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UK/US naval interoperability collaborative rersearch

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Abstract

This paper outlines a collaborative program of work being carried out under an agreement between the US and the UK which started in January 2000 and is due to continue for four years. The research and is looking at the operational problems of coalition force interoperability initial from a naval perspective at the command and combat system level but then moving to a wider domain to cover both land and air participation. Details are given of why the research is necessary, the objectives and the approach being adopted. It then provides some information on the experiences gain from the initial trials which have been carried out during the first six months of this year.

1. Introduction

Successful deployment of interoperable systems is essential in the emerging era of network-centric warfare. Increasing reliance on joint and coalition forces to achieve naval objectives has made more urgent the need for operational integration of diverse naval combat systems. The rapid introduction of Commercial-Off-The-Shelf (COTS) technology aboard ships, particularly information technology, has yielded many benefits, but has resulted in new problems as well. There is a pressing need to address some of these issues before the operational units are deployed into a hostile environment, at which time the lack of effective interoperability may adversely effect the ability of the participating units to work together. In this paper a collaborative research programme is outlined giving details of the overall objectives and the initial progress made so far towards achieving those.

2. Objectives

Under the auspices of the US-UK Memorandum of Understanding (MOU) concerning Technical Research and Development Projects (TRDP), a new collaboration programme on Naval Combat System Interoperability (NCSI) has been negotiated to evaluate how naval combat systems can be integrated for effective coalition force operations at platform and task force level in the context of the performance constraints associated with technical aspects such as architectural choices for such systems and the command issues such as interpretation of information.

It is the intent of this collaboration to expand the capability of both the UK and US defence communities to evaluate candidate technologies and architectures to improve the effectiveness of such operations. To that end, a set of UK test-beds will be integrated with each other and with a similar set of US test-beds to permit testing of greater scope. The first of these sites will represent the various naval domains (i.e. surface and subsurface) and, initially, the experimentation will address command level information exchange between the US and UK combat systems. The investigation will then move on to address the feasibility of task force integration at the sensor data level aiming at the final objective of allowing full naval task force data fusion to be carried out. Later stages will be expanded to include both the land and air elements of a combined task force.

The first stage of the project is being conducted as a joint effort specifically addressing information system architecture support for interoperability. The expected payoffs include:

- a wide-area network-based experimentation and interoperability capability that encompasses surface and subsurface combat systems for both the US and UK navies and is capable of addressing coalition force issues,
- understanding of the technical constraints and necessary architectural standards for assuring effective interoperability of naval combat systems,
- a modified design process for combat systems that reflects architecture-based development and standards-based architecture.

It will in the longer term provide a facility which can be employed to test out the coalition force capabilities in all areas of command, weapon and sensors fits before they are deployed in future platforms.

3. Scope of the Collaboration

The following work will be carried out under the agreement. It will be divided into several phases each of which will culminate with the generation of a demonstration to be carried out jointly between the two participants to show the achievements of the research work.

Phase I. Design, implementation and interconnection of NUWC and DERA Portsdown Open Systems Test beds to be utilised for a limited demonstration of COTS/OSA technology. This will allow for a one to one link and provide proof of concept for the future experimentation at the hardware level . It will also set the foundation for a common sim/stim capability to drive the experimentation and cover the exchange of basic picture information. The major activities are firstly to establish the link by the passing of tactical picture data and associated scenario information through the existing CORBA and DIS links and the sharing of control by both sides

Phase II. Design, implementation and interconnection of OSA test beds at NUWC, NSWCDD, DERA Portsdown, and DERA Winfrith to support an expanded demonstration of US NSSN and SC21 OSA technologies and UK CSTDF/CSI COTS/OSA technologies. This will expand on the levels of information which will be transferred between the systems and form the basis for the investigation of sensor information exchange which will enable additional data to be passed using CORBA and HLA or DIS.

Phase III. Advanced interoperability demonstrations using US and UK COTS/OSA technologies. This will expand on the level of complexity in the type of scenario and interaction between the sensor and command aspects of the systems and investigate the task force implications. It will also address the integration of information into the scenario from other than naval sources and examine the increased level of complexity this will generate.

4. Background

4.1 *Scope and Nature of the Application Domain*

The naval combat system is a complex development challenge. The system typically incorporates extensive information processing capabilities. The electronics fills an attack center manned by numerous skilled console operators. The software runs to nearly ten million lines of code.

This extremely large man-machine system operates in real-time to transform data from thousands of sensor elements into information on which the attack center staff predicates decisions that effect ship control/maneuver, identification, classification and localization of contacts, and deployment of weapons and countermeasures. The system must operate effectively twenty-four hours a day for months at a time. It must be resilient in the face of attempts by outside forces to manipulate, confuse, and defeat it. It must be maintainable in situ by the crew that interacts with it. The most important time for it to operate with maximum efficiency is when it is completely overloaded. Obviously, operability is a major concern with a requirement for information display to operators to be highly intuitive so as to minimize reaction time and maximize optimal decision-making.

Because the combat system is so large, it must be subdivided into smaller parts to facilitate its development. Intellectual control over the development could not be attained without doing so. Also, the parallel development activity that results reduces the development cycle time. Experience has shown that the down side is a challenging integration activity at the end of the development cycle where available funds and schedule are always most strained.

Because combat systems are so expensive, there is a need to construct them from already available modules or ones previously invested in. It is not feasible to throw the previous generation combat system away and start the new development from scratch every few years as appears to be the process in the commercial world. Thus, the notion of "reuse" of previously developed items and the adoption of COTS technology is particularly attractive.

Also, because combat systems are driven by the need to meet real time performance constraints, it is important to take advantage of rapid advances in hardware and software technology. To assure that performance goals are met, it is important to design the system in such a way that it readily admits the replacement of components with more advanced technology that provides performance gains. Thus the concept of an open architecture is of more than passing interest.

It is clear that modular construction, open architecture, COTS technology, and re-use of available components are attractive notions as regards combat system development. In a real sense, the combat system is an interoperable system of subsystems. The most recent challenge for the naval platforms is to further require that these combat system as a whole interoperate with other fleet combat systems to prosecute battle force, joint, and/or coalition force missions.

4.2 *Interoperability and the Combat System*

In a development world centered on the reuse of COTS piece parts, the traditional definition of "development" becomes obsolete. Instead, the development activity becomes predominantly an integration and test activity. That integration and test activity is aimed at achieving an effective assemblage of linked subsystems that must interoperate effectively to provide a platform-level combat system capability. As has been noted, that platform-level combat system must also be capable of interoperation with other platform combat systems to achieve successful collaborative prosecution of battle force missions.

It is instructive to consider the source of the interoperability mandate. There are three seminal factors at play here. They are the reduction in defense budgets, the expansion of mission requirements, and the emergence of casualty avoidance as a priority in armed conflict. The reduction in defense budgets has resulted in a significant consolidation of defense industry and a significant reduction in the size of defense forces, thus reducing the marketplace for defense products. These, in turn have led to increasing partnership (among corporate entities, between government and industry, and among the defense acquisition activities in allied countries) in developing such specialized products as combat systems. The expansion of mission requirements and the casualty avoidance mandate have contributed to a significant expansion of information needs. In the one case, new missions result in new information being needed to deal with previously unprecedented activities. In the other case, avoiding casualty means having information of such a precise nature that physical risk to combatants and non-combatants alike is minimized. The casualty avoidance strategy, coupled with the expanded information needs results in an increasing focus on information warfare as the first best way to fight. The fact that defense forces are smaller and yet require greater information assets means that coalition force operations are more and more the norm. The net result of all of this is that interoperability is a key performance objective for combat systems of all kinds.

It is clear that interoperability is a highly desirable attribute for a combat system. It is much less clear how to achieve interoperability goals through application of specific design guidelines. Intuitively, use of COTS products and open architecture are important to cost-effective achievement of interoperable systems. However, there is much confusion in defense acquisition circles over what the terms mean, much less how to achieve interoperability. Too many acquisition managers are ready to proclaim salvation from adoption of COTS-based development and/or OSA without really understanding the impact of their decisions in this regard.

It may even be the case that COTS technology is in conflict with the mission critical environment. Military systems would certainly benefit from the ability to rapidly insert components with improved technology. Leading edge capability at the earliest moment is highly desirable. Therefore, rapid insertion of COTS technology supported by open system engineering of the combat system appears inherently beneficial. However, consider that the military environment demands assured, intuitive operability of the combat system. Commonality of user interface has a very high priority if operators are to do the optimal thing instinctively. But the very fact that there are competing products in the marketplace derives from their differences, not their commonality. If they did not have some claim to uniqueness they would have no place in the market. Thus, the diversity of implementations deriving from the COTS marketplace considerations poses operability risks in an open system environment. An important problem then is where to draw the line between *identicality* which preserves operability and facilitates interoperability and supportability, and *diversity* which provides for the fastest availability of advanced capability, avoids obsolescence, and precludes vendor lock.

There are a number of other problems and weaknesses attending to COTS-based development and open architecture as well. Among these are:

- How to test and certify a system incorporating COTS components for which there is no design disclosure
- How to handle configuration management in a COTS environment where items with the same product model number may in fact incorporate different sub-elements with subtle performance differences
- How to compute the total ownership costs of COTS-intensive systems
- How to change budgeting paradigms to support the shorter technological refresh cycles and early obsolescence of COTS products
- How to provide fleet elements with a unified logistics support capability that embraces COTS products
- How to define objective measures of openness of architecture

5. TRDP Programme

The objectives of this TRDP is, through the design, implementation, integration and utilisation of a set of interconnected Open Systems Architecture Test beds, to:

- leverage US and UK technology insertion programs in support of combat system design for present and future operational platforms through mutual participation in planned test events and demonstrations;
- establish a capability for wide area network-based experimentation to address the evaluation of integrated Naval combat systems for effective coalition force operations at platform and task force levels;
- collect data on the facility with which commercial hardware and software technology components can be integrated with existing naval combat systems and new systems employing heterogeneous components;
- identify issues associated with the naval combat system data interchange at the command and sensor level; and
- evaluate, through experimental application, the effectiveness of advanced techniques and tools in support of the construction, acquisition, and through life upkeep of naval combat systems.

6. Initial experiments

As indicated by the Phase 1 description the first task will be to set up the basic communications link and identify the commercial technology that is available to support the exchange of combat system data. There is every reason to believe that while there are claims made by industry that they have the technology there will need to be a considerable amount of effort spent in producing an effective communication network with the necessary levels of reliability in all areas. This will form the base for future work and will be used to resolve all the issues associated with the 'understanding' of the data which is exchanged. It will need to investigate the format and structure of information, the information architecture, and allow both sides to reach an agreement on their interpretation of that information within their own environment. There is no point in exchanging data that is not useful and the early tests will need to identify the basic levels that are acceptable by the two systems in terms of enhancing the system capability with the introduction of new information but at the same time not overloading it with useless data. There will be several tests over the first period of the TRDP culminating in a demonstration of the basic capability to exchange combat system information on a common scenario synchronised between the two sites. It will also demonstrate the management and control software that will be needed to support the running and monitoring of future experiments.

6.1 *Interoperability between Surface and Subsurface Platforms*

In a more general subject area, it will be necessary to investigate the relationship between a subsurface platform and surface platform and the transfer of information between them. It will be necessary to investigate the use of current datalinks (11 and 16) or other message formats and to consider whether the present operational procedures are acceptable in the new network centric environment. It might be an appropriate time to consider how best to handle the coalition force information in this situation as distinct from the present data link scenarios. Although existing L11 and L16 include some subsurface message formats they have been used little to date

As has been indicated above the first set of experiments will involve achieving basic synchronisation and interoperability between the two systems this will lead onto the more network centric aspects of the coalition force environment.

Large scale information transfer involving submarines is likely to be performed on a spasmodic basis, enabled only when a submarine is in contact with a surface platform. The purpose of this area of research is to determine:

- The effect on the above water platform of integrating such spasmodic and time varying information from a submarine into the rest of its tactical picture involving organic and non organic wide area non real time information.
- The effect on the under water platform of integrating real time information into its picture and subsequent handling of that data in terms of staleness, predictions etc.

This will build on the previous set of experiments which will have identified the types of information that could be exchanged and how this could be managed. The aim at this stage will be to compare the pictures compiled in the relevant surface and subsurface platforms particularly as time progresses without refresh, to determine whether the degree of drift between the actual and perceived positions outweighs the initial transfer of information and whether better staleness or prediction measures could be used to improve the pictures. It will also allow some assessment of the best options for interoperation between the surface and subsurface platforms in terms of the procedures covering such aspects as frequency of contact and amount of data exchanged.

6.2 *Sensor Triangulation*

As an example of the type of problem in the sensor domain the area of sonar triangulation would involve the use of the CSI test bed as a future UK surface platform with say only a passive sonar capability and the NUWC WAIF as the US subsurface platform with both active and passive sonar. The aim will be to investigate sonar triangulation between the sonar data from the surface and subsurface platforms initially using techniques developed for EW.

The first part of the task will be to determine what associated research is available within the UK and the US including:

- above water passive EW triangulation techniques
- land EW techniques.
- underwater passive techniques.

It will then be necessary to determine the level of information to be passed between the surface and subsurface domains to perform the necessary calculations depending on the chosen methods to be investigated. The foundations for this will have been set during the earlier information architecture investigations.

The first part of the experiment will be to exchange information between the UK surface and US subsurface pictures including:

- synchronisation data to allow time and grid synchronisation to be achieved;
- basic tactical picture data particularly surface platforms in the scenario which can be used correlate the above and underwater pictures.
- the agreed passive sonar information;

Once the basic exchange of messages is achieved then a sonar triangulation trial can be performed. Experiments will then be carried out to widen the scope of the sensors being considered and to identify how best to utilise the data available from both ‘platform’ test beds

This will form the basis for the next main area of research which will be addressing the data fusion and picture generation in a coalition task force environment.

6.3 *Force Data Fusion*

Once the US network has been extended to link to other US surface platform testbed facilities and the UK end has a similar extended capability, issues such as force data fusion across the coalition surface and subsurface platforms can be investigated. This opens up the possibility for investigating:

- The different operating characteristics of the UK and US navies,
- The different data fusion methods employed,
- The opportunity to exchange sensor data information at all levels,

It will also provide the ability to investigate the remote use of sensors and weapons such as EW, sonar, torpedoes and missiles between coalition platforms, initially starting with the sub to surface link and then expanding to the different platforms in the network. The network at this stage should be capable of allowing land and air platforms to be integrated as part of the environment and the full coalition battle space scenario addressed, building on the experience gained from the earlier investigations and experiments.

A further area for investigation will be extending the experiences gained from the investigations into the spasmodic type of interaction to see if any of the lessons learned can be used in setting set up the joining and leaving procedures for a platform and a force network in terms of what is required and how it is controlled.

7. Effectiveness of Collaboration

In parallel with the research identified above, a major activity during this work must be the identification of measures of effectiveness for coalition force activities. While it may be possible to exchange information it is essential that there is some means of assessing the effectiveness of what is being achieved. This will need to take into consideration both the national and coalition requirements and to what level the coalition platform systems will be integrated into a task force unit. It will of necessity not only address the technical issues but will have to deal with the command and doctrinal issues which will arise.

8. Experience gain

The configuration of the collaborative system set up so far is shown in figure 1, this identifies the network connectivity which has been used for the initial tests/trials to prove out the connectivity and the capabilities of the system as a whole and also to allow those involved to work out the necessary operating procedures for the interactions.

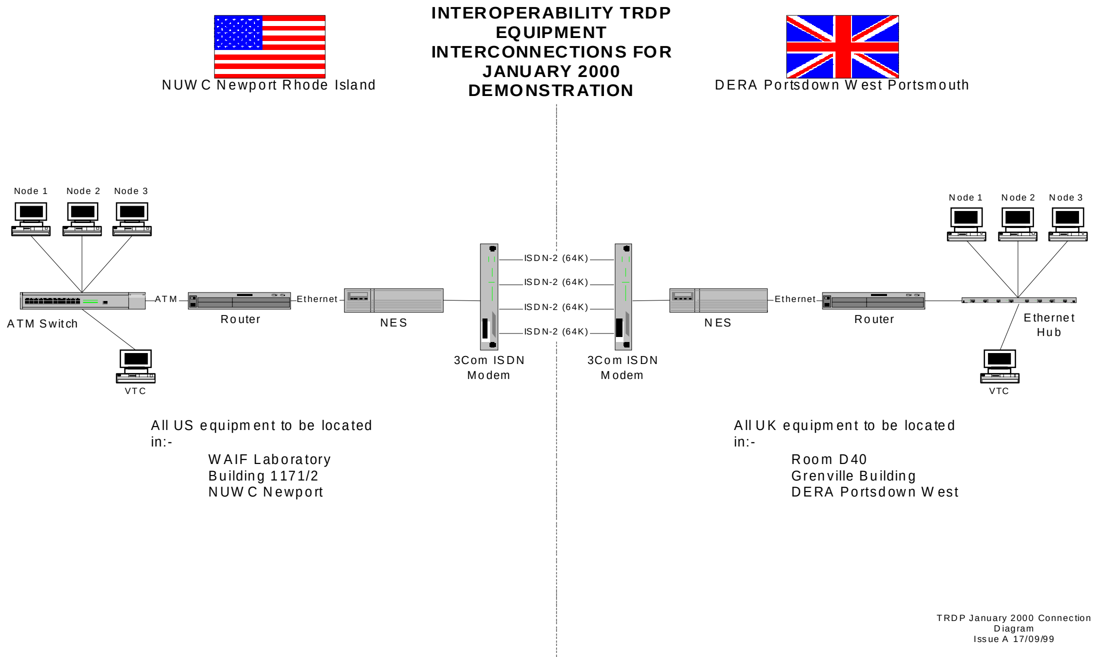

Fig 1 UK/US connectivity

The two sets of heterogeneous workstations are linked to their own internal networks at both sites. The sites are then connected using a Remote Access System (RAS) and Motorola Network Encryption System (NES), via ISDN lines.

The RAS provides terminal server and remote access services via analog and ISDN BRI &PRI connections in a multi-protocol network environment. It consists of a base router module, port expansion module and user installable I/O modules and it integrates multi-protocol remote access server and WAN router technology with high performance 56Kpds (V.90) and/or ISDN modems.

The NES is used to provide the security needed for the exchange over the link. It is a security device designed to Secure Data Network System (SDNS) standards endorsed by NSA, providing confidentiality, data integrity, peer identification, authentication and audit services. They are configured to customer hardware requirements and are user software configurable at the application software, Identity Based Access Control (IBAC) table and static routing tables level.

From the UK point of view the four ISDN lines have not worked out as expected. The actual bandwidth is not fixed and this has caused problems. The situation seems to be that no bandwidth is guaranteed and even though they are 128k lines they may not be operating at that level. This unpredictability has meant that on occasions the service over the lines has not been adequate to support the level of communications required.

There has also been some problems with RAS which on occasions does not seem to be able to cope with line failure in a controlled fashion. When one line fails or drops the RAS does not look for the next available line but shuts itself off or crashes.

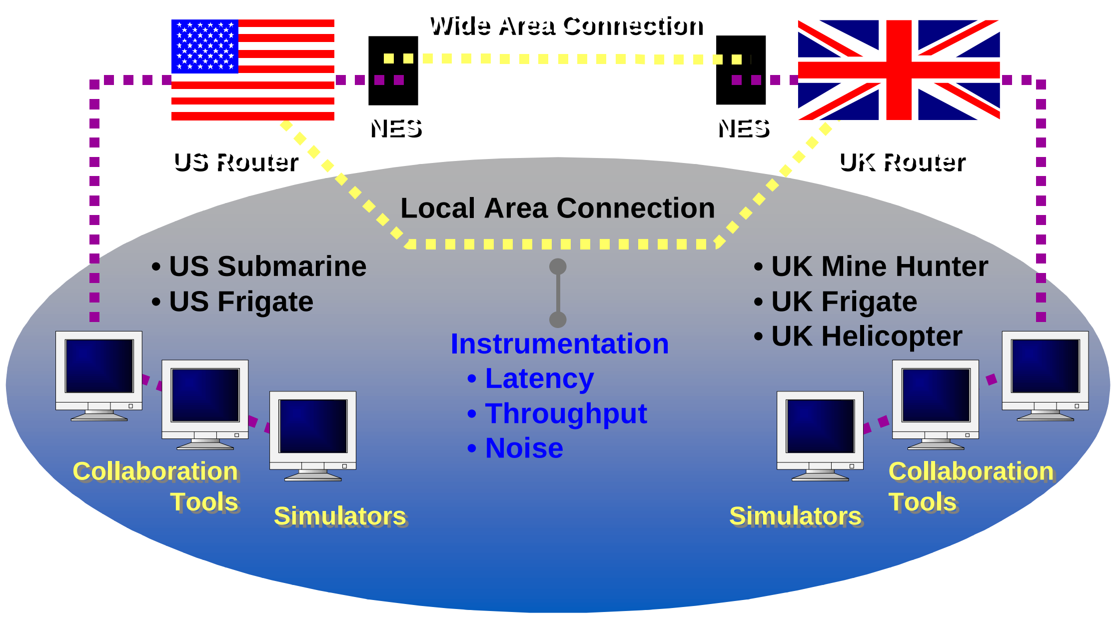

Fig 2 Trial configuration

It is clear from the experience gained so far using the configuration shown above that there is a need for very sophisticated monitoring capabilities at all levels to provide the information on what is happening at all times in the network. For example one of the things we noticed is that the audio signal does not seem to be given priority over the video during a video conferencing session but we are unable to monitor the network well enough to see if this is the situation or not.

Another problem which has been manifest on the UK side is the need for more heterogeneous equipment to provide the ability to run a wider range of software for evaluation rather than the under powered set of PCs which are available at present. As an example, the limited capabilities of the current equipment means that unless the machine has a separate video board fitted then the processor is fully loaded handling the video requirements of the camera alone.

This aspect is also significant if we are to use the most up to date collaborative software packages for the interaction. Our present capability restricts what can be used and tried by the lack of processor power as mentioned above and the restrictions caused by the use of the Windows NT environment.

It is also important for someone within the team to have a detailed understanding of the tool being used and to know how to configure it to provide the best results for use on the specific network. An example is our use of Microsoft NetMeeting where there may be a problem due to the incompatibility of the package size between it and the NES when there is a high transfer load but again the monitoring is not good enough to be able to identify this specifically as the problem. On the other hand the ability to share the desktop under NetMeeting is a significant benefit to our ability to work together and the product, although very much a generic tool, has been easy to use while the more specific 'in house' tool has had some problems. These may well have been associated with our limited understanding of it and the need to match it to our configuration.

From our limited experience so far these important points can be made:

- when putting this type of network together the ability to 'try before buy' in both the hardware and the software domain is necessary
- the need for a close market technology watch to see where things are heading and who the lead players are. (It's no good selecting a piece of hardware/software if the vendor is moving out of the market and will not be supporting it much longer even if it does seem to be what is required at the time.)
- someone within the team must be an experienced user of any tools to ensure that they are used effectively.
- there needs to be an heterogeneity within the workstation fit to benefit from the ability to run different tools in their appropriate environments.(In this type of research, one size does not fit all)
- adequate system wide monitoring is essential to find out what is happening when things don't work in the way which was expected.

9. Summary

The adoption of an early integration testing approach in the development of complex systems has proven to be a success. In fact, the U. S. Navy has since embarked on the establishment of a Distributed Engineering Plant (DEP) and a Collaborative Engineering Environment (CEE) modeled on their Wide Area Integration Facility (WAIF) experiences. From an architectural perspective, the development issues and the operational issues are seen to have much in common where test and integration are concerned. This approach is now being employed at the joint/coalition force level and the avoidance of operational problems achievable as a result of adopting such an approach is substantial.

Taken in its broadest view, interoperability is more than just connectivity and communications. Its import goes beyond just command and planning activities to embrace real time sensor data integration among collaborating platforms. The drive for interoperable combat systems is a natural consequence of the increasing emphasis on information warfare, of the increasing reliance on joint and coalition forces to achieve military objectives, of the increasing reliance on commercial technologies, and on the decreasing defense acquisition and research and development budgets. Needing or desiring interoperability is not the same as achieving it however. There remains much to do to bring about the interoperable combat systems needed for success in the era of network-centric operations and information warfare.

As we seek to manage an information landscape that is more comprehensive and diverse each day, it is important to guard against the technological imperative to do things merely because we can. Access to all information all of the time is not the optimal design objective for combat systems. It is not even desirable. We must also guard against the tendency to confuse technology with engineering. Proper use of technology requires that we engineer our systems with careful attention to architectural issues. There remains plenty of work to do. A near-term list might include:

Identifying the consequences of interfacing systems designed to different architectural standards

Developing measures of architectural openness

Overcoming obstacles to wide-area distribution of time critical sensor-to-shooter loops

Determining the extent of necessary commonality in deployed information infrastructure

Understanding and coping with terminological and training barriers to interoperable coalition force combat systems

Identification of an appropriate Combat System Interface Profile to support interoperability

Developing criteria for managing the information landscape

The bottom line objective in the search for combat systems that are both operable and interoperable must never be lost sight of: providing the right amount of the right information to the right place at the right time in the right format.

The experience so far from the first phase has validated the basic tenant that the problems under investigation are not simple. In order for two similar, yet fundamentally dissimilar, systems to work together requires a common understanding of the terminology and ways in which tasks are carried out. The learning curve is steep and progress at times seems slow but at least the problems are being identified and resolved before the real platforms, and the related costs which that would incur, are involved.