WSOA - Weapons System Open Architecture - An Innovative Technology Framework for Time Critical Target Operations

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Abstract

Weapons System Open Architecture (WSOA) introduces several key concepts and applications that are essential elements of a Network Centric / Joint Battlespace Infosphere application. The real-time redirection of strike assets will be demonstrated using an open systems "bridge" between legacy embedded mission systems and off-board C3I sources and systems. WSOA will establish the potential gains in warfighting capability due to the enabling technologies of collaborative planning, information mining, and adaptive embedded resource management within a Network Centric information architecture.

1 Introduction

Ten years after Desert Storm, conduct of time critical target operations remains one of the most difficult challenges facing US military forces today. Advances in Network Centric Warfare offer the potential to provide timely and coherent battlefield situation awareness. However, substantial obstacles still remain before gains can be realized. These obstacles include legacy software and embedded processors that do not fully exploit available system resources and limited communication bandwidth. In addition, fundamental technology that enables real-time command and control must be developed to react within enemy timelines. Central to this challenge is the real-time redirection of strike assets while en-route to a target. Redirection is achieved using a collaborative exchange of routing, targeting, and weapon delivery information and subsequent in-flight mission rehearsal. Moreover, this must be accomplished using legacy weapon systems and communications architecture.

This paper describes a demonstration program - WSOA - funded jointly by AFRL (Information Directorate), DARPA, the Open Systems Joint Task Force, the Computer Resources Support Improvement Program, and the Joint Tactical Terminal Program. WSOA addresses these needs by providing an open systems "bridge" between legacy embedded mission systems and off-board C3I sources and systems. This "bridge" is used to support internet-like connectivity between command and attack nodes. The foundation of this bridge is the creation of a Common Object Request Broker Architecture (CORBA) layer over Link 16. In addition, application of quality of service techniques and adaptive resource management technologies will ensure the timely exchange and processing of mission critical information by both attack and command nodes in even the most time sensitive situations.

2 Command and Control for TCT Prosecution

The research described here is fundamental to effective command and control in time critical operations. The application of commercial open systems technology to this problem addresses limitations that forestall successful attacks today. These limitations include: 1) Current tactical data link bandwidth constrains the operational utility of systems for collaborative planning and attack of mobile targets. 2) Static resource management schemes reduce the amount of processor and network resources available for real-time planning and target familiarization / mission rehearsal. 3) Finite computer resources of airborne elements balanced against hard real-time constraints associated with normal mission activities.

The airborne Command and Control (C2) node plays an important role in the execution of time critical targets (TCT). As the airborne controller, the C2 node is responsible for updating the strike mission within the context of the overall air strike package. Additionally, the C2 node provides access to complete imagery (either locally or via reach-back to CONUS) and an up-to-date intelligence picture. The attack node uses the C2 node as its repository of current information on targets and the environment to be encountered during the mission. The C2 node provides the redirected attack node the same level of confidence in the mission, the target, and the threat environment that would be available for a pre-planned mission.

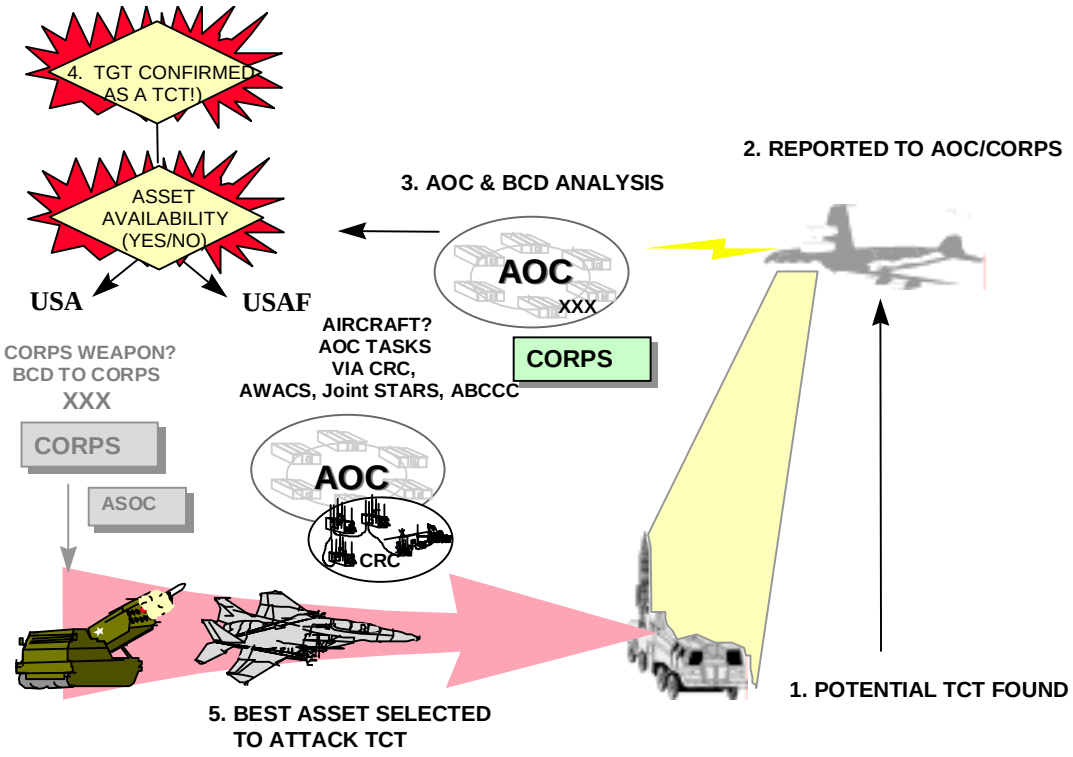

Figure 1 - TCT Prosecution

TCTs arise from the Joint Force Commander's (JFC) mission, objectives, priorities, and the dynamics of the battlespace. TCTs are fleeting opportunity targets designated by the JFC/JFACC

staff requiring an immediate response. This guidance may be set forth in daily situation reports by the JFC in the context of air operations. Once set, trained Air Operations Center (AOC) personnel can determine if new pop-up targets meet established criteria and designate the new target as a TCT. Theater missiles and launchers, surface-to-air missiles (SAMs), diesel submarines with advanced torpedoes, bridges, tanks, elite units, could all be TCTs if the criteria is interpreted as such. The steps involved from locating a potential TCT to selecting the asset for attack are shown in figure 1.

Resolution of the above C2 decisions is only part of the story. In WSOA we take the perspective of the attack node and airborne C2 node and identify how the C2 processes can be implemented in a Network Centric Architecture to enable successful TCT prosecution. Specific details including the scenario are described in the following paragraphs.

2.1 WSOA Scenario

In the scenario, the aircrews depart with the detailed plan developed using the most recent threat and other (e.g., weather, reconnaissance photos, etc.) data available in the hours prior to departure. The data used to plan the mission and the overall strike package tasked by the ATO may therefore be hours old by the time that the missions are executed. In the interim, threats may change, higher priority targets may emerge beyond the pre-briefed target list, updated reconnaissance and battle damage information may be available, and threats and other elements of the enemy order of battle may have moved.

We consider the case where an en-route F-15 Fighter aircraft is re-directed from its pre-briefed targets, primary and alternate, to an emergent higher priority target (TCT). The time urgency associated with the TCT prosecution make an immediate, detailed en-route re-plan and re-brief necessary for the mission to be successful. Otherwise, the extent of the mission redirection (including en-route target assignments or mission change) would dictate that the mission is deferred to the next day, after a more deliberate ground-based planning process could be utilized.

In order to respond to the emergent / re-allocated target scenario, WSOA will implement an architecture including an airborne C2 Node. The airborne C2 Node will function as the control and reporting center and will be assigned responsibility for "flexing" the ATO to accommodate emergent targets. This function is currently performed at the JAOC level. In WSOA, we are making the assumption that this authority has been delegated to the airborne C2 node by the JFACC. In order to accommodate this role, the airborne C2 Node will incorporate an ATO review and display capability, deconfliction tools, and mission planning / route development and analysis software that will be used to support the mission update. Also, the airborne C2 Node will be provided with tactical communication links providing near real-time threat information, and links supporting en-route communications / messaging with strike elements. The airborne C2 Node will collaborate with elements of the strike package to be “flexed” to form the updated strike plan and package to be constructed in response to the evolving situation. This collaboration will take the form of supporting the creation of the new route plans and target assignments and planning required to enable the selected aircrew to effectively develop, rehearse, and then carry out their time critical missions. Figure 2 below shows the basic elements of the WSOA scenario.

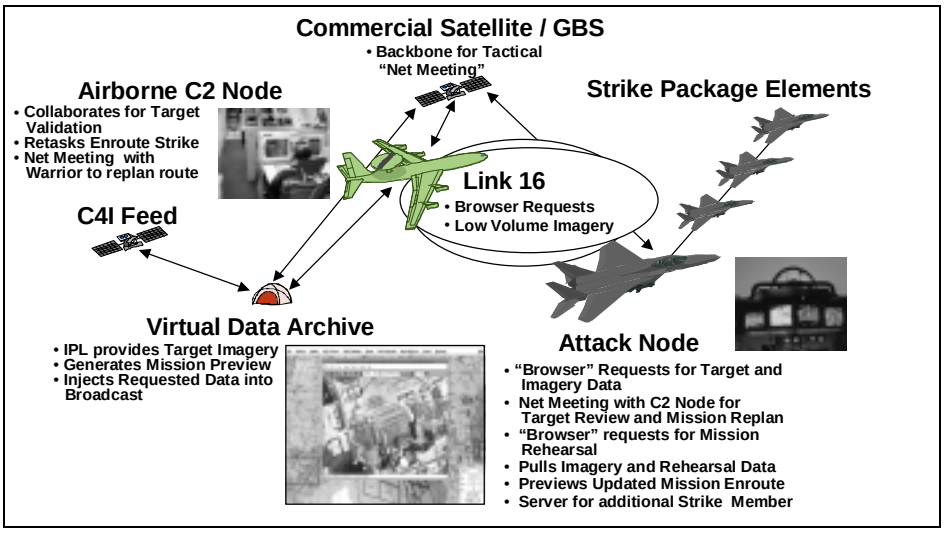

Figure 2 - WSOA Scenario

In it's role as an airborne JAOC, the C2 Node includes an image product library (IPL) as well as a virtual target folder (VTF). The IPL provides access to target imagery on facilities within the Area of Interest (AOI). The imagery could be resident locally (on mass storage on the C2 Node) or could be accessible via a "reach-back" to a ground facility. In theory, the airborne C2 Node could also be equipped with the capability to receive Global Broadcast Services as a source of near real-time imagery or imagery clips via a Joint Tactical Terminal.

Some of the features of IPL are described below. IPL provides the capability to do imagery searches based on multiple user-selected criteria. Candidate searches could include: 1) Provide a list of imagery based on the target facility Basic Encyclopedia (BE) number; 2) Provide list of images available in a region about a point; 3) Provide list of imagery available on a target facility sorted by time of collection, imagery spectrum, etc. The IPL is viewable using a NetScape browser to enable rapid location of appropriate target imagery. IPL also includes thumbnails of the imagery that provides a rapid visualization without the need to open very large images. Images for IPL are generally in one of several formats including: 1) NITF; 2) JPEG; or 3) GIF. Also, the images may be quite large in both area coverage and storage. Most imagery jointly displayed by an airborne C2 Node and F-15 Fighter will require "clipping" to provide right-size imagery coverage and compression to not overload communications bandwidth. The primary purpose of the imagery in the TCT scenario is to provide reference locations that will aid in establishing the relative location of the TCT. We are not assuming that the TCT is in the image - although this could be the case if the image had been produced by an Unmanned Air Vehicle and transmitted to the airborne C2 node.

The following are specific stages of a TCT-based WSOA demonstration. First, the IPL to be incorporated will be representative of a real IPL. The IPL will include imagery of multiple targets within the AOI and include imagery from several spectrums. The airborne C2 Node software will need the capability to: 1) Display the imagery; 2) Clip it to geographic size; 3) Compress it; and 4) Create thumbnail images.

The airborne C2 Node will also provide a virtual target folder. Briefly, a VTF consists of an electronic version of current "hard-copy" target folders. In the WSOA implementation, the VTF will provide the following information: 1) Target identifier - BE; 2) Facility description; 3) Mensurated points and target coordinate locations (DMPIs - Desired Mean Points of Impact) within the facility; 4) Target analysis including critical nodes; 5) Variety of imagery including annotations on the critical / mensurated points; 6) Threats around the target; and 7) Weaponeering information including recommendations for specific weapons and impact angles.

The airborne C2 Node will have responsibility for assignment of the new target to the F-15 as delegated by the JFACC. This may be due to the emergence of a TCT of higher priority than the original target of the F-15, shifting of defenses after the mission was initiated, or the result of recent battle damage information. Update of the target is especially relevant in the case of a strike platform like the B-1B that could have taken off for its mission many hours earlier with intelligence and target information that may be overcome by events. In either case, the airborne C2 Node functions as both a mini-AOC providing updates of the target list, re-assigns targets to en-route aircraft, deconflicts package elements, and works to re-plan the strike aircraft routes to provide high survivability and ensures airspace control.

The airborne C2 Node: 1) Establishes a new target; 2) Identifies the particular strike package element to attack the target based on his review of the in-progress ATO including weapons carried by the aircraft; 3) Initiates a planning process to develop the new detailed attack plan including specific route to be used; and 4) Provides the F-15 with the new target information. For WSOA, the new target update could be provided in the form of an alert (like an email alert) or nine-line brief identifying the target and location. In response to the alert, the F-15 Weapon Systems Officer (WSO) initiates a joint planning and review session with the C2 Node to: 1) Ensure proper coordination of the target attack including DMPI, identifying imagery, and attack tactics; 2) Provide the in-flight route adjustments required; and 3) Review any associated special instructions.

The specific target information is packaged into the VTF by the C2 Node and is available to the WSO for his review. The updated mission plan and supporting information from the VTF are the basis of the collaborative planning session between the airborne C2 Node and WSO.

During the collaboration session, the mission plan may be revised, the route / attack profile modified, threat information exchanged, and imagery annotated. For example, annotation could be used to locate the TCT, identify potential new threat locations or keep-out locations to minimize possibility of collateral damage, or describe intent (enemy forces moving to a particular location based upon some other sources of data). The F-15s will have the capability to: 1) Receive the alert notification of new task; 2) Receive the VTF providing summary target details; 3) Receive the equivalent of 9 line brief outlining the attack parameters; 4) Receive mission update providing display of recommended route; 5) Save and rehearse the plan; 6) Pull from the C2 node supporting imagery associated with the VTF - review thumbnail and primary imagery characteristics; 7) Send browser requests for additional imagery or other information based on defined search criteria (e.g. threats, weather, SAR map, etc.); 8) Fuse it with on-board data, and 9) Save it for use during the attack.

3 WSOA Technology Implementation

WSOA introduces several key concepts and applications that are essential elements of a Network Centric / Joint Battlespace Infosphere application. WSOA will provide the following: 1) Collaborative planning between attack and C2 nodes to respond to emergent targets via a tactical "Net Meeting" to support in-flight re-planning and re-targeting. 2) Information mining by the attack node using "browser" concepts with a virtual target folder to pull data from C2 nodes. 3) Use of tactical communication links including Link 16 to function as a "virtual backplane", supporting browser requests for imagery, targeting data, and other situation awareness information. 4) Order-of-magnitude improvement in Quality-of-Service (QoS) resource management needed to simultaneously prosecute mobile targets and support the hard real-time vehicle management functions.

3.1 Collaborative Planning

The attack node needs to be aware of the new mission and to understand the new environment that will be encountered en-route to the target, at the new target, and upon returning from the target. Collaborative planning also enables the C2 node to view the mission update within the context of the overall ATO. Collaborative planning will be implemented through use of a tactical Internet capability in which the attack node will function like a node on an Internet and request information from the C2 node. We will implement a "Net-Meeting" type of arrangement to enable the attack node and the C2 node to share the same displays and information. In essence, we will build a virtual attack node situation display on the C2 node. The display will be updated with real-time threat information. The display will allow the C2 node to annotate imagery and other products that will be simultaneously viewable via Link 16 in the attack node. In effect, this enables the C2 node and attack node to have a common understanding of the mission update and the environment to be experienced while en-route and over the target. This Internet connectivity is implemented using CORBA over Link 16 via a pluggable protocol. This technology is readily extensible to larger battlespace scenarios encompassing multiple legacy and emerging tactical and command nodes.

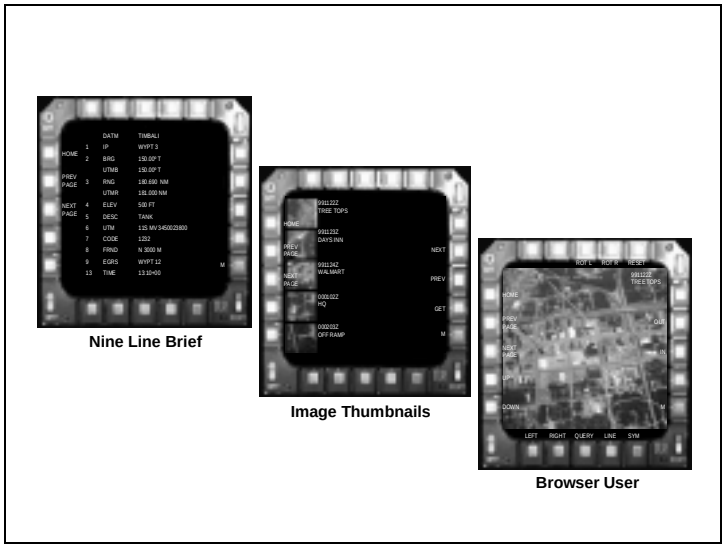

Figure 3 - Virtual Target Folder

3.2 VTF Implementation

One of the concepts central to our WSOA design is the Virtual Target Folder (VTF). The VTF is a repository of information about targets. The VTF concept is conceived as an electronic version of current hard copy target folders. The VTF includes descriptive information about the target, an index of available imagery, designated critical point locations, and threat information in the target vicinity. The VTF can be browsed by target identifier or target location. Figure 3 shows an example VTF display. In WSOA we will prototype the VTF concept and develop embedded system browsing capability consistent with the displays and controls available on the attack node. This will enable the attack node to readily mine the C2 node to retrieve an information package that is tailored to attack node needs. The content, including the level of detail provided within the package, will be adjustable based upon available data link bandwidth and processing throughput available. The package may also include the information necessary to generate rehearsal information required to preview a mission while en-route to the target area. Rehearsal information could include imagery displayed over terrain and oriented along the vehicle flight path.

Generation and playback of rehearsal data is computationally intensive. Application of dynamic Quality of Service (QoS) based technology to dynamically manage/allocate required processing resources while still meeting all hard real-time performance requirements will be demonstrated. This is achieved through a software "contract" negotiation that optimizes bandwidth and processor utilization based on desired imagery quality, desired timeliness, link availability, and processor availability.

3.3 Quality of Service (QoS) Management During VTF Download

The tradeoffs of timeliness versus image quality are managed during VTF image download. This is accomplished through image compression, image tiling, processor resource management and network resource management. When the fighter node requests an image from the C2 node, the image request is broken up into a sequence of tile requests. Each tile is a piece of the image and is, therefore, of smaller size. The number of tiles requested is based upon the image size while the compression level of an individual tile is based upon the deadline for receiving the full image and the expected download time for the tile. During image downloading the progress of receiving the tiles is monitored and the compression level of subsequent tiles is altered based upon whether the image is behind schedule, on schedule, or ahead of schedule. The image is tiled from the point of interest first, with the early tiles containing the most important target data, so that decreased content of later tiles will have minimal impact on the dynamic planning capabilities.

In addition to the in-band adaptation of tiling and compression as described above, out-of-band adaptation is provided using the processor resource manager and dynamic scheduler components of the system. The processor resource manager selects task event rates from the ranges available for different tasks to optimally utilize the CPU. The progress of the image download is monitored through the network and CPU monitors. If the processing of the image tiles falls behind schedule, the processor resource manager is prompted to attempt to adjust the rates to allocate more CPU cycles to the decompression of the next tile.

If these adaptation attempts are not successful application adaptation is triggered. The application adjusts its timeliness or image quality requirement, by requesting longer deadlines or lower image resolution to reduce the urgency or amount of processing needed.

Application of dynamic QoS-based technology to dynamically manage/allocate required processing resources while still meeting all hard real-time performance requirements will be demonstrated using the Real Time Adaptive Resource Manager (RTARM) developed by Honeywell Technology Center and the TAO dynamic scheduler developed by Washington University, St. Louis. The QoS adaptation is achieved through the Quality Object (QuO) framework software developed by BBN Technologies. The WSOA architecture can be seen in figure 4.

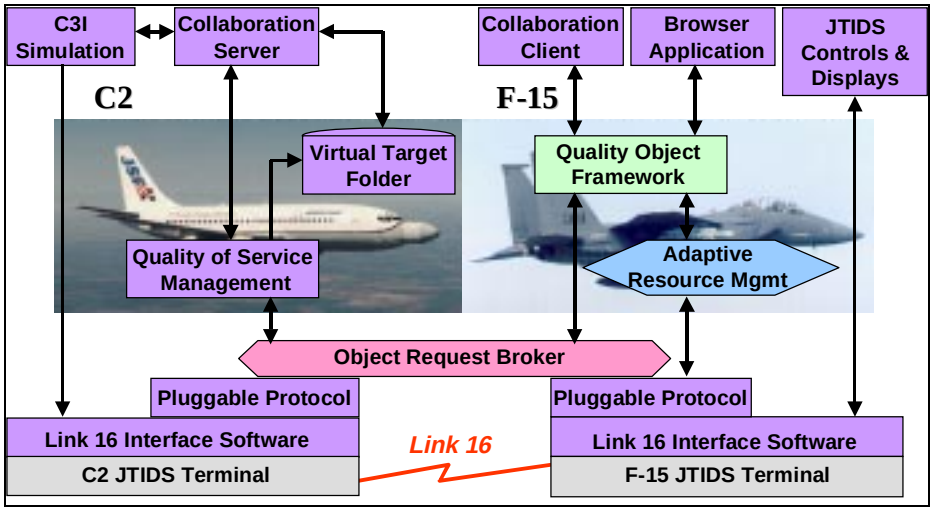

Figure 4 - WSOA Architecture

4 Conclusion

WSOA will produce a ground-based demonstration in summer 2001 and culminate in an airborne demo in fall 2001. The ground demo will include an attack node, a Boeing F-15 OFP executing on a desktop simulation, and a C2 node communicating via a simulated Link 16 interface. The live flight demonstration will have an F-15 and airborne C2 node communicating via a Link 16 interface. WSOA will establish the potential gains in warfighting capability due to enabling technologies of collaborative planning, information mining, and adaptive embedded resource management within a Network Centric information architecture.

5 Acknowledgements

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