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NET-CENTRIC SENSEMAKING SUPPORT FOR DECISIONMAKERS

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1 ABSTRACT

Command and control decisions are driven in large part by an understanding of the current situation in an Area of Interest (AoI). The quality, and resulting effectiveness, of these C2 decisions is strongly related to the accuracy, completeness, currency and ease of comprehension of the Common Relevant Operating Picture (CROP) presented to the decisionmaker by the C4ISR system.

Lockheed Martin Advanced Technology Laboratories (LM ATL) is actively engaged in the research, development and transition to operations, of advanced Net-Centric Sensemaking (NCS) technologies to generate a CROP that facilitates more effective command and control by decisionmakers, in a number of domains, including Army (with a focus on small unit operations in urban environments), Air Force and Homeland Security.

2 INTRODUCTION

This paper presents Net-Centric Sensemaking (NCS), an integrated suite of information processing services designed and developed to provide command and control decisionmakers with a more timely and more complete understanding of the current and future situation in the Area of Interest (AoI).

The C2 decisionmaker is presented with a number of operational problems (Section 3) including overwhelming amounts of information present on today's net-centric backbones; reduced manning; more agile, creative and flexible adversaries; and the need to operate in, and rapidly switch between, a wide range of mission types.

The LM ATL NCS architecture (Section 4) retrieves, analyzes and fuses data resident on net-centric backbones to meet select information needs of C2 decisionmakers, providing tools to improve knowledge management and the decisionmaking process.

The Tactical Overwatch Node (Section 5) is an implementation of the NCS architecture. The Tactical Overwatch Node (TON) contains a number of service groups, including services responsible for Intelligent Data Retrieval, Information Fusion and Shared Understanding (the sharing of situation understanding data with other nodes, both at the same echelon and at higher and lower echelons, in a multi-platform, distributed C4ISR architecture). The TON also contains common services that control processing and support knowledge management through the application of semantics, pedigree and confidence representations.

The NCS architecture has been exercised in a number of domains (Section 6) including Army small unit operations in urban environments, Air Force large scale country-on-country conflicts and Homeland Security maritime protection missions.

The NCS architecture and the TON have been researched, developed and demonstrated in collaboration with the Army Research Laboratory (Section 7) and draw on existing research in the areas of multi-level information fusion (Section 8).

3 OPERATIONAL PROBLEMS

A key objective for command and control decisionmakers is to be able to work within the adversary's decisionmaking cycle. This means that we must observe, understand and act faster than the adversary, while ensuring that our decisionmaking is accurate and complete to avoid, among other concerns, collateral damage and fratricide. The requirement for faster decisionmaking comes at a time when our adversaries are becoming significantly more agile, creative and flexible in their thought processes while presenting, due to their low signatures, little information to reason from. Our decisionmaking staff, from the analysts to the commanders, is being reduced while the number and type of missions that are being executed is increasing. The need for effective tools to support and improve C2 decisionmaking is critical and the NCS architecture presented in this paper was developed specifically to address this need.

In order for more rapid and accurate decisionmaking, the gap between the raw data (the observing) and the decisionmaking process (the acting) must be as small as possible. This is achieved through understanding. The term Situation Awareness (SA) is commonly used to describe systems that provide decisionmakers with a near real-time operating picture or tactical display that shows the location of forces (blue / red / blue and red) on a map background. However, SA provides the decisionmaker with only the first set of needed information. Situation Understanding technologies, also referred to as Sensemaking technologies in this paper, perform further processing of the SA operating picture to integrate a range of additional data (including traditional intelligence data) and inferencing services to ultimately present the decisionmaker with fully-substantiated estimates of the most likely, and dangerous, courses of action that the adversary is, and may be, pursuing. With these enemy course of action (ECOA) predictions in hand, the decisionmaker can focus exclusively on appropriate responses to the current situation – making our responses quicker and more effective.

Military groups are almost always organized hierarchically as a series of echelons. Decisionmaking in these organizations takes place at each echelon, while being coordinated within the echelon (horizontally) and with echelons below and above (vertically). Effective decisionmaking across the organization requires that the understanding of the current situation, from the perspective of each echelon, be coordinated and shared cooperatively within and between each echelon. This shared understanding is key, as information processed at both low echelons (a document located in a building in Baghdad) and at high, national-level echelons (a recent satellite image) should all contribute to the C2 decisionmaking process. Interoperability with Joint, Inter-agency and Multi-national (JIM) data and information processing resources, accessed across net-centric backbones, although currently a significant challenge, is a key requirement to further augment and support the command and control decisionmaking process.

4 NET-CENTRIC SENSEMAKING (NCS) ARCHITECTURE

Figure 1 presents the NCS architecture, configured for Army tactical operations plus interoperability with a representative selection of Joint, Inter-agency and Multi-national (JIM) data and information processing resources. In the center of the NCS architecture is the TON, an actual implementation of NCS that is discussed in more detail in Section 5.

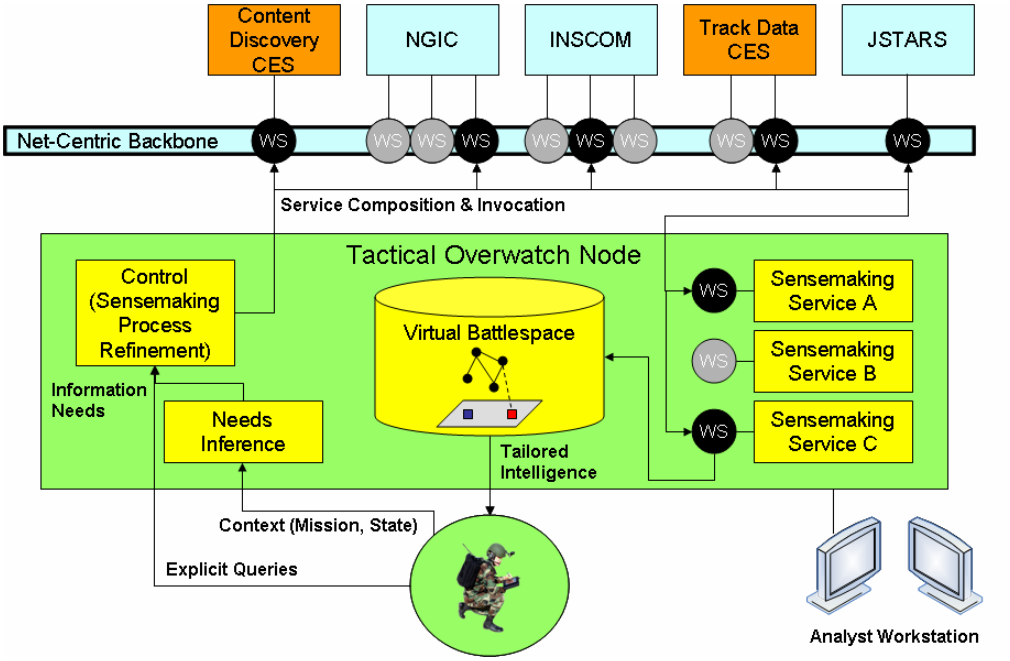

Figure 1 – Net-Centric Sensemaking Architecture

The driving force behind the NCS architecture is the decisionmaker's information needs. NCS was specifically designed to handle a range of decisionmakers, performing different tasks under different mission categories.

In Figure 1, our decisionmaker is a Platoon Leader, dismounted in an urban environment. The mission, current state (including location, location relative to the adversary and the Platoon's health and system status) and a set of other continuously updated parameters are combined into a data structure called "context". Context is created and continuously maintained for each decisionmaker that the TON is responsible for. Each TON may support one or more decisionmakers, each performing different missions and in potentially different states.

NCS accepts information needs in two ways, implicitly and explicitly. Implicit information needs are generated within the NCS architecture by the Needs Inference service. This service contains logic that reasons over the current context of the supported decisionmaker and infers the most likely information needs of that decisionmaker. For example, determining the size, heading and intent of a crowd in the vicinity of our Platoon for the Platoon Leader would be one such derived information need. Implicit information needs are generated both when the decisionmaker has no time to express their needs (such as when they are under fire) or when the

decisionmaker may have overlooked or failed to explore a certain analysis of the current situation. The second set of information needs (the explicit needs) is generated directly by the decisionmaker.

Information needs, both implicit and explicit are queued, merged (if possible) and prioritized in the main control process of the NCS architecture, the Sensemaking Process Refinement (SPR) service (a significant extension of the Joint Directors of Laboratories Level 4 Fusion Process Refinement functional concept). SPR generates, in a just-in-time manner, a unique sequence of data retrieval and information processing steps that constitute a workflow to address each information need in the SPR queue. This dynamic composition / orchestration of data retrieval and information processing services is unique in that it does not rely on a pre-enumerated set of processing workflows, a set that cannot be formed given the many degrees of freedom present in the decisionmakers' missions and situations.

Net-centric backbones are being developed extensively within the DoD and the JIM community as a whole. Examples include the Distributed Common Ground Stations Integration Backbone (DIB), the Horizontal Fusion Collateral Space and the overarching GIG. Services on these backbones include both data providers (such as a JSTARS track database) and providers of information processing (such as a weather effects model). The NCS, through a combination of Net-Centric Enterprise Services (the DISA standard set of core net-centric backbone services) aware agents, and the augmentation of service definitions with semantics, is able to invoke services on net-centric backbones according to the dynamic workflows generated by the controlling SPR service.

In addition to the data provider and information processing services available on external net-centric backbones, the NCS architecture includes a suite of internal Sensemaking services. These services perform the majority of the Sensemaking / Situation Understanding processing on the partially processed data entering the TON. The Sensemaking services perform what the Joint Directors of Laboratories Data Fusion Lexicon calls Level 2 Situation Refinement and Level 3 Threat Refinement processing. This processing establishes relationships (Level 2) between the entities, environment and events in the current situation and uses this network of relationships, along with properties of the various elements of the situation, to infer (Level 3) the most likely ECOA. The categories of Sensemaking services are discussed in more detail in Section 5.

At the core of the NCS architecture and the TON implementation is the Virtual Battlespace (VBS). The VBS stores the results of the Sensemaking services processing in a form that not only preserves detailed pedigree on these results, including the data and processing steps that led to them, but also attempts to present inferences on the current situation in a form that is readily understood, and trusted, by the decisionmaker. A key feature of the VBS is that it unifies the CROP with the Common Relevant Intelligence Picture (CRIP), combining both operations and intelligence in one structure and reasoning pool, for the decisionmaker. The VBS achieves this unification by cross-linking the traditional track picture of the CROP with a node-and-link conceptual graph representation of the CRIP favored by intelligence analysts.

The final processing step within the NCS architecture is to take the results of the invocation of the SPR generated workflow (composing external and internal data retrieval and processing

services), generated specifically to address the information needs of the decisionmaker, and disseminate these results, in a bandwidth-aware fashion, to the decisionmaker for display, comprehension and action / response generation.

5 TACTICAL OVERWATCH NODE

Figure 2 presents a summary view of the TON, an implementation of the NCS architecture. The TON was primarily developed to support Army small units operations in urban environments.

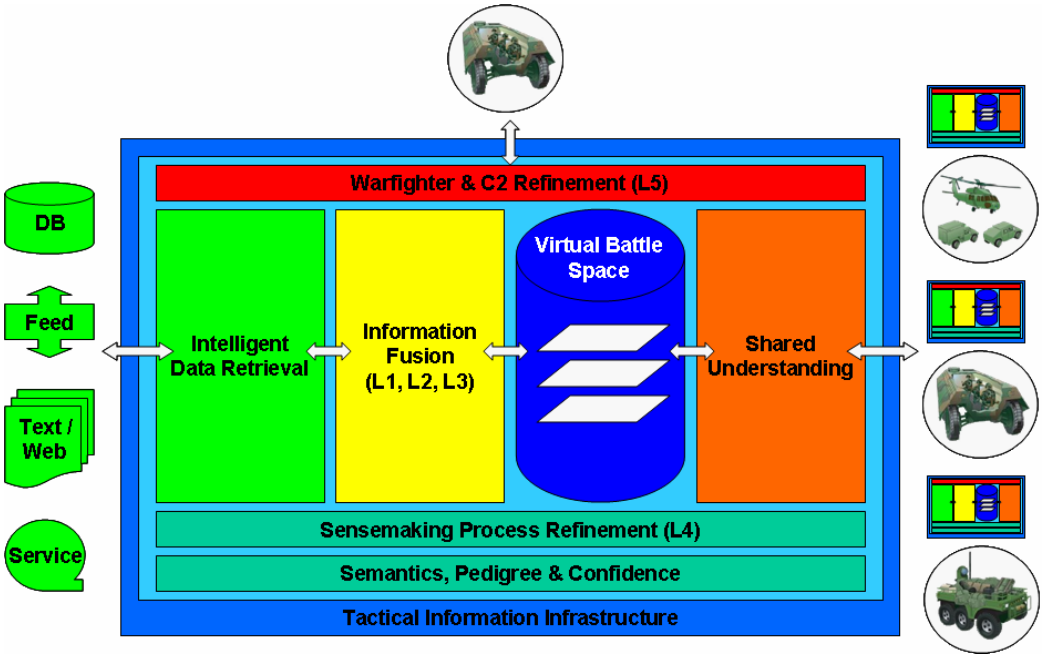

Figure 2 – Tactical Overwatch Node (Summary View)

The TON is divided into a number of service groups shown in Figure 2; these groups include: Intelligent Data Retrieval; Information Fusion; the Virtual Battlespace (VBS); Shared Understanding; Warfighter & C2 Refinement; Sensemaking Process Refinement (SPR); Semantics, Pedigree & Confidence; and the Tactical Information Infrastructure.

Figure 2 shows external information sources and information processing services, accessible through net-centric backbones to the left of the diagram, with other platform nodes in this distributed C4ISR architecture shown to the right of the diagram.

The services within Shared Understanding maintain the context of each decisionmaker resident at other nodes within the overall architecture. This may be the dismounted Platoon Leader, a Battalion S2 or a Joint Commander. SPR reasons over the context to dynamically generated workflows that invoke Intelligent Data Retrieval and Information Fusion services. Results are persisted in the VBS and disseminated to decisionmakers via Shared Understanding. Semantics, Pedigree and Confidence services provide a common internal language for representing data in the TON, along with the pedigree of, and confidence in, that data. Semantic mediators are also present that handle the conversion of data representations at the interfaces between the TON /

NCS and external services on net-centric backbones. The Tactical Information Infrastructure provides various Information Assurance and network Quality of Service tools.

Figure 3 shows an exploded version of the key service groups within the TON, with the first set of services shown in green related to Intelligent Data Retrieval; the second set of services shown in yellow related to Information Fusion; the third set of services shown in blue related to the Virtual Battlespace; and the last set of services shown in orange related to Shared Understanding.

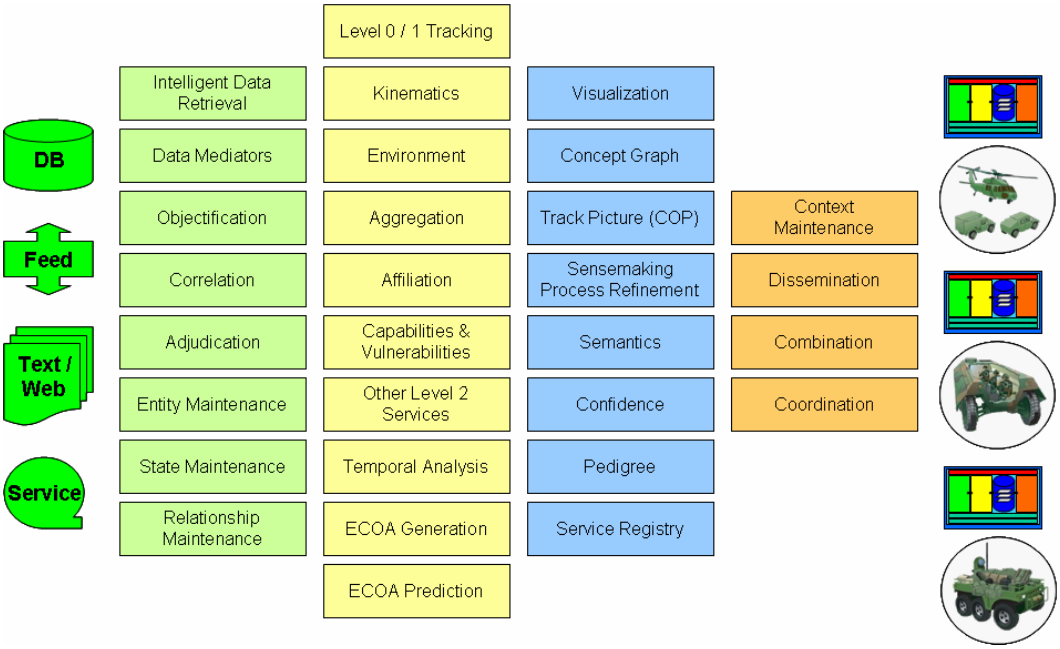

Figure 3 – Tactical Overwatch Node (Detailed View)

The Intelligent Data Retrieval services retrieve data from external systems, typically through net-centric backbones. Mediation of that data takes place at the TON system boundary with the data then being correlated (if possible) with existing entities in the VBS. Adjudication, although still basic within TON, is responsible for resolving any conflicts present in observations of the same underlying entity from multiple data sources. Entity, state and relationship maintenance perform the generation and updating of the properties and associations between the objects in the VBS as new data enters TON.

The Information Fusion services contain a wide and extensible set of relationship formation and enemy course of action generation and prediction services. Situation analysis is performed from a number of analysis perspectives (such as kinematics, environment interaction, affiliation, and capabilities and vulnerabilities perspectives) and every one of the results from these perspective analyses must then be integrated before course of action analysis can be performed. Temporal analysis, still in the early stages of development within NCS, attempts to analyze sequences of events and how they impact entities within the VBS. The goal of Information Fusion is the generation and prediction of ECOAs. Generation is a key processing step as today's asymmetric threats rarely repeat their previous behaviors for long, thus any "bottling" of previous aggregate behaviors for future pattern matching is likely to fail.

The VBS is built from a track picture cross-linked with an intelligence picture stored as nodes and links in conceptual graphs. Intelligence analysts favor the node-and-link representation and use tools that create and manipulate (albeit manually) these representations; the node-and-link conceptual graphs within the TON are created and maintained by automation – though they can be controlled by the decisionmaker if necessary.

Shared Understanding creates and maintains context on the decisionmakers that TON is supporting with Situation Understanding / Sensemaking analysis and results. These results are disseminated to the decisionmakers by Shared Understanding and results from other coordinated platform nodes in the distributed C4ISR architecture are combined into the VBS (currently in a very simple way). Future research and development is being focused on inter-platform coordination and combination of Situation Understanding results from different platforms.

6 PROTOTYPE DEMONSTRATIONS

The Net-Centric Sensemaking architecture and its implementation in the Tactical Overwatch prototype node have been demonstrated in a number of domains including Army tactical simulations involving Companies and Platoons and in actual MOUT exercises at Fort Benning, GA involving a Battalion S2 and S3 and a Platoon Leader.

The NCS architecture components, primarily the ECOA generation and prediction have been demonstrated in simulated Air Force scenarios and also in the littoral spaces of both foreign and domestic shores.

Application of the NCS technologies to further domains, and detailed user evaluations of the effectiveness of the NCS technologies, is planned.

7 ACKNOWLEDGEMENTS

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