June Hong, “Data Mining: A Long Term Dream,” IEEE Intelligent Systems, Nov/Dec 1999