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# Distributed Analytics and Information Science

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***Abstract – To address future coalition operations in congested, cluttered, contested, connected and constrained battlespace, the US Army Research Laboratory and the UK Defence Science and Technology Laboratory are developing a new research program on Distributed Analytics and Information Science International Technology Alliance. In this paper, we present an overview the two interrelated Technical Areas which when jointly studied will advance the theoretical foundations of distributed analytics and information science in the context of coalition operations. These areas are (1) Dynamic, Secure Coalition Information Infrastructures and (2) Coalition Distributed Analytics and Situational Understanding.***

**Keywords:** analytics, fusion, distributed, networks, security, information processing, military, coalition.

## 1 Introduction

Coalition operations are becoming increasingly prevalent and increasingly complex. Recent coalition operations are placing significantly greater burdens on the people and technologies that are deployed and coalitions are forced to counter adversaries that increasingly have access to advanced communications, information, and analytics technologies.

The need for technologies that support dynamic coalitions which bring together a number of different partners into a single operation or mission has never been greater. This implies a degree of transience of existence and membership, distinct from persistent alliances with permanent infrastructure, such as North Atlantic Treaty Organization (NATO). Each partner brings different cultures, different policies and procedures, different systems and networks, all supported by a variety of technologies. These must be brought into harmony to achieve common goals.

Future conflicts will occur in congested, cluttered, contested, connected and constrained battlespace, and adversaries will use a mix of high-end and low-end asymmetric techniques to exploit coalition weaknesses. Coalitions need to develop an understanding of complex situations and problems involving sets of interacting entities or actors with many dimensions (military, economic, political, social, legal, etc.). The ability to understand, predict, and adapt to the behaviors of these complex adaptive systems is critical to enhancing the ability to conduct coalition operations.

A key focus is enabling the rapid and secure formation of ad hoc teams with an emphasis on dynamic coalitions which bring together a number of different partners into a single operation or mission. The ability to flexibly and securely share and process data and information distributed amongst multiple disparate ad hoc teams, perform distributed analytics, and derive situational understanding to provide insight and foresight are critical to future coalition operations [1-10]. Some key challenges include:

• **Ad Hoc Coalition Teams**. Ad hoc coalition teams must be formed rapidly and adapt under dynamics caused by changing missions, tempo, mobility, environment and membership.

• **Distributed Operations**. Data, context, processing, analytics, and situational understanding must be accomplished in distributed and dynamic environments and be effective, efficient, robust, secure, and resilient while supporting collaborative decision making.

• **Resource-constrained**. The operational environment, especially at the edge of the network, is highly resource-constrained including military personnel, bandwidth, energy, processing power, and data storage capacity and cannot rely on centralized network or security services nor overload users.

• **Data Complexity**. The data are highly dynamic, varied (including structured and unstructured data), complex, context-driven, and uncertain (noisy, volatile, incomplete, untrustworthy, hidden, adversarial).

• **Heterogeneity**. Coalitions will utilize a heterogeneous mixture of technologies, policies, levels of trust, data schemas, security mechanisms, and data services. Coalition information infrastructures are derived from the

composition of disparate security, networking, and information systems.

• **Dynamics**. The operational environment is highly dynamic as ad hoc coalition teams change, information is transformed, assets move, situational understanding evolves, and time-sensitive missions are adjusted.

• **Understanding Complex Situations**. Coalitions will need to understand, predict and adapt to the behaviors of complex situations and problems involving sets of interacting entities or actors with many dimensions (military, economic, political, social, legal, etc.).

To address the challenges outlined above, the US Army Research Laboratory (ARL) and the UK Defence Science and Technology Laboratory (DSTL) are launching a new research program on Distributed Analytics and Information Science (DAIS) International Technology Alliance (ITA). In this paper, we present the basic research component of the DAIS ITA Program Announcement [1]. In Section 2, we present an overview of the DAIS ITA research program and the two technical areas. In Section 3, we present the technical challenges and the associated research topics to be addressed in Technical Area 1 in Dynamic, Secure Coalition Information Infrastructures (DSCII). In Section 4, we present the technical challenges and the associated research topics to be addressed in Technical Area 2 in Coalition Distributed Analytics and Situational Understanding (CDASU). In Section 5, we discuss the research linkages between the technical areas. Finally, in Section 6, we summarize the research challenges associated with the DAIS ITA program.

# 2 DAIS ITA Research Program

Fundamental research is needed to meet coalition operation challenges and support: (1) the dynamic adaptation of secure, resilient infrastructures to support context and semantically-aware distributed analytics; (2) the ability to integrate and exploit data and information distributed across the coalition information infrastructure; and (3) the derivation of situational understanding of complex situations by human users synergistically supported by machines. To achieve the DAIS ITA's goal, it is imperative that a multidisciplinary approach to basic research is used to advance the fundamental knowledge of secure, context and semantically-aware distributed analytics so that generalizable theories and methods can enable dynamic and distributed situational understanding in coalition operations. Two interrelated technical areas have been identified that when jointly studied will advance the theoretical foundations of distributed analytics and information science in the context of coalition operations. A successful collaborative research program lays the scientific foundations for a theory of distributed analytics and information science that combines new and emerging developments in theory with innovative extensions of existing theory, computationally efficient modeling and simulation techniques, and theoretically principled experimental scientific verification and validation. To make progress, the research should exploit the significant inter-dependencies between the networking, security, analytics, and human aspects of these two technical areas and should be supported by experimentations. Scientific experimentation is a crucial element of multidisciplinary research as it validates research results and findings under realistic conditions and often provides additional research insights [1].

# 3 Technical Area 1: Dynamic, Secure, Coalition Information Infrastructure (DSCII)

Research is needed to provide the fundamental underpinning science for enabling distributed, dynamic, secure coalition communication/information infrastructures that support distributed analytics to derive situational understanding. Assets at the tactical edge are disadvantaged by resource constraints (communications bandwidth, constrained and dynamic connectivity, finite energy, computing and storage, and the human's ability to process information). It is likely that nodes may change roles and hence the changes in services they offer or consume in response to changes in the environment leads to dynamic resource (re-)allocation problems. Tactical coalition operations are often very dynamic and assets (sensing and communications, policies, goals, rapidly shifting traffic patterns and demands) will be heterogeneous. With the growing proliferation of sensors, as well as access to structured and unstructured data, the Warfighter at the tactical edge could be deluged in data. Appropriate data analytics and delivery mechanisms must cope with this potential overload, both at the physical as well as the cognitive levels.

Hence, to address the challenges of dynamic environments and disadvantaged users, it is necessary to develop techniques for dynamic, self-configuring services that build services "on-demand," taking into account changing mission needs, context and resource constraints. The importance of protecting information and assets remains a priority. Information assurance across heterogeneous networks with varying degrees of trust remains an issue, while operations at the tactical edge require effective protection and management of integrity and availability.

## 3.1 Content-based Software Defined Networking

Software-defined networking (SDN) offers a separation of control and data planes, thus potentially easing complexity

of dynamic network management. Content-based networking has the potential to allow distributed information sources to be discovered, assessed, and processed so that networks are context and content-aware and not independent, data-agnostic bit pipes [11-13].

SDN has the potential to be an enabler for establishing, controlling, and securing complex disparate coalition information infrastructure arrangements. However, to realize these benefits, many challenges need to be addressed including coping with limited knowledge of topology, heterogeneity of protocols and policies, differing time-scales, security concerns, decentralized distributed operations, and latency between the controller and the controlled assets.

While the conventional SDN paradigm of centralized control offers optimality, decentralized control may offer advantages in disrupted networks. It is therefore necessary to develop the requisite underpinning knowledge leading to principled methods that enable the trade between centralized and distributed control planes, and optimal policies for creation, management, and communication between control plane fragments, whether as peer to peer or through a hierarchy of supervisory planes.

Important research issues include the following:

• **Control Plane Configuration Across Coalition Networks**: Research is needed in software-defined information-centric networking that supports secure coalition operations using logically distributed and decentralized control plane architectures that operate across heterogeneous networks. Of interest are models and tools for the formal study, verification, and analysis of algorithms and protocols that support inter-operability, adaptability, and resilience of heterogeneous coalition networks and network components. In addition, research is needed for establishing performance bounds and complexity tradeoffs and for creating, managing, and communicating optimal policies between control plane segments. It is expected that networks at the tactical edge will consist of mobile ad hoc networks (MANETs), but infrastructure and cellular networks must be exploited where available and when feasible.

• **CBN-enabled Network Management**: Abstractions, models, mathematical frameworks, and tools are needed for content-based networking (CBN) that enable discovery of, access to, and processing of information sources in environments with highly variable data tempo and mobility. Appropriate performance metrics need to be developed and fundamental limits and tradeoffs need to be established for CBN. In addition, research is needed to develop innovative paradigms in network protocols enabled by SDN to better support mission and context awareness, and to create coherence between management functions (such as network, services, security, spectrum, etc.). Routing and (de-) prioritization of data flows in CBN may require an understanding of the data content and should be integral to SDN. CBN is key to supporting semantic interoperability for shared coalition situational understanding.

• **Measurement and Control**: Research is needed to develop appropriate definitions of network state and approaches, algorithms and tools to infer network state and topology/connectivity, and development of appropriate (state) consistency models and trust models. Distributed dynamic control of the heterogeneous networking is needed to provide maximize security, resilience, and performance. Principles of distributed processing of monitor data and related distributed analytics are needed to facilitate the provision of situational awareness (SA) across the contextual layers, reporting at the appropriate level to support decision making and ensure a consistent SA picture. Prediction of future demand as an input to network management and provisioning are needed to anticipate overload or resource limitations to enable an optimal response.

## 3.2 Policy-Based Secure Coalition Information Infrastructures

The Warfighter at the tactical edge will have access to information from varying sources, with varying provenance and credibility, and subject to diverse policy requirements. Information processing in support of collaborative coalition decision making requires methods to provably show that content information and services are only used as agreed by coalition policies. These policy mechanisms must ensure that the required level of security is achieved without reliance on centralized security services and under significant risk of compromise. It is expected that security concerns will be jointly addressed with networking, analytics, and situational understanding research. Particular emphasis should be placed on developing analytical frameworks, simulation techniques, and experimental methods that can assess the effectiveness of the security mechanisms, together with its impact on decision making in a complex dynamic hostile environment. This security analysis should cover scalability issues, security proofs, and security tradeoffs under a variety of network and user constraints [14-15].

Important research issues include the following:

• **Dynamic Policy-Based Autonomous Management** of both coalition information and infrastructural services that dynamically adjust to mission changes, network dynamics and policy changes. Techniques for rapidly negotiating, establishing and executing composite coalition policies from ad hoc teams with different assets, roles, security mechanisms, trust, and policies. This includes policies for the use of data/fusion services, analytics, and information

infrastructures as well as the security policies to protect them.

• **Policy Analytics**: Foundational techniques are needed to model, analyze and formally verify policy managed secure adaptive coalition information infrastructures including assurance of dynamic policies, identification of policy conflict, conflict mitigation strategies, and decision support for policy negotiation. In addition, such policy analytics must consider the human-in-the-loop so that processing by both humans and machines is supported.

• **Security for Distributed Information Services**: Develop fundamental models and mathematics to describe key aspects of Information Assurance, and their impact on each other. Develop foundational techniques for balancing and integrating security features. This basic research should lead to mechanisms that enable users of security services to make complex cost-benefit judgments, balancing multiple objectives such as operational impact, time, and effort required to comply against their ability to achieve their mission goals. Examples of security services include fine-grained data protections, distributed access control, discovery, processing, replication, and concurrency control that can be distributively applied with heterogeneous coalition policies.

• **Security Metrics**: Lack of a set of adequate, sound and underpinning set of security metrics hampers effective quantification of security, understanding of fundamental limits and tradeoffs in the design of security countermeasures, choice of security architectures, and optimization of security in the design and operation of information technology infrastructures. Security metrics must be quantifiable, realizable, and traceable. Security metrics should be identified and investigated to support:

- Effectiveness, comparison and reasoning about security functionality
- Security composability and security in composed systems and services
- As a component of risk management

## 3.3 Composability, Position, and Adaptive Distributed Data Services

In a dynamic coalition scenario, it is likely that a subset of nodes might be able to dynamically change roles. The ability to fight through in a degraded dynamic networking environment calls for basic research in composability and positioning of distributed coalition data and information services for and on disadvantaged nodes at the tactical edge. Data and information services of interest include aggregation, summarization, fusion, computing, and other services as envisaged in TA2.B (Dynamic Context-Aware Gathering and Information Processing Services). Composition of services will be goal-driven, based on the (dynamic) mission. The distributed composition and federation of services across the coalition will be constrained by policies, security issues and network state, and these constraints will impact the functionality of the composed service.

Research must address the ability to predict the feasibility of achieving the desired composed functionality as well as the cost of achieving and maintaining this composition. The problem of composability of services is a joint information processing and networking problem. An important challenge is in understanding how selection and positioning of the distributed processing services affects the higher layer task performance. There is a strong temporal component due to the network dynamics and changing nature of the tasks as well as with underlying information in the network which requires any solution to be dynamic and evolve over time.

Important research topics include the following:

• **Composability of Distributed Coalition Services**: Fundamental understanding of the composability of distributed services to support coalition information processing in dynamic environments with principled approaches for building composite information infrastructures. Emphasis is on the basic science leading to understanding the composition of services and the resulting performance of the composite system of services. Appropriate metrics for such composition must be defined and bounds on performance established. Research must enable the ability to predict the feasibility of achieving the desired functional composition, as well as the cost of achieving and maintaining this.

• **Positioning of Services**: Distributed methods to position, manage, and secure information services across dynamic heterogeneous coalition networks to support efficient, resilient, and distributed/collaborative decision making. Positioning and repositioning must consider the location of information sources, context and state of the users, capabilities of information processing assets, and coalition policies, all of which may dynamically vary (and at different time scales).

• **Adaptive Data Service Negotiation** to provably maintain, and provide assurance of, coalition security policies in resource-constrained and distributed environments for both the services to be shared and the data to be exchanged or processed. This basic research will require common architectures, components, and information exchange mechanisms.

# 4 Technical Area 2: Coalition Distributed Analytics and Situational Understanding (CDASU)

Multidisciplinary research is needed to provide the fundamental underpinnings for Coalition Distributed Analytics and Situational Understanding (CDASU). The context of future ad-hoc coalition operations at the tactical-edge has four important considerations: each has significant impact on the research required to underpin the distributed analytics and derived situational understanding. The four considerations are:

- The complex multi-actor situations which require resolution, requires understanding of the mutability of the actors involved, the environment they exist within, and rapid dynamic adaption of information and analytics as understanding changes.

- Coping with the volume and complexity (variety, velocity, value, viscosity and veracity) of information distributed across the Coalition's dynamic resource constrained information infrastructure will require distributed data processing and analytics to be undertaken by machines (supporting humans).

- The high tempo and time sensitivity in the tactical environment demands the ability to rapidly, and in a distributive manner, reconfigure/adapt the Coalition information system to address the rapidly fluctuating set of Coalition tasks with the rapidly fluctuating set of Coalition assets.

- Finally, technical systems must be aligned with human needs and capabilities, and support human understanding.

## 4.1 Modeling and Interaction for Situation Understanding

The socio-technical information system must be driven by the needs of the Coalition users and support them in understanding the diverse and dynamic range of situations presented to the Coalition at the tactical edge. A primary challenge is how to represent and model such complex adaptive multi-actor human systems. A second challenge is how to make best use of Coalition human capabilities, via use of appropriate interaction and visualization techniques. Such techniques need to be appropriate for deployed military operations: in such operations the vast majority of users are generalists as opposed to highly trained data scientists. Also such operations are highly dynamic, temporally challenging, and in an unfamiliar socio-cultural environment [16-18]

Important research topics include the following:

- **Modeling Mutability of Complex Adaptive Human Systems:** Research is needed into formal theories, representations, and models of the underlying mechanisms of how human groups and organizations (sub-classes of complex adaptive systems) evolve. The research must address, (a) group and sub-group path-dependent reactions to external and internal stimuli (including probes), (b) resilience/mutability of these systems and their closeness to a catastrophe (c.f. chaos theory), tipping point or phase change, and (c) recognition and discrimination of particular behaviors of interest. The research must address a range of group types such as (a) transient and localized groups such as crowds and mobs, (b) regionally centered/focused groups with a shared value system and goals, and (c) dispersed, loosely connected groups.

  A key goal of this research is to develop effective fundamental mechanism models (or sub-models which can be composed) which can be customized (and subsequently calibrated) to represent the set of interacting groups of interest (utilizing information and understanding distributed across the Coalition).

  Research is also needed to develop a framework to represent the relationships between the analytic goal (i.e., desired understanding), the fidelity of the mechanism model, the quality/velocity of information about the group and the uncertainty of the resulting understanding. The research's purpose is to characterize the trade-space for the coalition tactical-edge environment and enable the creation of a prioritized set of relevant information goals.

- **Problem and Goal-driven Coalition Information Processing**: Research is needed into formal theories, representations and models to underpin the analytic process and ensure it is driven by user need. Research is needed to develop effective and efficient methods to: (a) recognize the style of understanding needed (e.g. novel ('unknown unknowns') versus routine ('known unknowns'), open versus closed questions, complex versus simple) and the required tempo; (b) choose the appropriate set of analytic methods for the problem type, determining the information goals for these methods (including concepts such as precision and appropriate evidential requirement) and selecting appropriate interaction approaches (e.g. split of roles between human and machine); and (c) decompose the analytic and information goal into a set of prioritized and atomized queries (to be executed within the information system). The research will need to take account of the need to avoid surprise, the granularity of understanding required at different levels of command and how to mitigate well-known human cognitive biases.

- **User Context, Interaction and Visualization**: Enabling the users at the tactical-edge operating in very dynamic situations to utilize information more effectively requires an understanding of their context and intuitive

ways of (collaboratively when needed) interacting with and visualizing information. Therefore, research is needed to (a) model the tactical-edge users context (including mission goals, tempo of operation, cognitive skills and loading) in a manner which can be utilized within the information system to tailor the processing and delivery of information, (b) develop mechanisms and frameworks to enable intuitive iterative interaction between the tactical-edge user and the information system (including visualization, alerting and challenge), (c) develop frameworks and mechanisms to enable tactical-edge coalition users to collaboratively undertake visual analysis of information, and (d) develop models which enable selection of mechanisms without the need for exhaustive trials. The research must be multidisciplinary taking due account of cognitive design and perceptual principles and interaction with the distributed information system, and the generalist (as opposed to data analytic specialist) nature of the tactical-edge user.

## 4.2 Dynamic Context-aware Gathering and Information Services

Given the dynamic, resource-constrained and distributed nature of operations, a continuous set of distributed choices will need to be made about how the coalition information system resources should be employed to satisfy the needs of the dynamically varying set of coalition tasks. The problem is further complicated as a single resource could potentially contribute to multiple tasks (frequently concurrently), and a single task will require multiple resources (in a temporally and/or spatially distributed manner). Solving this problem requires addressing issues associated with the impact and priority of tasks in a distributed manner. In addition, the dynamic composition of content based information services requires the ability to contextualize the set of distributed data and services. Further, maximal information exploitation whilst supporting the human component within highly dynamic coalition tactical environments without increasing their cognitive loading (including skill requirements) is aided if the machine component can directly process human provided representations.

Important research topics include the following:

• **Optimizing the Matching of Coalition Resources to Tasks:** Given a dynamically varying set of operational tasks and available information system resources, where a single resource can potentially contribute to multiple tasks, the selection of which tasks to attempt to satisfy requires the ability to effectively and efficiently match resources to tasks in a branching many-many temporally and spatially complicated or complex manner. Thus basic research is required into theorems, frameworks, and mechanisms required to dynamically match tasks to resources. The research should enable the development of a distributed matching service, supported by a quantified understanding of the trade-space and assessment of the robustness of solutions. Further it should illuminate the higher-level trade-space between the scope of the asset to task matching system, the matching problem type (e.g. complicated or complex) and performance of the distributed matching services. Auction based approaches need to focus on empirically validated mechanisms to assign 'money' to 'consumers' in hierarchical coalition organizations dealing with a mixture of important and urgent tasks.

The research should develop empirically validated theorems, frameworks and mechanisms to assign relevance, significance and/or value to (categories of) information based upon the information's expected impact upon situational understanding. Non-auction based mechanism to assign significance or value are of interest.

• **Contextualization of Disparate Coalition Data Sources and Services**: Research is needed to develop the information service frameworks, mechanisms and schema required to enable the characterization and contextualization of data sources (gathering and storing both structured and non-structured data) and the available information services distributed across coalition networks. Given the situation understanding information goal in dynamic resource-constrained coalition environments, characterization and contextualization are needed at the data source layer to enable relevant distributed data sources to be discovered and, at the service layer to match available relevant information services to the relevant data sources and coalition information goal. The resulting frameworks, mechanisms, and schema must be flexible and configurable to account for the varied computing resources and platforms and be extendable for new types of coalition data sources and services. Finally, it is desirable to have rich contextualized representations that are human understandable in order to enable intuitive user interaction with them.

• **Intuitive Machine Processable Representations**: Research is needed into intuitive symbolic representations that are directly machine-processable. This means that value-loaded symbolic representations obtained from a user do not need to be transformed into a different representation (c.f. computer language) before being processed. The research should focus on both text and diagrammatic representations. The research should focus more on the feasibility of the representation dealing with the richness and variability of encoded meaning within ad-hoc coalition teams (including scalability, processing power) than the ease of human externalization and assimilation. The research will enable more effective interaction between ad-hoc coalition teams and machines, as it will enable the machine to adapt, and contribute to the user's externalized information and cognitive frames

without the user needing to be skilled in computer programming.

### 4.3 Distributed Processing and Analytics

To fully exploit the opportunity provided for situational understanding by the increasing volume, velocity, and variety of data and information available across the resource constrained dynamic coalition information infrastructure requires the seamless task-based integration, modification, and extension of low-level and high-level information fusion mechanisms. Also, research is needed to modify and extend the current state of the art in standard data analytic techniques and paradigms (as they are designed for operation in static and high performance computing environments) for tactical-edge users [10, 19].

Important research topics include the following:

• **Distributed and Integrated Fusion for Situation Understanding:** A key coalition goal is to improve the entire information process from signal processing through to situational understanding. Basic research is required into formal theories and techniques to enable the linking and integration of low-level information fusion with high-level information fusion across a distributed enterprise involving a mixture of human and machine information processing agents to achieve situational understanding. Thus, research into formal theories and techniques will need to address, in an integrated manner, both the disparate coalition sources and decision support objectives: (a) the fusion of disparate data and information that is hard and soft, structured and unstructured and; (b) selection and tailoring of knowledge-based reasoning components.

• **Distributed Data Analytics in Coalition Environment**: Given the data rich edge, basic research is needed to enable analytics of the variety, velocity, volume, veracity, value, and viscosity distributed coalition data. The research into distributed data analytics should address analytic services providing (a) distributed learning (including data mining) of distributed coalition data (structured and unstructured) in near real time, (b) aggregation, integration and summarization of large distributed volumes of heterogeneous information into more compact representations whilst also retaining the characteristics most important for situational understanding (e.g. uncertainty, discord and novelty), and (c) assurance and assessment of the risk and uncertainty associated with distributed learning systems. The research should also address how to model performance trade-offs to enable autonomic in-system decision-making about combined analytic and data resource management.

• **Enabling Analytics of Distributed Coalition Data**: Given the data rich edge, basic research is needed to enable analytics of the variety, velocity volume, veracity, value, and viscosity of coalition data distributed across dynamic resource-constrained coalition networks. In particular, basic research is needed to enable adaption of enterprise-based approaches or the development of novel extendable mechanisms for distributed processing job and data handling which can be utilized on such distributed, dynamic, and resource-constrained coalition networks. This basic research should address both distributing the analytics to the data sources and distributing data to analytic services with dynamic resource constrained coalition networks. The research should also address how to model performance trade-offs to enable autonomic in-system decision making about combined analytic and data resource management.

## 5 Research Linkages

Research in each of the TAs must be performed in the context and constraints of complementary research in other areas. Technical Area 1 and Technical Area 2 research must fit coherently together via joint and integrated research and experimentation where networking, security, analytics, and human research challenges are jointly addressed. There are many possible joint research opportunities, and there are clear research linkages between the two TAs that need to be exploited to enable distributed data analytics supporting distributed end users at the tactical edge in dynamic coalition networks. For example, dynamic policy-based management affects how the distributed coalition services are dynamically composed based on the coalition resources available that best match the mission tasks. In order to optimize the matching of available distributed sensor, data, and information resources based on user's task needs, the underlying coalition network infrastructures must adapt and provide context-aware composition of coalition services. To effectively perform distributed data and information fusion from disparate coalition sources for situation understanding, it is necessary to compose and position the needed network services (e.g., policies, processing algorithms, computing resources) at the right network nodes at the right time.

It is expected that research linkages and interaction effects between technical areas and research outputs will be explored and verified through use of experimentation. As noted above, experimentation is a crucial element of multidisciplinary research as it scientifically verifies and validates research results and findings under realistic conditions and often provides additional research insights.

## 6 Conclusion

In this paper, we present the basic research component of a new International Technology Alliance (ITA) research program in Distributed Analytics and Information Science (DAIS) with the goal generating interest from the research community to meet the significant challenges associated

with coalition operations. It is imperative that multi-disciplinary and collaborative approaches are applied to realize: (1) the dynamic adaptation of secure, resilient infrastructures to support context and semantically-aware distributed analytics; (2) the ability to integrate and exploit data and information distributed across the coalition information infrastructure; and (3) the derivation of situational understanding of complex situations by human users synergistically supported by machines. The goal is to develop fundamental underpinning research to enable secure, dynamic, semantically-aware, distributed analytics for deriving situational understanding in coalition operations.

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