Technical Evaluation Report

Dr. Galina L. Rogova
Encompass Consulting
9 Country Meadow Drive
Honeoye Falls, NY 14472
USA

rogova@rochester.rr.com

1.0 THEME AND FOCUS OF THE MEETING

Maintaining coherent situation awareness is essential for military decision makers. Given knowledge of the environment and the threats it presents, the military commander is able to take informed decisions and assess the impact of those decisions more effectively. Situation awareness requires contextual understanding and interpretation of the events and behaviors of interest, which can be achieved by utilizing higher level fusion processes (situation assessment and impact prediction). Higher level fusion processes employ information about objects, intelligence information, historical databases, and domain knowledge to recognize relations between these objects and dynamics of these relations. Contextual information is particularly critical in current asymmetric threat environments, in which the Level 0 and 1 – signal/feature and platform identification and tracking – are far less important than characterizing the composition, activity, capability and intent of insurgent organizations. At the same time, with recent advances in the ability to gather, store, and analyze a wide variety of data from multiple geographically distributed heterogeneous sources, determining how best to process this information in order to generate an accurate and timely situational picture has become a major challenge.

The goal of the NATO/RTO Specialists' Meeting on Information Fusion for Command Support, held in The Hague, The Netherlands, on 8 and 9 November 2005, was to confront this challenge by facilitating an exchange of information on the state of the art of the designing situation and threat assessment processes. The NATO/RTO Specialists' Meeting is a separate part of the Final Demonstration event of the IST Task Group IST-038/RTG-016 on Information Fusion Demonstration. These activities are the follow-on of the IST Symposium IST-040/RSY-012 on Military Data and Information Fusion (October 2003, in Prague, CZ), which showed the importance of discussions on higher level fusion problems and methods in order to provide necessary support to modern military operations.

The specific objectives of the Specialists' Meeting on Information Fusion for Command Support were to:

- Present the state of the art on computer assisted high level military information fusion in a Command and Control and Intelligence environment.
- Enhance understanding of the role of automated information fusion in Command and Control.
- Discuss adaptation and integration of current defense and non-defense methods and technologies for application to Intelligence and Command and Control.
- Introduce future, more innovative concepts and integrated systems that are under research or developed and applicable to information fusion.
- Identify challenges in context sensitive information interpretation.
- Provide forum for scientific exchange on methods of information fusion in defense and security and the discussion of related user requirements.

The announced topics of interest included:

- Defense and security requirements for data interpretation and information fusion
- Concepts of military data and information fusion for
  - Situation awareness, situation assessment
  - Threat and impact assessment
  - Intelligence preparation of the battlefield
  - Information fusion in military planning and resource management
  - Classification and identification of elements of the battle space and evolving threats
  - Intelligence processing in Anti-Terrorism
- General fusion methods
  - Qualitative and Quantitative fusion methods
  - Semantic approach to information fusion and ontologies
  - Context sensitive information exploitation
  - Content extraction from unstructured data using natural language processing techniques
  - Representation of military and security knowledge
  - Modeling of terrorist activities for defense and securities agencies
  - Research challenges toward achieving robust high level fusion methods
  - Application examples and demonstrators of data and information fusion
- Architecture of intelligence fusion systems for C4 dominance
  - Resources: COTS S/W, data, training materials, generic scenarios and case studies
  - Fusion visualization

Theses topics represent but not limit a wide variety of problems to be solved in order to provide military decision makers with reliable and robust decision support. Obviously, it was practically impossible to discuss all the topics in a two day meeting. Nevertheless most of them were addressed in two keynote and one invited speeches and 16 session presentations. In addition, some of these topics were discussed during the Final Demonstration event of the IST Task Group IST-038/RTG-016 on Information Fusion Demonstration.

Presentations were organized in four sessions:

- Military Requirements and Experiences
- Fusion Methods
- Semantic Approach to Information Fusion
- System Concepts, Applications and Demonstrators

The next section will present a brief description of the technical content of the keynote speeches and each of the four technical sessions.

2.0 TECHNICAL CONTENT

2.1 Keynote Speeches

First keynote speech entitled "A Model for Situation and Threat Assessment" was delivered by Mr. Alan Steinberg of CUBRC, USA. Mr. Steinberg pointed out that situations were more than multi-states and therefore, their assessment required a new methodology rather than extension of the Level 1 methods. He presented ideas on designing methods for representing, recognizing and discovering situations of interest. He also discussed challenges of designing such methods, which included characterization of reliability and performance of all the sources of information, human machine task allocation, and ontology design, management and evaluation.

The second keynote address was delivered by Dr. James Llinas, Professor of the State University of New York at Buffalo and Director of the Center for Multisource Information Fusion. His speech was entitled "Service-Oriented Architectures, Network-Centric Warfare, and Agile, Self-synchronized C2: Impacts to Data Fusion Process Design". In his presentation, Dr. Llinas pointed out that information sharing and shared understanding and awareness of military situation enabled by Network Centric Warfare within the Service-Oriented Architecture (SOA) concept greatly increase agility, speed of command, and synchronization in C2. At the same time the SOA concept is not completely developed and represents challenges for designers of Data fusion services. The presentation called for joint efforts in holistic type research and development on Community of Interest /Complex Adaptive System side of the Network Centric Warfare paradigm, which would require research and development to be aimed not only at the agent-based techniques but also at the human side of the problem. This multidisciplinary research would involve collaboration between agent, human factor, and data fusion communities.

Both keynote presentations established a framework for session presentations, which offered some solutions to the problems identified in keynote speeches.

2.2 Technical Sessions

2.2.1 Session 1. Military Requirements and Experiences

There were two presentations in this session, which addressed the problem of interoperability and information sharing, especially important in the modern world, which requires cooperation between different agencies as well as between different nations. The first presentation (Rabaey *et al.*) entitled "Intelligence base: strategic instrument of an organization" introduced the concept of the Intelligence Base designed to support the needs of an efficient and effective intelligence system for storing, managing, and sharing information and intelligence. The underlying architecture was based on Service-Oriented Architecture, which gives the flexibility and the agility to respond quickly to changes and to connect with other systems. Although the presentation discussed the needs of military organizations, the Intelligence Base Architecture could be used by civilian enterprises. The second presentation by Ücüncü and Demirezen summarized the formatted message concept and presented a new adaptive and self correcting system to support information exchange between nations. The purpose of this system (AdatP-3) is standardization of messages used for message exchange to improve interoperability between NATO authorities and systems.

2.2.2 Session 2. Fusion Methods

This session comprised six presentations discussing possible approaches to higher level fusion. The first one, "Cognitive Situation awareness for information superiority" by Laudy, Mattioli, and Museux identified deficiencies of existing Command Support systems and suggested an approach to improve such systems. The paper stressed the importance of developing a unified theoretical framework and human-centered approach to information fusion. This assertion was also the main theme of the keynote speeches. The authors propose an approach to situation analysis, which relies on understanding and modeling user

perception and a complex event processing. The proposed approach concentrates on document analysis for situation representation and assessment. The road traffic surveillance problem was used to illustrate the approach.

The next three presentations in this session discussed applications of Bayesian methods to a number of fusion problems. The first two of them applied Bayesian networks to assessment of threat and combat-ID in decision support systems (Bladon *et al*.) and effect based planning (Bullen). Bayesian networks, which serve as a graphical representation of probabilistic relationships between elements of the domain of interest, have recently received significant attention in the fusion community. Although both presentations pointed out to the benefits of utilization of Bayesian networks in fusion, which were demonstrated in simple case studies, they also identified multiple problems of application of this technique to high dimensional real life dynamic problems. The third presentation entitled "Decision Support for Asymmetric Urban Warfare" by Enderwick and McNaught discussed utilization of Bayesian networks and Influence diagrams, an extension of Bayesian networks, for support intelligence interpretation. The presentation described an application of this methodology in an asymmetric urban warfare scenario. The authors of this presentation argued that although the time required for developing a Bayesian Network or Influence Diagram made it impractical within a high tempo real life scenario, this methodology might be useful for sensitivity analysis during the intelligence preparation phase and as decision support tools for areas such as troop allocation and operational planning. At the same time, this presentation also identified possible difficulties of utilizing this methodology in practice.

The fifth presentation of this session (Grégoire) discussed fusion of symbolic knowledge expressed in logic and possible problems of applying strict logical rules to fusion of several different and partial propositions. The presentation identified three problems and some approaches to solution for each of these problems. The problems addressed in the presentation are: (1) effects of inconsistency, (2) necessary conditions can become sufficient ones, and (3) precise information can be hidden by more general knowledge.

The session was concluded by an invited presentation entitled "Preparing the Way for NATO Network Enabled Capability (NNEC)", by Turner. Mr. Turner described the goal, objectives, and challenges of the processes of allied command transformation for improved NATO capabilities. He outlined the concept of NATO Network Enabled Capability (NNEC), which requires the ability to integrate various components of operational environment, and described a NNEC feasibility study, an R&D effort aimed at investigation of information interoperability issues. The presentation pointed out that the future NATO capabilities require further research in the areas of information fusion and information interoperability.

2.2.3 Session 3. Semantic Approach to Information Fusion

Session 3 comprised four presentations with each of them addressing the high importance of semantic approaches to higher level fusion. First presentation (Bares) discussed the important role of semantics in designing a decision aid and introduced a concept of semantic enrichment, which can significantly improve operational knowledge. Semantics can be enriched by symbolic fusion and by compatibility relations expressed in the framework of fuzzy logic. The presentation was concluded by an example and possible extension of the semantic enrichment process.

Both second and third presentations of this session were devoted to the problem of text extraction and fusion. This problem represents a significant component of situation assessment since, as the presentation by Dr. Noble reminded us, "much information important for battlefield assessment is transmitted as unstructured text" and therefore it is very important to be able to structure it, fuse the most valuable pieces, and present the fusion results in a concise way to decision makers to improve situation awareness. The presentation by Goujon and Frigière described learning methods for automatic extraction of structured knowledge from text and subsequent use of this information for text fusion. The presentation gave a brief description of the state of the art of the methods of automatic information extraction, and introduced a new supervised learning method, its implementation, and the results of its evaluation. The presentation by

Nobel described a process for structuring, fusing, and assessing the credibility of open source information in order to help a decision maker to use critical pieces of information otherwise buried in less important information. The process employed formal ontologies of the domain and a commercial tool for evidential reasoning.

The final presentation of this session introduced a threat recognition system under development (Schade, Biermann, and Frey), supporting information exploitation within the Collation, Analysis, and Integration steps of intelligence production. The presentation described the processing steps of the system and an ontology, which had been already implemented and tested. The described processing included categorization and classification of each single reported event with subsequent analysis and unification of such events. The ontology, one of the central features of the system, comprised taxonomy, rules, and schemata to encode domain knowledge. Another important system feature was incorporation of a human operator into the system.

2.2.4. Session 4. System Concepts, Applications and Demonstrators

This session comprises five presentations describing systems and architectures representing enabling capabilities for situation and threat assessment. The first presentation by Dr. Ulla Uebler introduced SCOOTY, an online and offline speech classification system, which could store, process, and classify audio signal. Speech classification along with text analysis discussed during the previous session is a valuable capability to be utilized in intelligence production. The speech classification algorithms presented included classifiers for speech detection and enhancement, language and speaker identification, and topic and word spotting. Classification results obtained by each classifier can be combined with all available meta information. Three scenarios are described in order to demonstrate different ways of utilization of the presented system.

The second presentation (C. Dorman and K. Phelps, presented by K. Kierzkowski) included a life demonstration showing how remotely sensed data and an enterprise GIS could help military commanders to make better and faster decisions. The demonstration used a realistic intelligence-related military scenario utilizing satellite imagery and NATO's current, standard Geographic Information System (GIS) to show how all the information could be fused, analyzed, and visualized to support surveillance, target detection and monitoring and operational planning.

The next 2 presentations were concerned with enabling capabilities for decentralized fusion. One of them (Jacob, Kaveh, and Ghanea-Hercock) introduced Nexus, an intelligent, robust, and scalable middleware for service discovery and fusion in highly volatile service-oriented network architectures. The presentation described the decentralized service oriented approach to fusion in general, Nexus features, design choices, and applications. The authors also provided valuable discussion on advantages and disadvantages of the key technology within the Nexus middleware and presented two Nexus-based applications (Emergency response and Convoy scenarios). The second presentation on Network Enabling capabilities (Jennings, Johnston, and Wright) described one of the key technologies providing technical solutions to NEC, namely Autonomous Software Agents. Agents were designed to co-ordinate different assets under incomplete information, to distribute decision-making and control between assets, and to provide flexibility of response and ability to cope under different degrees of control (autonomy). The feasibility of specific methods and techniques was illustrated on a number of disaster recovery vignettes.

The last presentation of this session (Sari *et al.*) entitled "A Generic Fusion Tool on Command Control of C4ISR Simulations" provided description of the developed in Turkey C4ISR simulation tool called Agent driven Simulation Framework (AdSiF), which combined many interoperable components into a virtual environment to provide an environment resembling real world. AdSiF, an information fusion tool, executed fusion process by utilizing predefined rules. The presentation demonstrated this fusion tool on a simple example, in which multiple sensor information was utilized for target state estimations. The authors argued that this rule-based tool could be utilized for higher level fusion, provided the necessary rules are defined during run time.

2.2.5 Final Discussion

The meeting was concluded with an interesting final discussion, which reiterated and summarized main findings of the meeting and outlined future direction of the research. Below is the transcript of the discussion.

Mark Rabaey: It is necessary to take into account military perspective and ensure participation of decision makers. Operations other than war have slower tempo; this makes on the spot information quality assessment/verification possible (in contrast to maximum tempo combat situations). There is a danger of a model-driven approach: what if the opponent discovers a model you operate and uses it against you?

Jean Rohmer: We always are between two tracks.

A track	B track
there is a solution, find it!	there is no solution, but we must survive anyhow!
optimize	do not optimize
acquire knowledge	discover and forget knowledge (just accumulating is not enough)
use software standards	innovative standards, design from scratch (future standards is contradiction on terms)

We should assess ourselves to determine how we qualify and fit within the tracks.

Gaetan Thibault: The desire to develop a new system is triggered by a change in the environment; this change is evolutionary but results in step action once a critical amount of changes is accumulated. NCW is in essence about information and how it can be exploited to support decision makers and their collaboration (how and who). This perspective should drive the design and development of information fusion systems.

People are rediscovering collaboration by bridging interoperability. We have to bring a new style of collaboration (sharing and interoperability). The key problem: how to implement core services to support collaborative commander, staff, and ultimately soldier? We have to create a road map, with has a top-down design and a bottom-up implementation. There is a triangle: technology, user, and process. Balance in this triangle is essential. If a change occurs in one parameter – the others should either reject the change or adopt and evolve adaptation. It requires incremental step-by-step adoption of new systems since users often refuse to accept too radical changes in the way they work.

Alan Steinberg: The meeting achieved a lot of progress in understanding the problems we face (distributed fusion, situation assessment), which is the first step towards solving these problems. The problems are much more complicated than previously thought. This is a definite progress compared to Prague meeting where the consensus was that the information fusion problem is not understood.

Joachim Biermann: It might be that we are starting to gain better insights and come to realizations that this is a really large-scale problem and it will take a long time to get to a solution that we expected. The progress is slow but it exists.

Jean Rohmer: Software technology is not neutral.

Gaetan Thibault reiterated that in the triangle “Process-People-Technology” changes should be made incrementally, one vertex at a time.

Joachim Biermann concluded the final discussion: Hopefully this event will result in future networking a maybe repeated every year in the same place.

3.0 TECHNICAL EVALUATION

Advances in sensor development, internet, communications produce enormous amount of heterogeneous information of various significance, often of low fidelity, contradictory and redundant, especially those from public available sources (Open Source Intelligence OSINT) or provided by human sources (Human Intelligence HUMINT). Military decision makers have to make sense of this "fog of information" and produce contextual understanding of current distributed situation and predict its impact to be able to make timely and correct decisions. They have to be able to share intelligence and exchange information not only within and between different agencies but also between different countries. This represents both a significant opportunity and a real challenge to the data fusion community, which focuses now on designing new methods to meet this challenge and provide a commander with a coherent composite tactical picture to support timely decision making.

The content of the meeting presentations addressed current trends in information fusion, which represent shifts from designing methodology for target tracking and state estimation to development a theoretically grounded methodology for contextual understanding of dynamic situation in the framework of the Network Centric Warfare within the Service-Oriented Architecture (SOA) concept. The presentations of this identified key factors and possible approaches to designing such methodology and systems. They also illustrated some work in progress on R&D initiatives directed to designing such methodology. Presentations were grouped in the sessions with topics of each of them well represented major challenges of designing decision support for future global effect based military operations characterized by agility, and integrated intelligence and logistics.

The Program Committee did an excellent job in selecting papers, which revealed the challenges of providing commanders of the future with situation awareness and addressed possible approaches confronting these challenges. The committee organized a meeting at which any person interested in this domain could obtain important information and value.

The analysis of the questioner distributed at the end of the meeting and filled out by half of the 64 participants demonstrated an overall success of the meeting. Although there was no unanimous opinion about the best paper many participant named several presentations very good and useful. Only few participants named the worst paper. It was found that the time allowed for presentations was about right. Finally the vast majority found the meeting significant and extremely useful for them and their organizations.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this meeting was to facilitate an exchange of information on the state of the art of the designing situation and threat assessment processes and discuss the challenges and possible approaches to designing such processes. The meeting was successful and, as it was concluded during the final discussion by Mr. Steinberg, achieved a lot of progress in understanding the problem and represented a step ahead as compared to the previous meeting on Military Data and Information Fusion held in 2003 in Prague.

Below is a brief summary of problems revealed by the presentations and during the panel discussion, which have to be addressed in the future basic and applied research and development:

- Unified theoretically sound but realizable methodology of modeling and recognizing complex situations and threat.
- Context based domain representation.

- Sophisticated techniques for characterization of reliability and performance of all the sources of information.
- Ontology of relationships and situations recognizing fuzziness; methods of ontology management and evaluation.
- More sophisticated method of structuring and extracting uncertain heterogeneous information.
- Specification, design and evaluation of Data Fusion capabilities for Network-Centric Warfare/Network-Enabled Capability environment.
- Understanding of dynamic requirements of C2 community.
- Sophisticated methods to support information sharing among NATO countries to promote interoperability while ensuring security and access control, which is particularly critical in the current asymmetric threat environments.
- Evaluation of designed methods.

The presentations at the meetings illustrated initial R&D initiatives, which addressed the problems of designing information fusion based systems to support military decision making. The majority of these initiatives are at the experimental stage only and more research is required to meet the immediate and future needs of the analysts in the new asymmetric threat environment. This research should be a joint effort of domain specialists who have to provide insight into military processes and requirements, and multidisciplinary R&D community, which has to include experts in information fusion, multi-agent systems, human factor, ontology, and knowledge representation communities.

It is important for RTO to participate in such research, carefully monitor its progress, and facilitate exchange of the problems, state of the art, and research plans in similar meetings in the future. It is also necessary to facilitate direct interaction between domain experts, researches, and system developers. It could be done through, for example, a series of Advanced Study Workshops (ARW), which will bring together military domain experts along with experts in information fusion, human factors, ontology, and knowledge representation. The ARWs will help to develop better understanding of user requirements as well as possible approaches and solutions, their relevance and applicability to real life problems through a combination of technology presentations, smaller working group discussions, and case study development.