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Concepts for Recognized Operational Support Picture (CoROSP)

Literature Survey

Brenda Brady
Tamara Keating

Prepared by:
NRC Canada Institute for Scientific and Technical Information
1200 Montreal Road, NRC Campus, building M-55
Ottawa, ON K1A 0R6

Contract number: SDA 07-001/017
Contract Scientific Authority: Micheline Bélanger and Jean Berger
418-844-4000 ext 4734 and 4645

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Prepared by:	Brenda Brady, Technical Information Analyst Tamara Keating, Technical Information Analyst

Business Information

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1 SUMMARY

More than 1,700 scientific publications and 238 patents were analysed for this report. Analyses were based on text analysis and the co-occurrence of words in the metadata of the documents to identify important research fronts in the domain of military logistics, with specific emphasis on decision support, predictive analytics, search and retrieval, visual analytics and user interfaces.

Generally, we can conclude that while there is much research being conducted on predictive analytics, decision support, visualization, and search technologies within the military logistics domain, implementation of these technologies is far behind. Neither does it appear that any country has been completely successful in fully linking systems designed primarily for logistics with those intended to support command and control in the field. Rather, it seems that the two systems are running in parallel, with some rudimentary attempts at functional linkages. The main challenges that may be impeding this progress are problems of data integration of legacy systems and interoperability for coalition forces, and the difficulties associated with designing a common and unifying interface for heterogeneous data and decision scenarios. Key enabling technologies in data integration and information fusion are semantics, ontologies and web services.

The main logistics requirements that are dominating areas of study are mission planning, asset visibility and condition based maintenance, particularly for aircraft and vehicles. There is also a significant amount of discussion related to cost cutting, cost-effectiveness and business planning. There are many synergies between ROSP and enterprise resource planning for other markets and industries and it has been observed that this is a much more commercial market than is the case for most defence technologies. Several large global firms such as SAP, Lockheed Martin, IBM, and Oracle control the majority of market share and it appears that many logistics systems developed for commercial markets are being adapted for military purposes since these COTS solutions do not often have the full functionality required by military applications.

The data clearly show that decision making, decision support tools and predictive analytics are significant research thrusts within this domain, and that modeling and simulation techniques and tools are key enabling technologies in this area. On the visualization side, key enabling technologies are geographic information systems and mapping capabilities to show assets in transit as well as battle space visualizations within a geographic context.

Based upon comparisons of search technologies in the logistics domain versus search technologies in the tactical situational awareness domain, it appears that the implementation of search technologies are more advanced for the tactical side than for the logistics side. This same conclusion was reached for visualization technologies and visual analytics. Frost & Sullivan comment in several of their logistics market studies that no one comprehensive integrated defence logistics software solution exists in any marketplace in any country. Thus, a fully integrated common operational picture system that provides a logistical and a tactical point of view remains a challenge, however many countries are embarking on modernization programs and implementing systems that begin to merge these two domains.

Further study is recommended in the areas of user-defined interfaces, performance metrics, predictive analytics in other fields and information search and retrieval in other fields.

2 BACKGROUND

2.1 Context

Sustained military capability requires knowledge systems that are integrated, networked-based, agile, adaptive, and flexible. These systems support multi-dimensional operations ranging from supply chain management and logistics through real-time mission situational awareness. Situation awareness is traditionally defined in terms of perception, understanding and projection. The Concepts for Recognized Operational Support Picture (CoROSP) project seeks to address all of these aspects.

The capabilities of the ROSP of particular interest to this study include the following elements:

A ROSP capability must extend classical perception (e.g. total asset visibility and tracking) to enterprise-wide "knowledge visibility", including not only visibility of resources, readiness status, tables of organization and equipment, and geographic attributes, but also expanding its meaning to capability, plans/schedules, execution constraints, behaviours and any information aimed at providing end-to-end supply network visibility (topology, capacity, state, business process and procedures).

A ROSP capability must provide situation understanding by facilitating the analysis and monitoring of operational plan execution, asset visibility and related readiness, and to track assets in transit.

ROSP requirements for situation projection include elements such as forecasting/prediction and likely environment evolution, demand, possible courses of events and actions, supply chain and logistics distribution system simulations, intent diagnosis, pattern recognition (supply production and customer demand), and options impact.

2.2 Key Issues

DRDC Valcartier has been charged with the development and demonstration of a Recognized Operational Support Picture (ROSP) incorporating the functionalities and features as summarized above, and adopting a comprehensive approach. The key objective will be to demonstrate the value of such a product to the Canadian Forces. Products already on the market or in prototype stage, underlying technologies of these systems and major players are key concerns.

This study will concentrate on two themes, each with its own specific questions as outlined below, but all addressing the key issue of a survey of the state of the art and the major players.

1 – Review of operational support/situational awareness products and requirements
To assist with their project, the CoROSP team has requested a survey of products, either already on the market or at the prototype stage, that seek to provide support in the area of logistics (asset visibility and inventory control) and/or logistics-relevant situational awareness (operational support such as troop readiness, location based reporting) in a military context. These products may combine elements of logistical and situational

awareness, but should do so in as integrated and comprehensive a manner as possible, i.e., they should provide functionality in more than one domain.

2- Review of the state of the art
This study will allow DRDC researchers to scope their project's objectives, and will provide them with a review of the state-of-the-art (technology of existing and prototypical systems). It will also help them to identify experts (civilian and military), existing expert interactions/relationships and potential research partners or industrial collaborators.

For this study, three key themes were identified to form the basis of the searches and analyses (all within the context of logistics and operational support):

- Decision support technologies and tools, including prediction and forecasting, analytical tools and modeling & simulation in support of decision making.
- User's tailored visualization, which is related to providing a user-based or role-defined interface to the CoROSP system, and touches on many aspects related to visualization of information
- Information retrieval and queries, which includes the ability for a user to query the system and to dynamically generate analyses as required or to dig into the data as needed

2.3 Key Questions

Part 1 – Review of operational support/situational awareness products and requirements

i. Which information technology products already exist, either in commercial markets or at the prototype stage, to support military logistical operations and logistics-relevant situational awareness?

ii. What are the key features (functionalities) of these systems and what operational requirements do these features support? Describe and characterize these systems in terms of functions and value (relevance, known limitations/deficiencies, strengths and weaknesses). Provide a table that compares the functions of each system reviewed.

iii. Based on published requirements documents, what are other operational requirements that these systems could support, but which are not necessarily found in already existing products? (i.e. what are other military organizations' wish lists?)

Part 2- Review of the state of the art

iv. What are the enabling technologies and emerging technological trends for these systems? Trends to analyze may include *but will not be limited to*: support for data types and integration, semantic underpinnings, data mining and analysis capabilities, interoperability, a web-centric approach, decision support and information sharing functions.

v. What is the readiness/maturity of the enabling and emerging technologies?

vi. Who are the major academic, government and industry players (author affiliations/organizations) in this domain worldwide? What are their areas of expertise?

vii. Who are the leading experts (individuals) in this field worldwide and what are their areas of expertise? Who are the leading Canadian experts and what are their areas of expertise?

3 FINDINGS

3.1 Commercial and prototypical systems

In Part 1 of this project, we reviewed findings from various market literature reports on military logistics systems and conducted a survey of systems already deployed or in development. An Excel spreadsheet providing details on these systems is provided as an attachment to this report (filename: CoROSP systems.xls).

The following initiatives of particular interest were identified:

- Global Combat Support System (GCSS) (USA)
- Battle Command Sustainment Support System (BCS3) (USA)
- Common Logistics Operating Environment (CLOE) (US Army Logistics Innovation Agency; under development)
- Adaptive Logistics Project (US Army Logistics Innovation Agency; under development)
- Net-Centric Decision Support Environment (NDSE) (US Army Logistics Innovation Agency; under development)
- Logistics Network Enabled Capacity (UK; umbrella operation for various logistics projects)
- Future Logistics Information System (FLIS) (UK; under development)
- Management of Materiel in Transit (UK)
- Military Integrated Logistics Information System (Australia; under development)
- Situational Awareness Logistics Tool (Australia; demonstration project)

All of these projects are characterized by the participation of commercial enterprises -- often global defence and IT firms such as SAP, Lockheed Martin, Boeing, or Raytheon -- and by high-value, long-term contracts. Contractors also frequently form consortial arrangements to deliver on complex requirements. In December of 2010, for instance, the UK announced an 11-year, £800m contract with Boeing Defence UK for the Future Logistics Information Services (FLIS), a “system of systems” to manage logistics operations and integrate them with both industry and the front line. Boeing is expected to outsource elements of the package to other defence and IT firms.[1]

In the past decade, most logistics projects have focused on integrating or replacing the numerous stove piped systems that exist to manage the supply chain and other logistical operations. In many cases, a phased approach is adopted: Australia’s Military Integrated Logistics Information System (MILIS), for instance, began

with the creation of a core system that can interface with defence financials, as well as Radio Frequency Identification (RFID) tracking. In the second phase, Australia will add capabilities such as support for deployments with communications-interrupted environments.[2] In the UK, the Ministry of Defence has begun with integration of land based systems (Project JAMES) and has progressed to materiel in transit as well as deployed inventory.[3] U.S. efforts have been focused on providing the communications networks and other infrastructure (such as network architectures) that support logistics information access and dissemination. The Global Combat Support System (GCSS) is an example of infrastructure developed jointly for all services which also allows for individual organizational differences, as separate hardware/software combinations have been developed for each branch.

Evaluative reports gathered as part of our phase one search suggest that one should not underestimate the complexity and difficulty of the initial integration phase. Several reports note that development efforts for the GCSS and similar systems have routinely run over budget and time due to unforeseen difficulties.[4] In an evaluation of the Battle Command Sustainment System (BCSS), one practitioner reports that the modernized and integrated logistics systems can drown the logistician in a sea of data (e.g., lists of RFID tags without a clear indication of what is in each shipment) without meaningful extraction and presentation of data. These systems appear to be more proficient at storing historical data than predicting or adapting to future demand and changing conditions. In the same article, the logistician recommends that future improvements need to be "task organized" and not "data organized".[5] A thesis on the BCSS system found deficiencies related to inadequate training, poor data integrity (especially due to lack of synchronization), lack of user friendliness, competition posed by competing software, and poor institutional management.[6] The U.S. Government Accountability Office also cited a lack of performance measures as an impediment to progress in the area of business system modernization (including logistics systems).[7]

The trend to joint and "focused logistics" – that is, transparent and up to date logistics functionality integrated with the broader operational picture – is nonetheless observed worldwide, and is notable in publications from defence agencies as well as the promotional literature produced by large corporations. In *Focused Logistics 2010* (published ca. 2003), the U.S. Joint Command calls for "full spectrum supportability"[8] and this is repeated in several strategic plans dated 2010.[9]

Logistics systems provider EDS (now a Hewlett Packard company) envisages a full-featured and well integrated logistics and common operational picture, with the capacity to interpret and respond as well as simply report, in a graphic depicting the layers and elements that contribute to a COP:

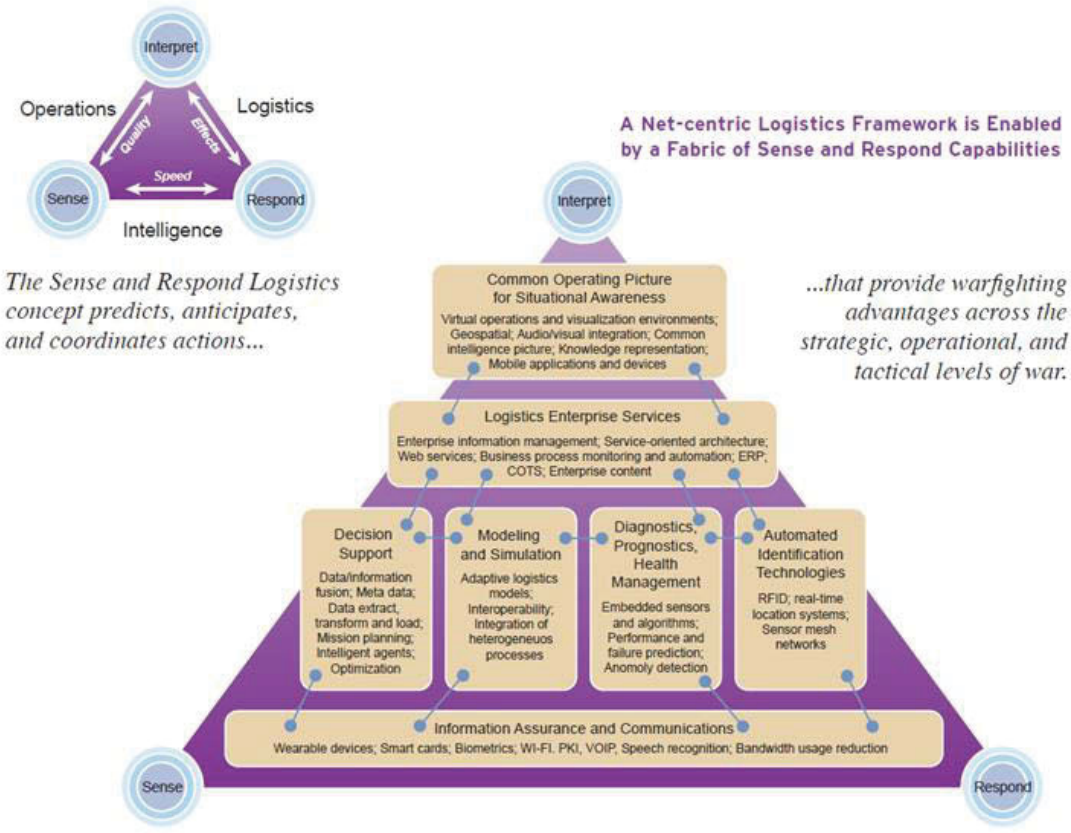


Figure 1. Sense and Respond Logistics Functionality as portrayed by EDS[10]

Logistics research and development initiatives of the past few years all cite the goal of making logistics systems more adaptive and predictive. Such was the intent of the Defense Advanced Research Projects Agency's (DARPA) Adaptive Logistics Project (ca. 2000-2003), which resulted in the commercialization of agent applications for intelligent logistics through the spin-off company Cougaar.[11] Some Cougaar-based elements have been incorporated in the BCSS system, and responsibility for further development of adaptive capacity appears to have shifted in the most recent period to the U.S. Army's Logistics Innovation Agency.

Budget requests and solicitations for logistics systems also call for enhanced mapping capabilities and visual features such as munitions watch boards,[12] architectural standards compliance,[13] decision support tools, and "measurable advances in logistics Planning, Decision, Execution, and Assessment."[14]

A review of market literature[15] on the subject of military logistics systems found that this is a much more commercial market than is the case for most defence technologies. Several large global firms such as SAP, Lockheed, Northrop Grumman, IBM, and Oracle control the majority of market share. Defence agencies are opting to use these contractors because of their experience in web applications and integration projects, but

also because their solutions are generally cheaper and easier to update and support than standalone in-house systems. Commercial off the shelf (COTS) solutions do not often have the full functionality required by military applications, however, in some cases users have reported system flaws in a few critical areas such as deployability, i.e., usability in asynchronous communication environments (poor synchronization of data and the inability to use systems while offline).

Modernization is being driven by experience in the Iraq & Afghanistan campaigns, where the ability to provide lean and agile logistics support has proven critical to success. As well as improved performance, defence departments are calling for cost-cutting and rationalization, and logistics integration exercises align well with this objective. Modernization and integration plans are also being enabled by improvements to security, web services and communications.

Challenges to logistics modernization identified in the market literature include:

- The continued existence of many (stove piped) legacy systems
- The complexity and difficulty of integration -- Frost and Sullivan reports that most projects are still stalled at this stage of development.[16]
- Issues related to deployability
- Interoperability requirements
- Budget and time requirements
- Large and fragmented supply chains
- Large size of inventories
- Change management issues
- Security concerns
- The presence of multiple logistics system vendors
- Lack of vendors with a complete solution. Although Frost and Sullivan identifies SAP as the vendor with the most comprehensive logistics suite of tools, their analysts also state that "…at present (2009), no one comprehensive integrated defence logistics software solution exists in any marketplace in any country."[17]

We will return to some of the "lessons learned" reported in Part 1 and the literature search later in this report.

3.2 Operational Requirements

The review for this section concentrated on identifying and summarizing key conceptual requirements documents, including government reports,[18] system descriptions,[19] third-party publications[20] and one master's thesis.[21] Seven documents were reviewed and a summary of the requirements specified in these documents are provided in the spreadsheet attached to this report (filename: CoROSP requirements summary.xls). Additional requirements documents were identified; however, most of these were specific to known systems, such as the Global Combat Support System (GCSS) from the United States. These types of documents were more appropriate for the review of known systems rather than for this generic requirements section. A list of additional resources is provided in the attachment *Evaluations, Reports and Lessons Learned* (filename: CoROSP recommended sources.doc).

We sought to extract from these documents key aspects related to conceptual functionalities (such as total asset visibility, logistics system performance and metrics). These functionalities are listed as rows in the spreadsheet, with brief descriptions of what that functionality includes contained in a note for that row, while each column contains the name of the document. We also sought to extract any requirements specifically related to architecture, information management and technical aspects of the implementation of the requirements. There was a general lack of technical specifications, except for the Sense & Respond Logistics Roadmap,[22] which maps capabilities to technologies in a visual way (see Chpt. 3). This report was therefore very valuable in providing a guide for the technologies to explore further in the rest of this study.

Further details for each functional area are provided in the spreadsheet. Overall, the dominant theme from all these requirements documents that was not evident from the review of known systems (section 3.1 above) is in the area of performance measurement and metrics, which means that performance metrics to assess the logistics system performance must be established in order to be better able to detect deviations in the system that may alert a decision maker to some action. In the RAND report,[23] this means: devising prediction and models to translate logistics process performance and resource levels to operationally relevant measures of effectiveness of the plan; sensing when deviations in logistics system performance will affect operational performance; and alerting decision makers to initial deviations in the plan, rather than reacting, after the fact, to situations affecting mission capability. The authors also state that emphases of metrics in the future need to be on "outcomes", rather than on "outputs". Metrics are also an important factor from the Canadian Auditor General's report which recommends the development of indicators and requirements for data gathered to assess system performance. Unfortunately, few of these documents specify what these metrics should be. One document from the US Office of Force Transformation contains specific metrics and should be very useful.[24]

With regards to decision support, we see recommendations for collaborative decision making, decision support tools for specific functions such as resource planning and distribution, but essentially decision support tools, applications, and systems that enable identification of and rapid adjustment to unintentional deviations from planned logistics operations. These requirements predicate the use of predictive analytics and modeling. According to Tripp et al., modeling, but more specifically agent-based models (ABMs) have been used extensively in combat modeling, but until very recently, there has been limited application in the logistics area. In new logistics systems, predictive modeling will be required at multiple levels: strategic, tactical and operational.[25]

The data collected in part 1 of this study points to the need to achieve functional integration as the first step of any logistics/COP endeavour. The data also attest to the challenges posed by integration. Lessons learned in Afghanistan and Iraq, and the prospect of increasing asymmetric threats make a strong case for agile and adaptive logistics provisioning and sustainment, however. Interoperability will also be a non-negotiable requirement of future systems, both for joint service systems and coalition campaigns.

These requirements for decision support and predictive analytics form the basis for the main body of this report, along with visual analytics, and search and analysis functions. Other requirements and recommendations suggested by Part 1 results and the literature search are as follows:

Standardization

Britain has also developed a Logistic Coherence Information Architecture (LCIA)[26] as part of its ongoing Logistics Network Enabled Capacity, and in the US, the Defense Infrastructure Information Initiative Common Operating Environment (DIICOE)[27] and Army Integrated Logistics Architecture (AILA)[28] also enable systems integration/interoperability and data and application sharing. Standards are seen as key to both current and future development.[29]

Common Interface or Operational Views

A 2007 commentary on the BCSS advocates for common operational views deployed as electronic layers as a means of providing a consistent tactical picture, one that can extend to logistics operations. Standardized views dictated by user needs and mission objectives and managed through interface layers views help warfighters maintain common understanding and focus.[30] They can also reduce the perception of complexity and buffer the impact of changes to new versions of an application.[31]

Multiple Visualization Techniques

Our results attest to the keen interest of commercial firms and defence agencies in visualization. In a 2005 document retrieved by the literature search, the authors state that:

> …there is a proper and formal way to approach designing visualization techniques for maintaining situational awareness in complex domains. Visualization techniques should be specifically designed or selected to align with one of the three identified stages of situational awareness - perception, comprehension, or projection - and with one of five standard uses of visualization: monitoring, inspecting, exploring, forecasting, or communicating. Greater value can be realized by selecting the right visualization technique to focus on each operational task, rather than searching for a single all encompassing solution to fit every need.[32]

Joint Development and Central Support

In his 2010 Masters' thesis on the U.S. Defense Department's logistics enterprise systems, Mark Jones states that:

> ….The design of the ERP solution needs to address requirements from all four Service Components. Technical requirements should be fairly standard. These include the ability to access the system from any environment with excellent or poor communication networks and the ability to handle a very large number of users. The functional requirements should also be fairly standard, that is, the same business processes to be used by all the Services. Examples are the ability to order a part, schedule maintenance, or track assets. However, this presents a tremendous change management issue for all of the Services since the functional requirements, when standardized, will most likely not resemble the current way business is being done in any of the four Services. The advantage is that a common language for logistics management is established, standard processes are exercised, and all Services conform to one system.

Other recommendations made by Jones include centralized build, sustainment, and post-deployment system support. [33]

Performance Metrics

Several agencies have made the case for good metrics as a means of documenting and improving performance and promoting adoption of future logistics systems. Although our search did not specify metrics and did not find any evidence of a standardized approach to logistic metrics, at least one document lists suggested explicit measures for military logistics performance.[34] Metrics for fusion and situation awareness such as timeliness, confidence and accuracy are suggested in a 2006 paper sponsored by the U.S. Air Force Research Laboratory.[35] The Department of Defense Performance Based Logistics concept has also garnered several publications that discuss performance metrics, particularly in the area of supply chain and contractor evaluation,[36] while others provide metrics for prognostic health monitoring and condition-based maintenance.[37] The remaining articles selected for this section are in the areas of inventory management, materiel readiness and metrics for supply chain modeling.[38]

Deployed Logistics: Bandwidth and Communications

Frost and Sullivan and others have noted that the first attempts at integrated logistics solutions have been less than wholly successful in the field, where communications can be intermittent. Although improvements have been made in this regard – SAP, for instance, now offers deployed and mobile applications that use satellite communications and can operate while offline, and courses[39] in how to set them up -- several articles retrieved in our search address logistics system techniques and how these can be minimized or made more efficient.[40]

On a similar practical note, researchers at the Defence Science and Technology Agency of Singapore recommend the use of synchronized services in response to general information searches, and asynchronous services for more detailed views. The same team suggests creation of accelerated tables and views for frequently accessed information. [41]

3.3 Review of the State-of-the Art - Overview

In total 1,675 articles were included for analysis for a general overview of the domain. These references include papers specifically related to logistics systems only. Details on the search strategies are provided in appendix 5.1.1. Results were analysed using *VantagePoint* text analysis software and *TouchGraph* visualization software.

3.3.1 Major Topics and Research Fronts

The following graph (Figure 2) is an illustration of the relationships between the top 250 terms in the dataset using *TouchGraph* software. The terms were weeded to exclude non-useful terms (e.g.: study, research, technology) and terms known to not have significant interest for the client (e.g. communications & networking). This tool allows us to visualize relationships based on a statistical calculation of the co-occurrence of words in the dataset. By clustering the terms together, natural clusters of topics within this domain are shown, which can sometimes be interpreted as research fronts.

Several clusters of particular interest to this study have been circled on the graph. These topical clusters show evidence of research being conducted in the areas of:

- semantics, ontologies and Internet;
- condition-based maintenance and autonomic logistics (especially for aircraft), closely related to failure analysis and reliability;
- collaboration, information exchange and sharing, closely related to searching and knowledge management;
- data mining, information management and data fusion;
- decision support and decision making;
- data management and visualization;
- risk analysis;
- scenarios, optimization and algorithms;
- agent-based modeling and simulation.

This graph illustrates that all of the topics that we expected to see in the data are evident and that they are clustering together in expected ways. This graph does not provide any indication of the magnitude of these subjects however, which is why further analyses are conducted in *VantagePoint*.

The clusters we observe in *TouchGraph* were used for further grouping in *VantagePoint*, which allows us to create one group of multiple terms.[1] In the master file, 77 such groups were created, covering 98% of the data. A graphical representation of the relations between these groups is provided in Figure 3. In this graph, the size of the node represents the numbers of documents associated with that node, relative to the rest of the nodes,

[1] For example, the terms “user-interface” and “graphical user interface” can be placed into one group, along with other synonyms for interfaces.

and the line in between the nodes represents the strength of the correlation between those two nodes, the stronger the line, the stronger the correlation. Some of the nodes have been coloured in the graph to highlight areas of particular interest for this study (the default colour is dark blue).

- Decision support, prediction, modeling & simulation
- Visualization, imagery, interfaces and displays
- Information search & retrieval
- Integration, architectures, interoperability, networking & communications

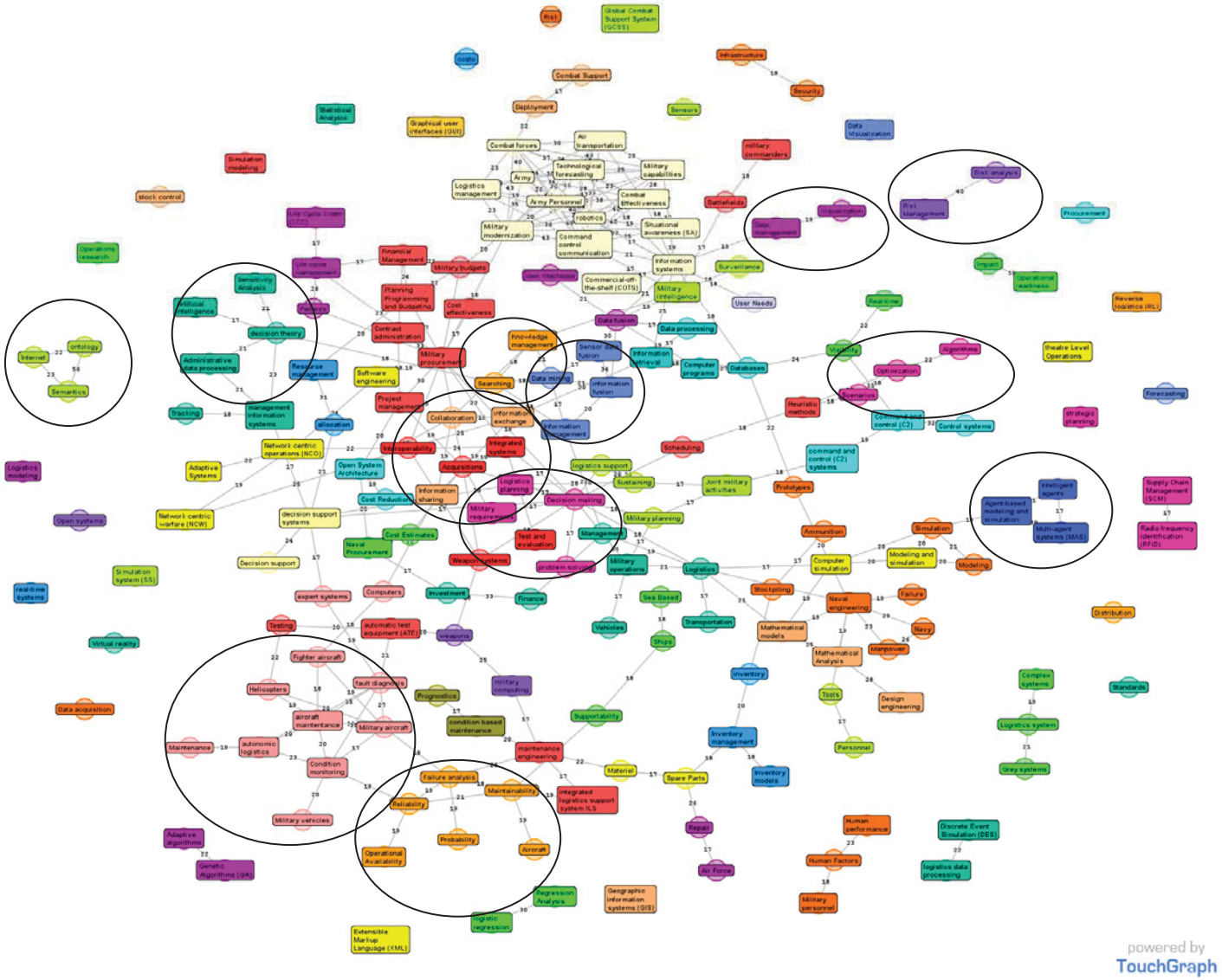
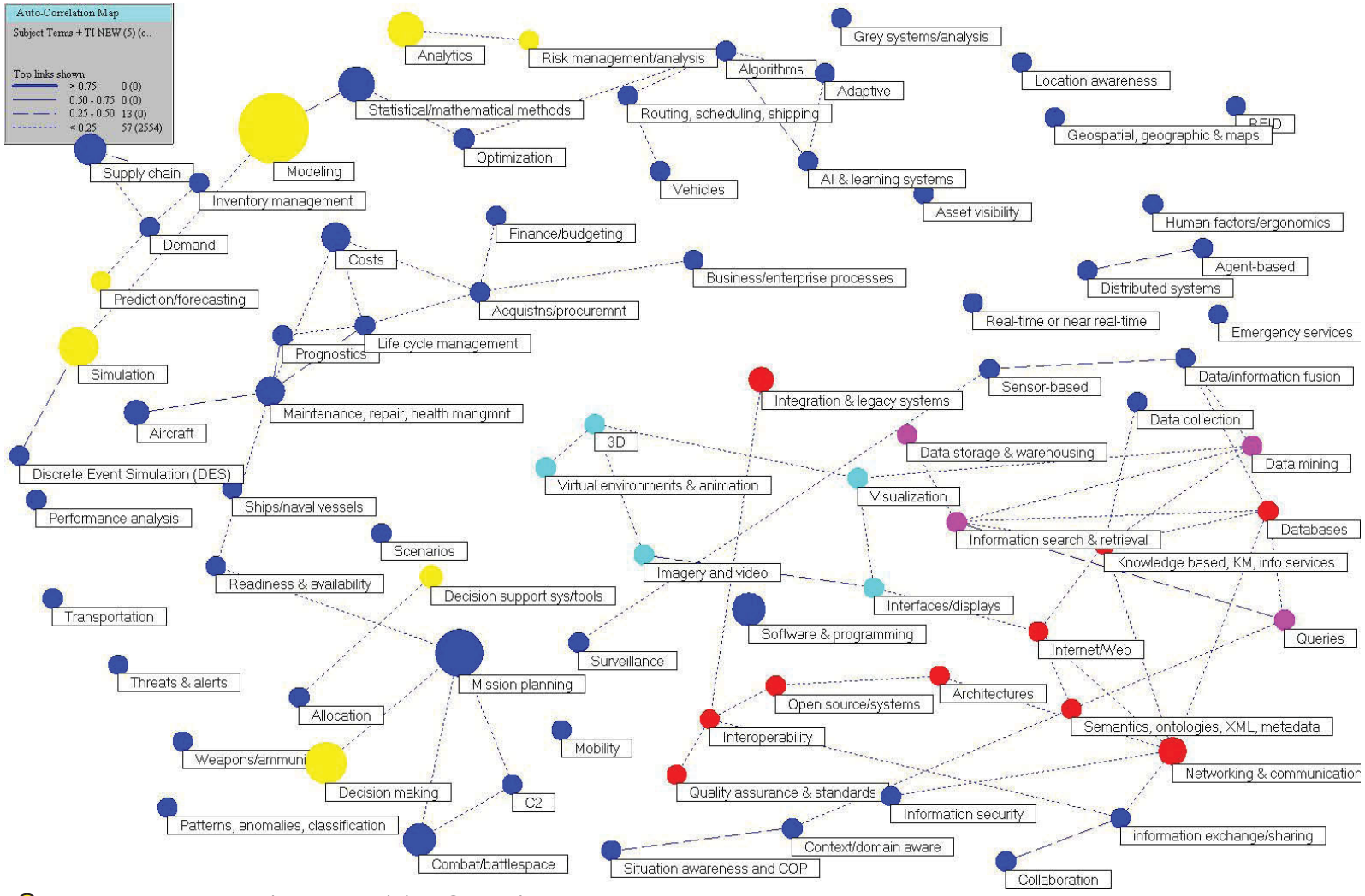


Figure 2. Cluster Map – top 250 keywords, all data



- Decision support, prediction, modeling & simulation
- Visualization, imagery, interfaces and displays
- Information search & retrieval
- Integration, architectures, interoperability, networking & communication

Figure 3. Research Topic Groups – all data

Some of the large nodes, which indicate higher numbers of publications and therefore stronger research focus, are:

- Modeling
- Simulation
- Statistical/mathematical methods
- Mission planning
- Decision making
- Combat/battlespace
- Networking & communications

Generally, the distribution of the numbers of publications by year shows a peak in 2008 and a decline in 2009 and 2010. We therefore looked for topics where there was a rise in the numbers of publications since 2008 to determine the "hot topics". These are illustrated in the figure below. Two of these topics, prediction & forecasting and risk management, are closely related to decision support categories and to costs and will be discussed further in section 3.4 below.

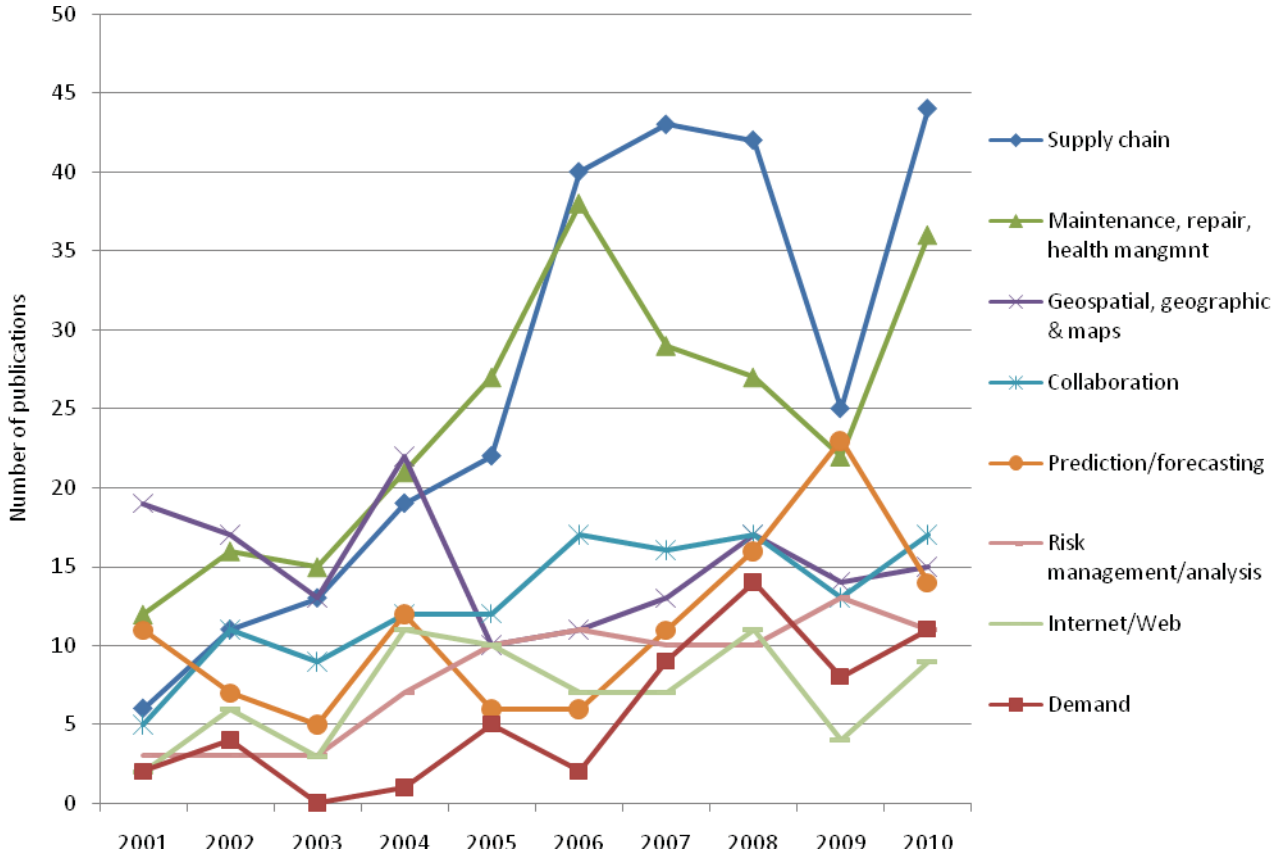


Figure 4. Topics with rising interest – all data

3.3.2 Major players

Figure 5 shows the organizations with the highest number of publications in the dataset. There is very high representation in this list by US defence organizations and research institutes. Further details on the authors and areas of expertise for these players are found in Appendix 5.4. Other important institutions not shown on this graph include National University of Defense Technology, China (10 papers), NATO Research & Technology Organization (9), Georgia Institute of Technology (8), Texas A&M University (8) and Carnegie-Mellon University (7). There is some representation from companies as well, including: BAE Systems (7), Northrop Grumman (7), Boeing (5), Lockheed Martin (5) and MITRE Corp. (5).

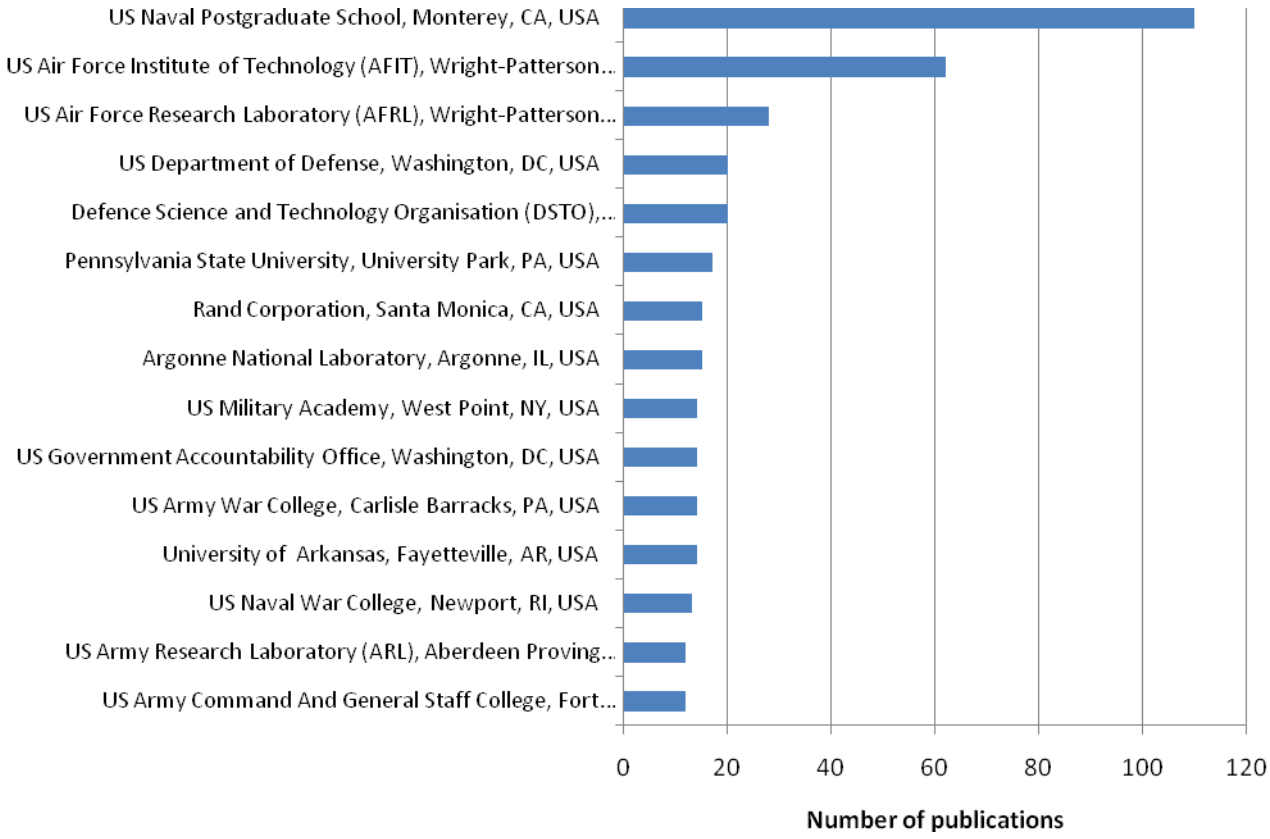


Figure 5. Major Players – all data

3.3.3 Experts

The following table shows the authors in our dataset with six (6) or more publications. Some of the authors have been grouped together into research teams since they co-authored most of their papers together. Further details on all of these authors and their areas of expertise can be found in Appendix 5.4.

Table 1. Leading Experts Worldwide (by numbers of publications)

Author Name(s)	Affiliation(s) of Author	Publication Years
Macal, C. M.[7][2]	Argonne National Laboratory, Argonne, IL, USA [7]	2004 - 2009
Van Groningen, C. N.[6]	Argonne National Laboratory, Argonne, IL, USA [6]	2002 - 2004
Kang, Rui[9]	Beijing University of Aeronautics and Astronautics, China [6]; Beihang University, Beijing, China [3]	2007 - 2010
Kuster, Egon[7]	Defence Science and Technology Organisation (DSTO), Edinburgh, Australia [5];	2004 - 2006
Cagle, Ron[6]	Gracar Corp., Dayton, OH USA [3]; University of Dayton, OH, USA [2]	2006 - 2008
Vincent, Patrick J.[6]	Northrop Grumman Information Technology, Fairborn, OH, USA [6]	2002 - 2006
Zhang, Liu[10]	Ordnance Engineering College, Shijiazhuang, China [4]	2007 - 2010
Li, Shiying[6]; Yu, Yongli[6]; Zhang, Yong[6]	Ordnance Engineering College, Shijiazhuang, China [3]	2007 - 2010
Reichard, K. M.[7]; Banks, J.[6]	Pennsylvania State University, University Park, PA, USA [6]	2005 - 2008
Chilov, Nikolai[6]; Levashova, Tatiana[6]; Smirnov, Alexander [6]; Pashkin, Michael [6]	Russian Academy of Sciences, St Petersburg, Russian Federation [6]	2003 - 2005
Cassady, C. R.[6]	University of Arkansas, Fayetteville, AR, USA [6]	2003 - 2005
Quill, Laurie[6]	University of Dayton, OH, USA [4]; Gracar Corp., Dayton, OH USA [2]; US Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH, USA [2]	2002 - 2007
Faas, P. D.[6]	US Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH, USA [4]	2003 - 2007

[2] Numbers in square brackets represent the number of references in the dataset pertaining to that element. For example, Macal, C.M., has seven (7) publications in the dataset. In all other columns, the numbers in square brackets represent the number of publications in the dataset for that element, attributed to the author in the first column. For example, of Macal's seven publications, all of them are attributed to Argonne National Laboratory.

3.3.4 Canadian Players

Only 20 papers in the dataset originated from Canadian institutions. DRDC-Valcartier and DRDC-Ottawa are responsible for nine (9) of these articles, with six (6) and three (3) articles attributed to each, respectively. Other Canadian institutions include University of Calgary (2 papers), Carleton University (1), Concordia University (1), General Dynamics Corp (1), Royal Military College, Kingston (1), University of Toronto (1), Université de Montréal (1) and École Polytechnique de Montréal (1). Further details on the papers and authors from these organizations are provided in Appendix 5.5.

3.4 Decision Support

A subset of the master data was created to include only papers related to decision support, modeling & simulation and various analysis techniques such as performance analysis, risk analysis, scenarios and diagnostics. This subset contained 1,333 unique references. The topical map of groups in this dataset was very similar to the figure for the master dataset (Figure 3) and so has not been reproduced here. Instead we will focus on three main themes identified by the client: analysis; prediction and forecasting (which includes modeling and simulation); and, planning and monitoring of operational support operations.

3.4.1 Analysis

Subject groups related to analysis (risk analysis, performance analysis, analytics in general, scenarios and statistical analysis) consist of 458 records or 34.4% of the dataset (458/1,333). If we include situational awareness as an analysis function, then the percentage changes to 39.8% (531/1,333). These figures indicate that analysis is a significant part of intelligent logistics systems. The subject group "analytics" on its own is not showing any rising interest in recent years, however, we can see that it is most highly correlated with modeling, logistics, costs, and maintenance & repair. The most common type of analysis is risk analysis, followed by mathematical/statistical analysis and readiness & availability. Other types of analysis mentioned include cost-benefit analysis, systems analysis, failure analysis (especially related to maintenance and repair of aircraft), and analytic hierarchy processes (AHP) and analytic network processes (ANP). The latter two methods are relatively new in this dataset, having only been mentioned regularly since 2006. We also see evidence of functional analysis and cognitive task analysis (related to human factors). All of these results suggest that analytical functions are being researched and implemented in logistics systems, with the highest focus placed on cost cutting or cost-effectiveness, as well as maintenance & repair.

According to the Sense & Respond Logistics Technology Roadmap,[42] some of the enabling technologies for analysis are:

- knowledge representation and management, which includes technologies such as semantics, ontologies and natural language processing, unified object modeling, data warehousing and online analytical processing (OLAP), image and video analysis and recognition
- total visibility and situation awareness, which includes asset identification data and services, risk assessment and risk information and user interfaces based on roles, needs and echelon
- Business Process and information management, which includes rules engines, Business Process Management (BPM), real-time business intelligence (BI), complex event processing, text mining, data stream mining and workflow tools.

All of these technologies are present in our dataset, with technologies related to knowledge management having the most prominent position among those listed above.

3.4.2 Prediction and Forecasting

As mentioned earlier, prediction and forecasting is one of the few topical groups in the dataset showing a rising interest rather than a decline in 2009-2010. The prediction & forecasting group (107 records) on its own is most closely related to mathematical/statistical methods, modeling, aircraft, artificial intelligence and readiness & availability. Modeling and simulation categories have been isolated to determine both *what* is being modeled and *how*.

Table 2 below shows *what* is being modeled or simulated, with the numbers in the table representing the proportion of the modeling references (573) and simulation references (321) that are devoted to a listed operational function. We can conclude from this table that mission planning is the function most commonly modeled or simulated. There are some slight differences in what is being modeled versus what is being simulated, with decision making, costs, supply chain and maintenance the highest functions for modeling and combat/battlespace, supply chain, decision making and aircraft for simulation. Though the numbers are not as high in this dataset for correlations of modeling and simulation to information search and queries, there is some evidence (21 articles) that research is also being conducted on modeling for search, with reference to algorithms, query models and simulation techniques.

Table 2. Percentage of modeling and simulation publications related to operational systems functions

	Modeling (%)	Simulation (%)
Mission planning	19.2	22.4
Decision making	17.8	15.0
Costs	17.6	11.8
Supply chain	17.1	16.5
Maintenance, repair, health management	14.5	13.1
Combat/battlespace	11.9	17.4
Business/enterprise processes	11.2	5.6
Aircraft	11.0	14.3
Decision support systems/tools	10.8	10.0
Acquisitions/procurement	8.7	8.7
Weapons/ammunition	6.6	9.7
Transportation	5.6	6.5
Readiness & availability	5.2	7.5
Vehicles	4.7	2.8
Inventory management	4.4	1.9
Demand	4.2	4.0

Figure 6 below shows the topical groups created from modeling and simulation terms to illustrate the emphasis on the subject in the dataset. These groups are based on specific terms in the database, while Table 2 uses the co-occurrence of words in the documents to calculate the relative figures. For example,

only terms like “decision model” or “simulation-based decision making” appear in the decision models group, however, in Table 1, any instance of the words “model” or “simulation” that co-occur with the word “decision”, is counted for the decision making line in Table 2. Figure 6 is therefore more specific.

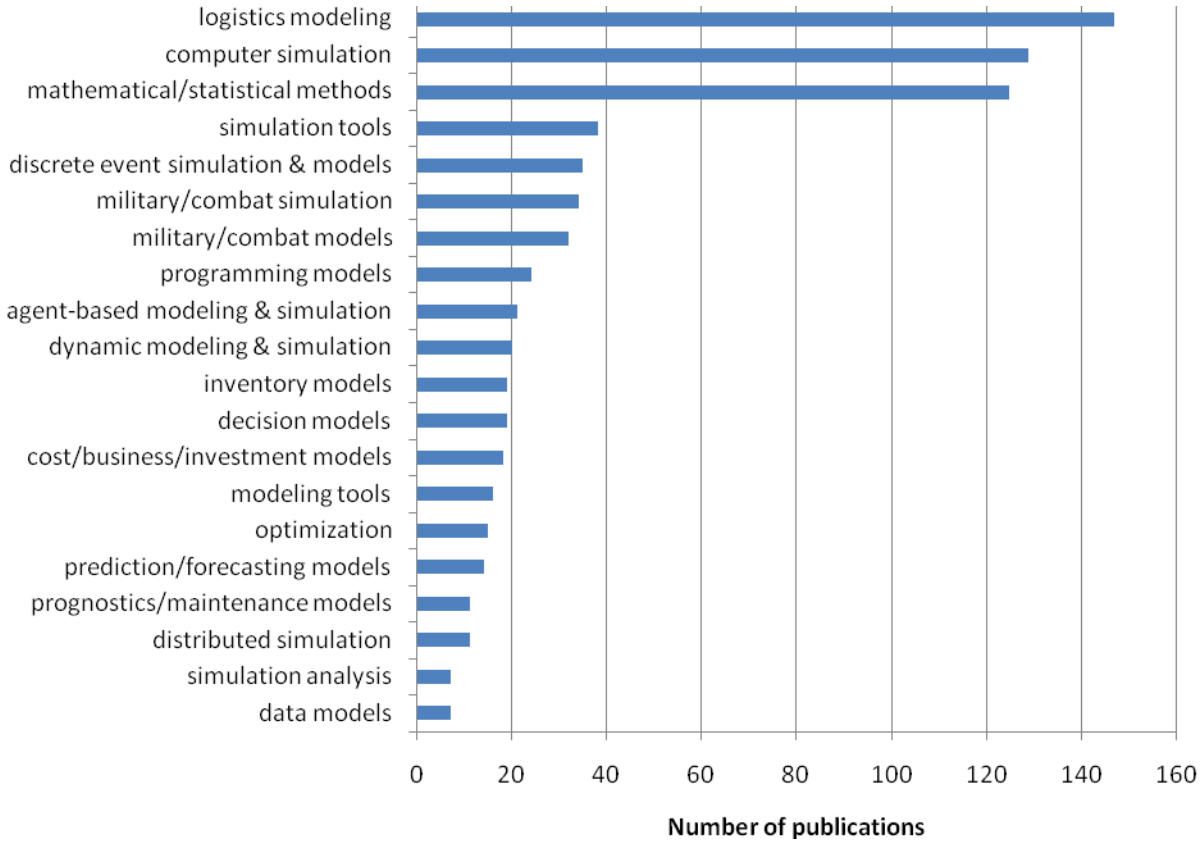


Figure 6. Modeling and Simulation terms – numbers of publications

Of the groups in Figure 6, only the following are showing an upward trend since 2008:

- Agent-based modeling & simulation
- Decision models
- Cost/business/investment models
- Prediction/forecasting models

These observations seem to support the general hypothesis that modeling and simulation for decision support and predictive analytics are important trends in logistics systems at the current time. That agent-based modeling and simulation is an important trend has also been observed in the literature, particularly by Robert Tripp of the RAND Corporation.[43] Finally, as was seen in Table 2 – modeling & simulation and possibly other prediction and forecasting techniques are strongly linked to cost analysis, cost-effectiveness and budget planning for the military.

3.4.3 Operational planning and monitoring

To analyse the information related to operational planning and monitoring, a subset of the data containing 409 records was created. This dataset is comprised of records related to operational readiness, operations research, operational effectiveness, mission planning, logistics planning, and the like. Some interesting subcategories became evident in this subset that did not have relatively significant results in the entire decision support database, namely: planning, operations research, metrics and measurement and requirements/needs assessment .

Figure 7 lists the top 25 topics in this dataset, sorted by number of publications. Figure 8 shows all the topics in the operational planning subset. The nodes coloured turquoise are those that are particular to this subset of the data.

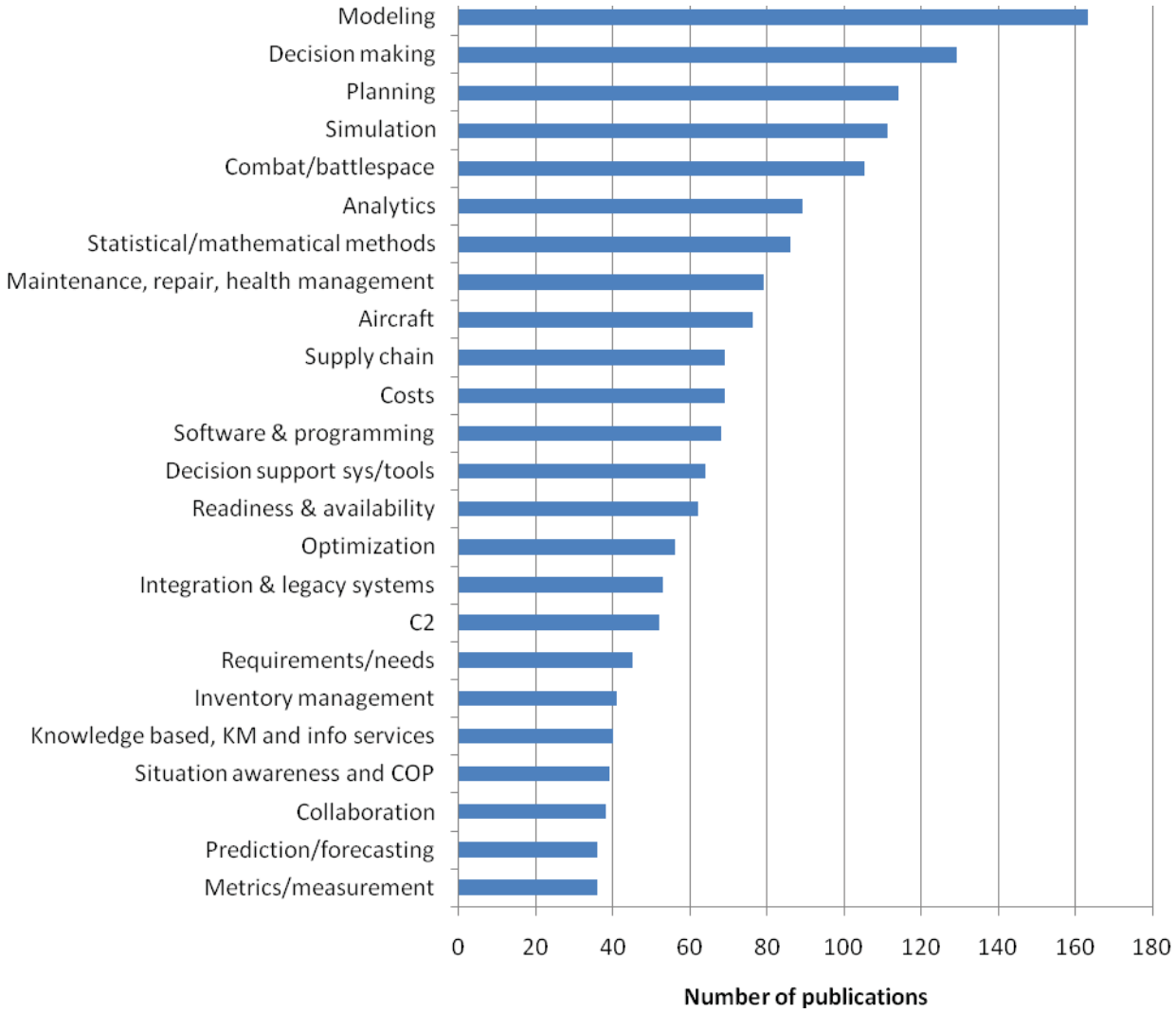


Figure 7. Operational planning topical groups, number of publications

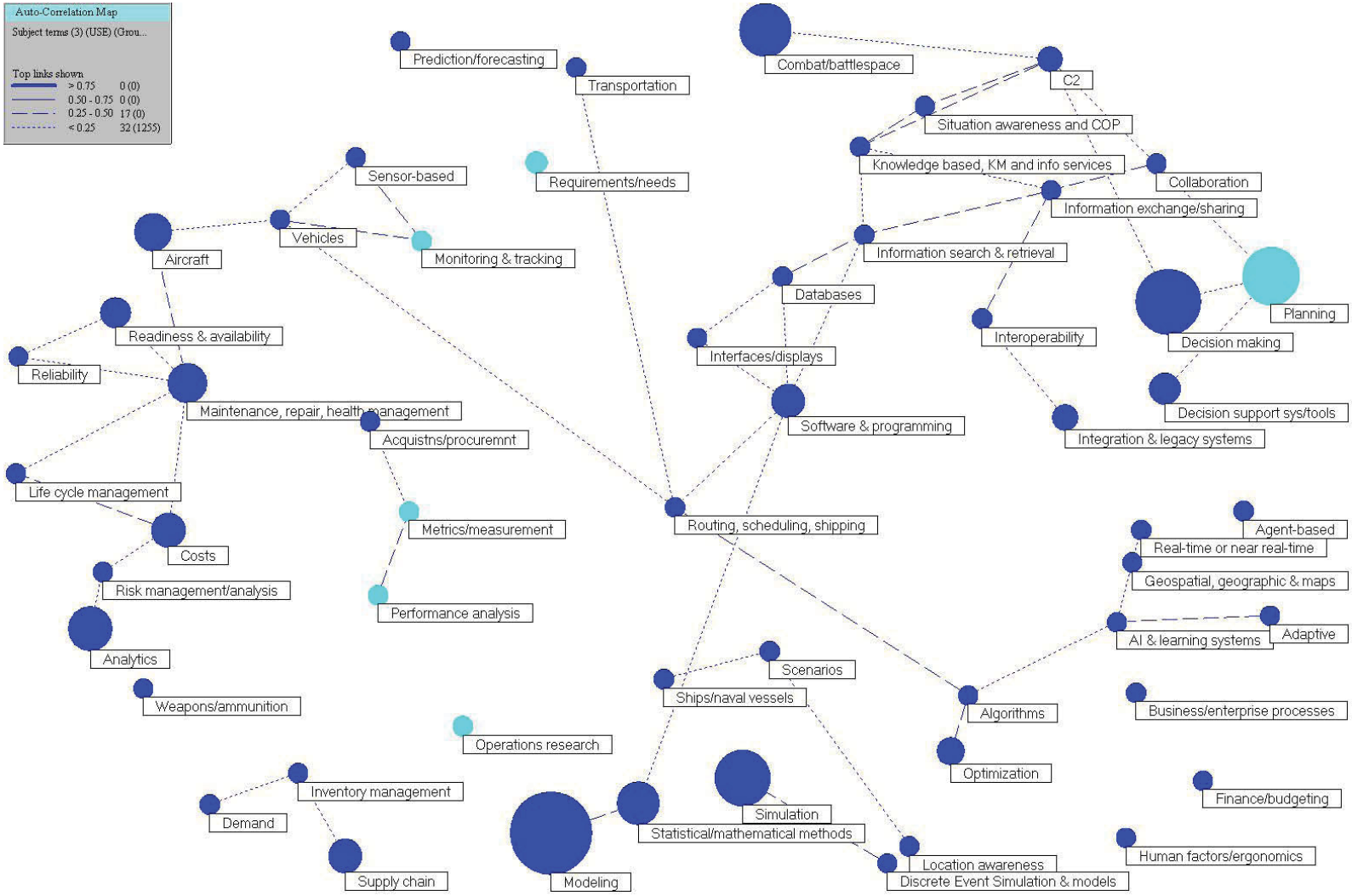


Figure 8. Topics map - operational planning subset

Groups not found in other subsets of the data

3.5 Information Search and Retrieval

The original search strategy for this project was designed to capture scientific and technical content on how logistical systems are being used to inform the common operational picture (COP), with special emphasis on capabilities for prediction, search, and visualization. In the latter two subject areas, however, results were slight. Two supplementary searches were therefore conducted to retrieve information on search and visualization technologies for situational awareness (SA) and the common operational picture, without specifying logistical applications. In both cases (search and visualization), the supplementary searches found content that describes a more "tactical" context, focused on situational awareness in combat.

The results of the supplementary searches help to place the nature and development of the logistical role in the broader context, and also establish which technologies are already being used for SA and COP generally. The parallel sets of logistics/COP files (abbreviated as LOG and COP) for each subject area can be compared for similarities and differences that speak to the maturity and/or emergence of technologies. In the analyses which follow, the files are referred to as SEARCH & LOG (logistics emphasis), and SEARCH & COP (broader, COP results).

While some subtle differences exist between subject areas, for purposes of comparison, we decided to organize subject content from all datasets retrieved using a common thesaurus.

For SEARCH & LOG, 67 groups were applied to subject terms in 137 records. 99% of the dataset was grouped.

For SEARCH & COP, 63 subject groups were used for terms found in 213 records, covering 97% of the data.

The overall volume ratio relationship between the two files is almost 1:2 for LOG to COP.

When the files are compared, some groups demonstrate a disproportionate weight in one group versus the other. In most cases, this is simply a function of the search strategy – logistics search terms in the original search retrieving stronger logistical content for instance -- but the differences also uncover differing emphases that suggest different approaches or problems to be solved.

The smaller SEARCH & LOG set shows higher relative occurrences than SEARCH & COP in groups reflecting typical logistical functions such as asset visibility and lifecycle management. SEARCH & LOG also demonstrates a stronger emphasis on business processes and budgeting, unsurprisingly so given the amount of acquisition and procurement in the area. Modeling, simulation, statistics, and data management (databases, storage, etc.) also receive relatively greater attention. Search activity/technology in the area of logistics plainly relates to establishing readiness or predicting availability based on life cycle data or routing decisions. Financial data are also important.

Figure 9 highlights areas where groups for the smaller SEARCH & LOG file had results deemed strong or disproportionately high when compared to SEARCH & COP. Where no occurrences are reported for SEARCH & COP, the group content was non-existent in that set.

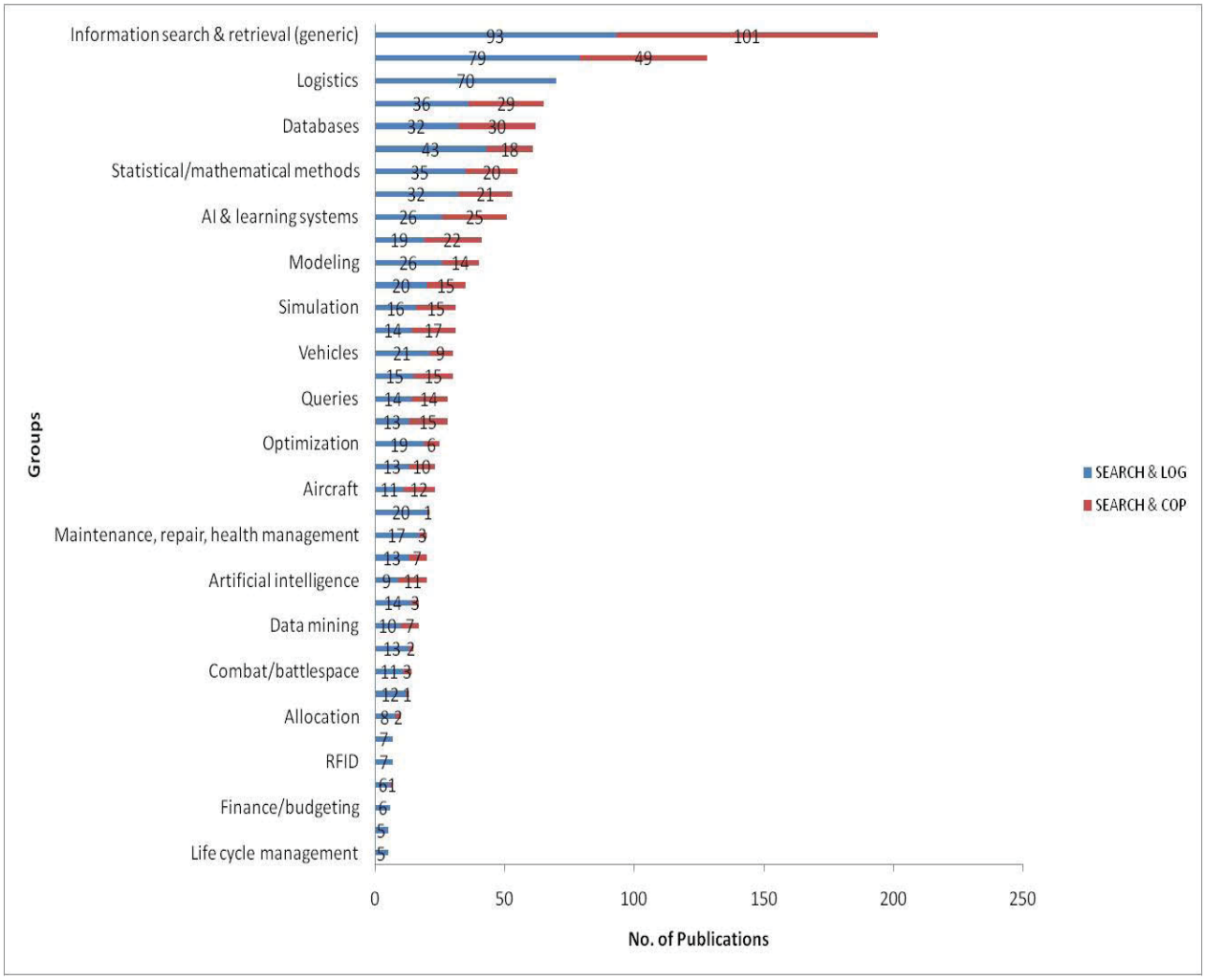


Figure 9. Subject groupings with higher or disproportionate strength in the SEARCH & LOG dataset

By way of contrast, groups shown in Figure 10 demonstrate a stronger relative presence (more than double) in the SEARCH & COP data. Imagery, videos and visualization are more prominent in the dataset for the common operational picture, as are semantic and geographic technologies, threat detection, and data and systems integration.

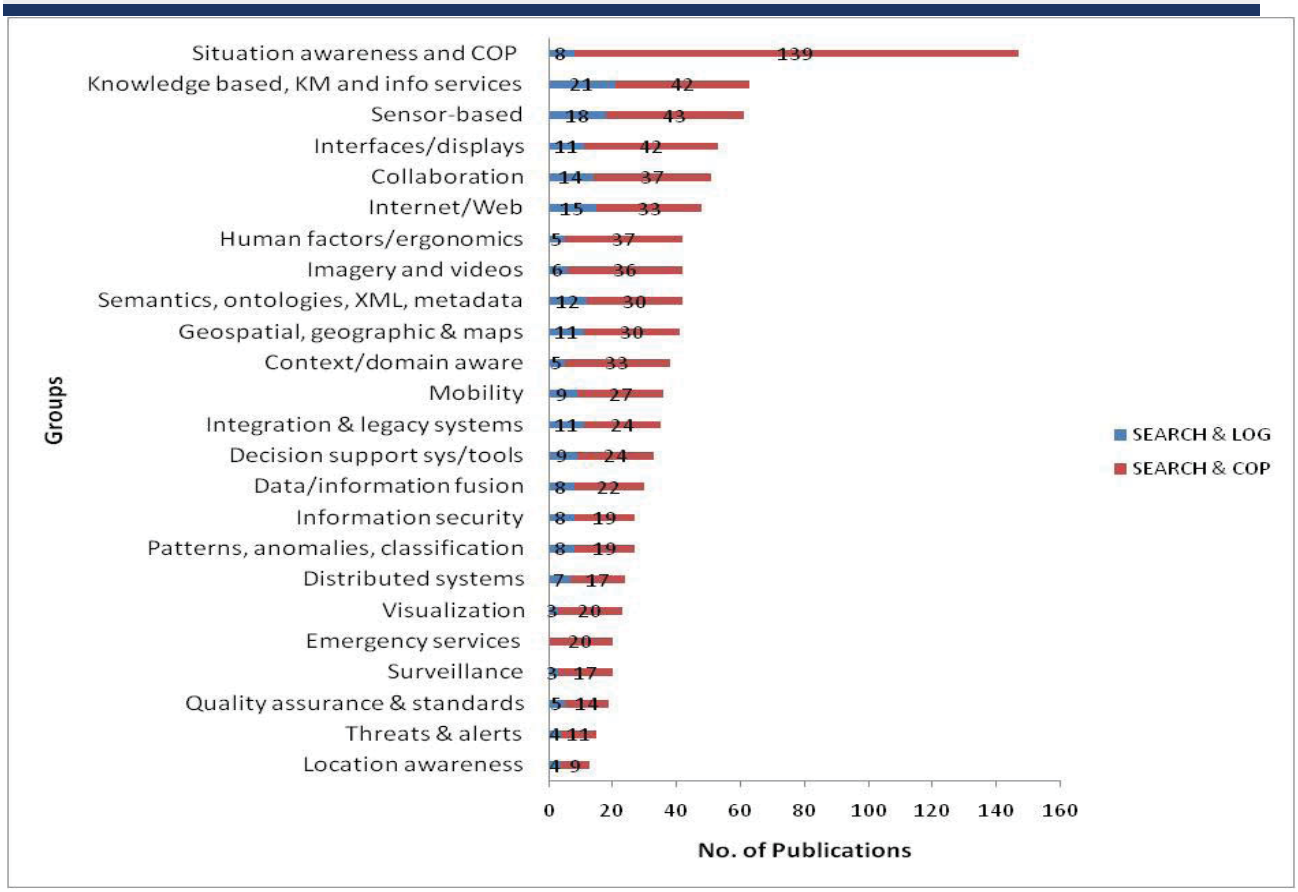


Figure 10. Subject groupings with higher or disproportionate strength in the SEARCH & COP dataset

3.5.1 Search Topical Maps

SEARCH & LOG dataset

In Figure 11, we see the relationship between search and retrieval and mission planning and inventory management. While the functions emerge clearly, there is less content on the underlying technologies, with a few exceptions. Just at the left-centre of the map, for instance, we see a fuchsia-coloured link between Queries and Semantics, ontologies, XML, and metadata (used to enable search across multidimensional data in disparate databases, it can be surmised). Data fusion is linked both to sensors (at top, green) and decision support. At the bottom of the map in red, optimization techniques (and related algorithms) are correlated with routing, shipping, and scheduling plans, especially for vehicles (fleet management).

SEARCH & COP dataset

For SEARCH & COP (Figure 12), semantic technologies (upper right quadrant, fuchsia) are linked to artificial intelligence methodologies and algorithms used to mine data (including images and videos) for patterns and anomalies related to surveillance. Visual analytics and interfaces are also appear in the small green Visualization cluster at the bottom of the graphic. Logistics content is slight in this picture, expressed only in the red nodes linked for Acquisitions and Data collection at the right of the graphic. Most of the analytical activity in this file and graphic appears to be related to threat detection on sensor-gathered data (mid-left, yellow).

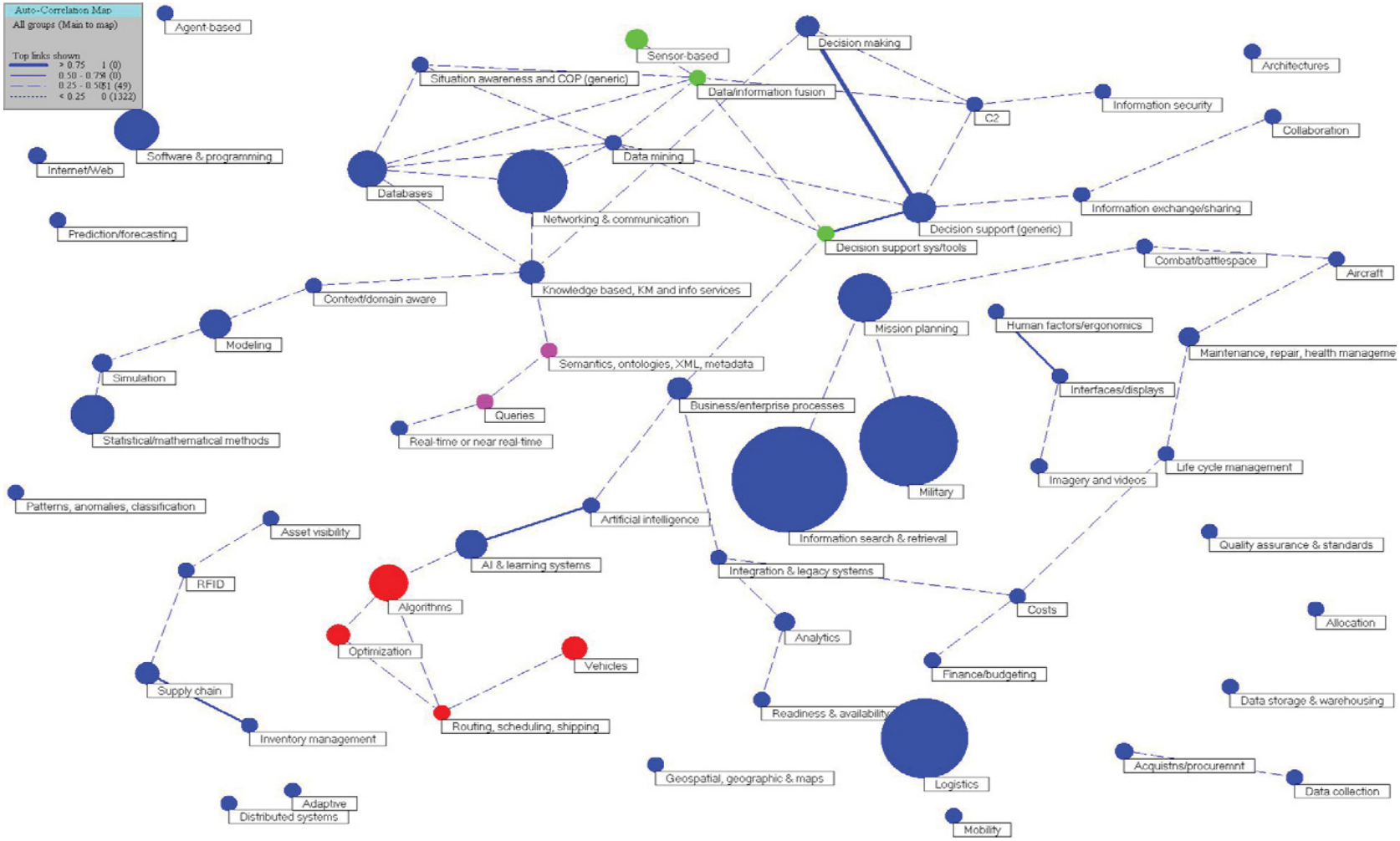


Figure 11. Groups Map: SEARCH & LOG dataset

- Data fusion, linked to sensors and decision support
- Queries, semantics
- Algorithms, strongly linked to optimization, routing and vehicles

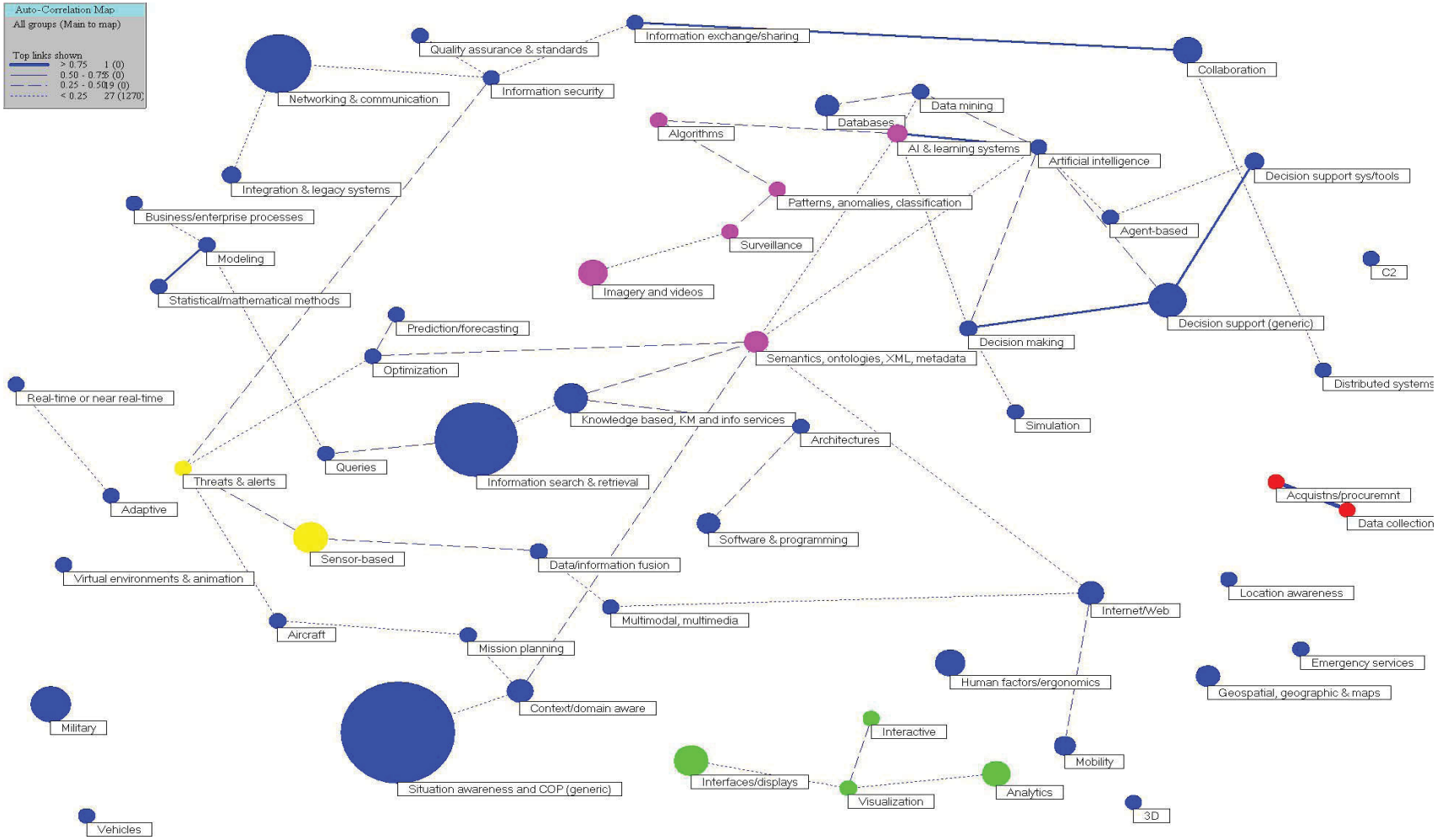


Figure 12. Groups Map: SEARCH & COP dataset

- Sensor-related groups
- Visualization, interfaces and displays for analytics, particularly interactive
- Imagery, surveillance and pattern recognition, related to semantics
- Logistics-related groups

3.5.2 Drilling Down in Search & Retrieval

For further details on which search and retrieval technologies are being adopted and their areas of application, we crossed references for some of the key search/retrieval groups with other group headings. In most cases, the correlations speak more to functional areas such as decision support than to specific technologies, although the recurrence of networked solutions, communications, and semantics suggest that these are critical components for COP requirements and for the extraction and dissemination of data in a distributed, diverse, and real-time environments. Simulation and modeling technolgies also emerge as key elements of intelligent searching, i.e., producing good answers requires not just plain searching and matching, but also simulation and modeling. Both files also explore human centric design, and for the SEARCH & COP data, there is also considerable discussion of technologies to manage context, and how these contribute to both system efficiency and user engagement.

Table 3. SEARCH & LOG subfile: Subgroups (total of 137 articles)

Group Name (total articles)	Functional/Technology Areas (No. of articles with co-ocurrences by group)	Remarks and References
Information search & retrieval (93)	• Logistics (50) • Networking & communication (47) • Mission planning (40) • Modeling & simulation (35) • Software & programming (30) • Databases (29) • Algorithms (25) • Statistical/mathematical methods (24) • Decision support (21) • AI & learning systems (17) • Vehicles (16)	This largest group in the SEARCH & LOG data reflects the wide range of search functions under consideration and the challenges presented by exploitation and integration of distributed systems and multidimensional data. This group includes a Berger, Boukhouta et al article on underlying netcentric architectures, a case study of real-time database management for logistics (based on optimized SQL queries), discussions of semantic technologies and metadata, the application of intelligent agents, and a report on a layered, object-oriented approach.[44]
Logistics (70)	• Networking & communication (31) • Mission planning (28) • Modeling & simulation (25) • Algorithms (21) • Vehicles (15)	Many of the problems addressed in this group involve vehicle scheduling, routing and maintenance, and how to use standards, algorithms and AI to better manage predictable events and plan missions.[45]
Networking and communication (56)	• Information search & retrieval (47) • Military (41) • Logistics (31) • Databases (27) • Modeling & simulation (18)	This group features articles on coalition operations, enterprise command and control, and stresses that architectures and data standards precede and enable any kind of knowledge-centric search.[46]

Group Name (total articles)	Functional/Technology Areas (No. of articles with co-ocurrences by group)	Remarks and References
Modeling & simulation (42)	• Information search & retrieval (35) • Logistics (25) • Statistical/mathematical methods (24) • Algorithms (17) • Optimization (15) • AI and learning systems (14)	Discusses how modeling and simulation contribute to query processing and (logistics) problem solving such as routing decisions in uncertain, dynamic and mobile environments.[47]
Decision support (27)	• Information search & retrieval (21) • Decision making (19) • Logistics (13) • Software & programming (9) • Business/enterprise processes (8) • Collaboration (7) • Data mining (7)	Examples include reports on multi-party inventory management, multi-agent data mining of integrated systems for equipment reliability forecasts, knowledge discovery as one of several layers in a service-oriented architecture, and use of the tabu search algorithm in logistics decisions.[48]
Semantics, ontologies, XML, metadata (12)	• Information search & retrieval (8) • Networking and communication (8) • Knowledge based, KM, and info services (7) • Logistics (7)	Logistics and other query capability in a networked environment rests on XML and related semantic capabilities.[49]
Integration & legacy systems (11)	• Military (9) • Networking & communication (9) • Business/enterprise processes (6)	Various articles on the importance of systems integration to the modernization of defence information technology. Logistics ontologies are proposed as one method of integration.[50]

Table 4: SEARCH & COP file: sub-groups (total of 213 articles)

Group Name (total articles)	Functional/Technology Areas (No. of articles with co-ocurrences by group)	Remarks and References
Information search & retrieval (101)	• Situation awareness & COP (66) • Networking & communication (44) • Knowledge based, KM and info services (29) • Decision support (26) • Modeling & simulation (26) • Sensor based (26) • Context/domain aware (21) • Semantics, ontologies, XML, metadata (18)	The SA/COP search function uses massive and diverse datasets, and must rely on aggregation, rule mining, classification, ranking and similar techniques to efficiently process queries and present answers. Netcentric frameworks are the norm, and security is also a concern. Semantics and ontologies form the basis for much of the functionality.[51]
Interfaces/displays (42)	• Situation awareness & COP (28) • Information search & retrieval (20) • Human factors/ergonomics (12) • Networking & communication (12)	This grouping discusses the human-centric elements that contribute to a good visual interface, and also the awareness categories (location, activities, etc.) that must be included in the SA/COP interface.[52]
Context/domain aware (33)	• Situation awareness and COP (30) • Information search & retrieval (21) • Networking & communication (16) • Semantics, ontologies, XML, metadata (12)	The 33 items in this sub-topic speak to the importance of role, geographic, or temporal context-sensitive systems on a number of fronts such as timeliness and user engagement. Context is usually managed through rules-based systems and domain ontologies.[53]
Geospatial, geographic & maps (30)	• Situation awareness and COP (21) • Information search & retrieval (15) • Decision support (11) • Networking & communication (11) • Software & programming (8) • Analytics (7)	Discusses the dynamics of handing geospatial entities in SA/COP information systems. One article also describes the Canadian geospatial data infrastructure.[54]
Semantics, ontologies, XML, metadata (30)	• Situation awareness and COP (23) • Information search & retrieval (18) • Knowledge based, KM and info services (16) • Context/domain aware (12)	Semantic and related technologies can be used as filters and can reduce runtime and efficacy of queries in complex, highly fused information environments.[55]
AI & Learning Systems (25)	• Situation awareness and COP (17) • Information search & retrieval (15) • Algorithms (10) • Decision support (10)	Almost all examples describe tactical sitational awareness. The articles describe how AI can improve queries and results in environments where decisions must be based on uncertain data. The nature of human-agent interactions

Group Name (total articles)	Functional/Technology Areas (No. of articles with co-ocurrences by group)	Remarks and References
		is also discussed.[56]
Queries (14)	• Situation awareness and COP (9) • Simulation & modeling (7) • Knowledge based, KM and info services (5)	Discusses query languages and interfaces for visual, multimodal, dynamic, and mobile environments.[57]
Real time or near real-time (12)	• Networking & communication (8) • Situation awareness and COP (8) • Knowledge based, KM and info services (5) • Imagery and videos (4)	Discusses network and processing constraints and real-time exploitation of data – most frequently data derived from sensors and videos or images – in tactical situations. One paper discusses real-time simulation.[58]

3.5.3 SEARCH: Overall and Group Publication Velocities

Overall, for both SEARCH datasets, the data show a rise in the 2007-2008 period, followed by a decline. This pattern is echoed in most cases for the topical groups analyzed. One exception is the *Mission planning* group from both datasets, which shows a slight increase or recovery near the end of the period.

For the SEARCH & COP file, apart from *Mission planning*, no other groups show a recent increase in publication activity, and the pattern for some of the key search and retrieval groups is similar to that of the overall dataset. Even some supposedly "hot" topics such as mobility show a downward trend in these data:

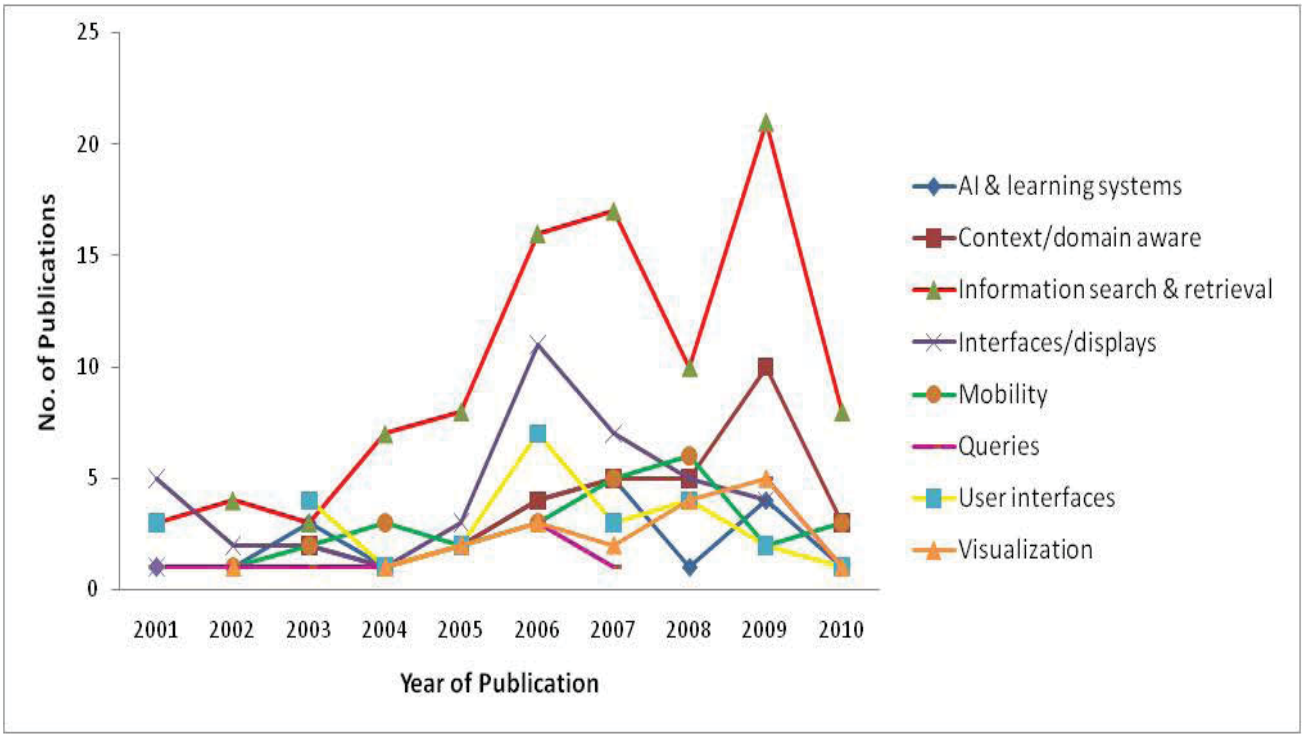


Figure 13. SEARCH & COP: Selected groups, publications by year

The pattern is similar for SEARCH & LOG. Even for groups with ascendant velocity, the rise is slight, and the the early period shows a very mixed publishing performance. The inclusion of topics such as aircraft, vehicles, maintenance and geospatial data in this ascendant group speaks to the importance of equipment availability and location (as determined by search) to military missions, and these appear to be the earliest functional areas for adoption. Collectively, however, these curves would appear to indicate that overall, the research effort for SEARCH is sustained but not as robust as some other technology areas such as visualization, documented later in this report.

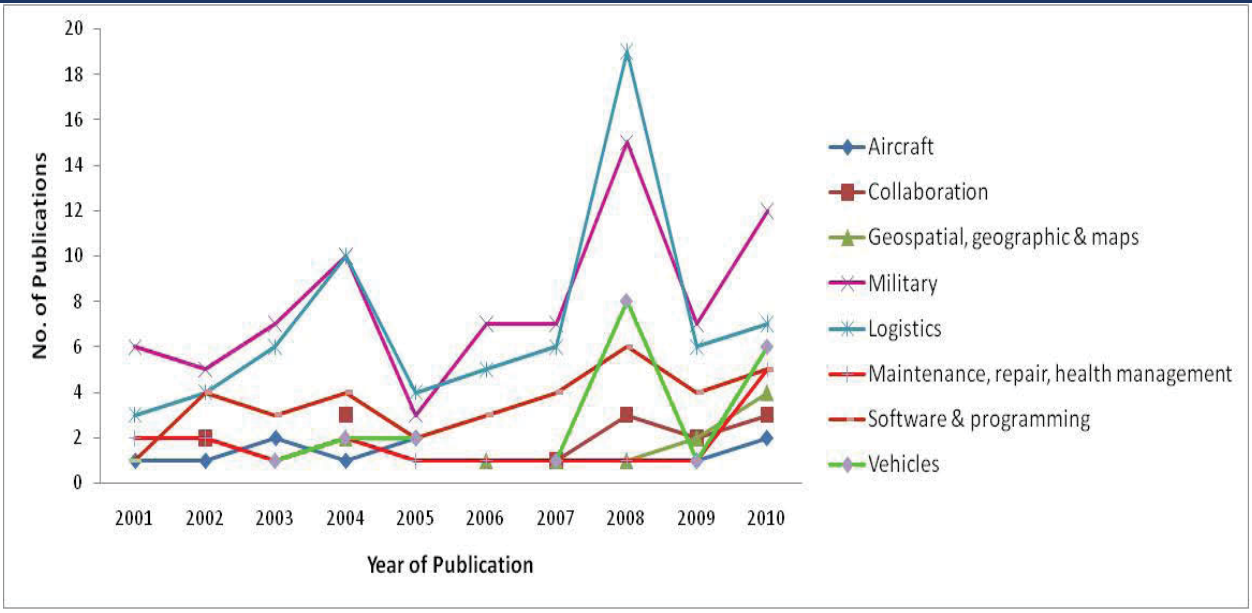


Figure 14. SEARCH & LOG: Groups with rising velocity of publication

3.5.4 SEARCH Organizations

The top research and publishing organizations differ substantially on each of the SEARCH LOG/COP lists. Only Australia's Defence Science and Technology Organisation (DSTO) appears in the "top" lists for both datasets. The SEARCH& LOG group is quite international in nature and is notable for the presence of various military agencies , while SEARCH & COP shows a stronger American (and academic) presence. SEARCH & COP is also notable for the presence of one company, Raytheon, which also occurs in the patent dataset.

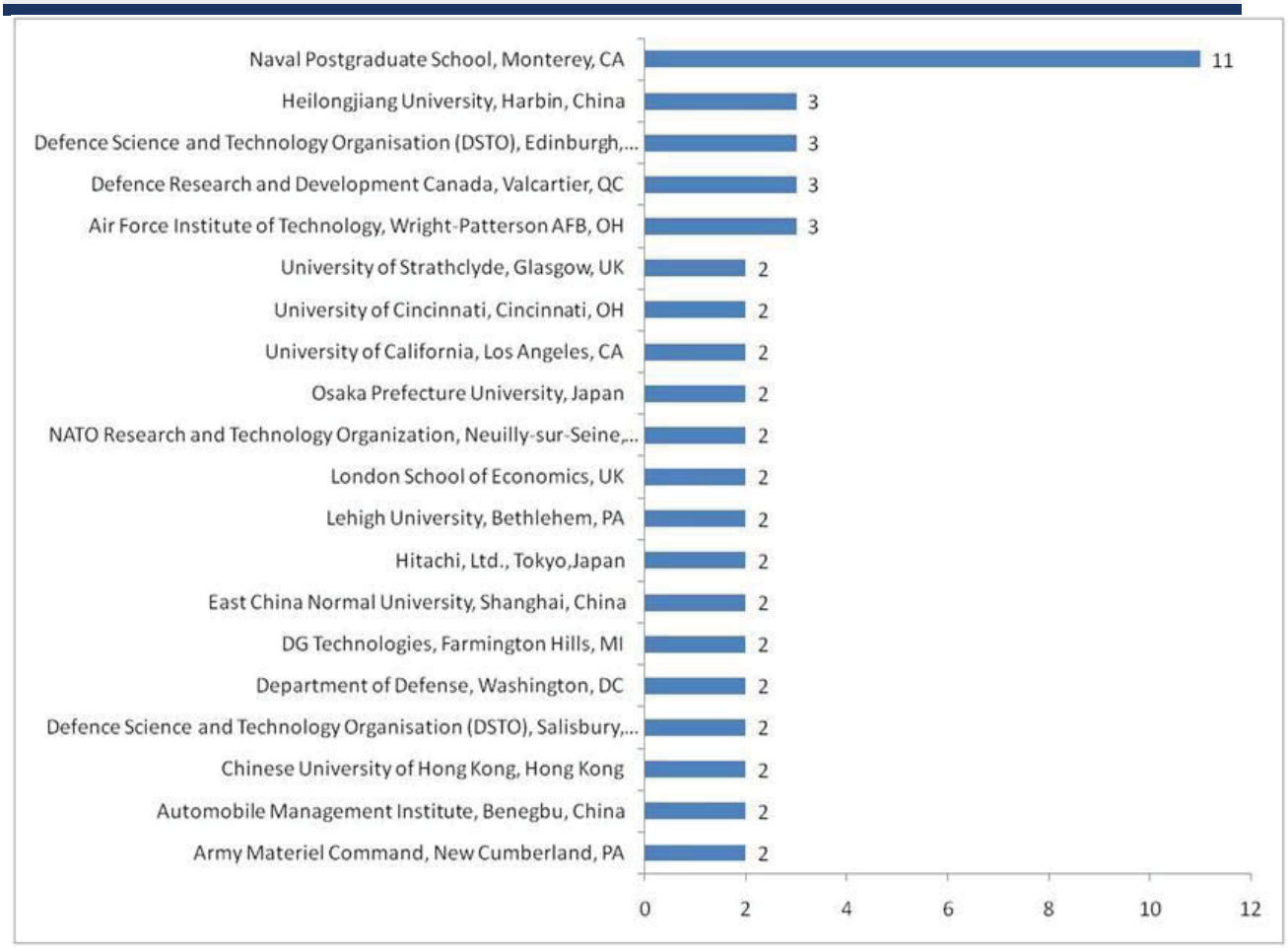


Figure 15. SEARCH & LOG organizations, 2 or more publications

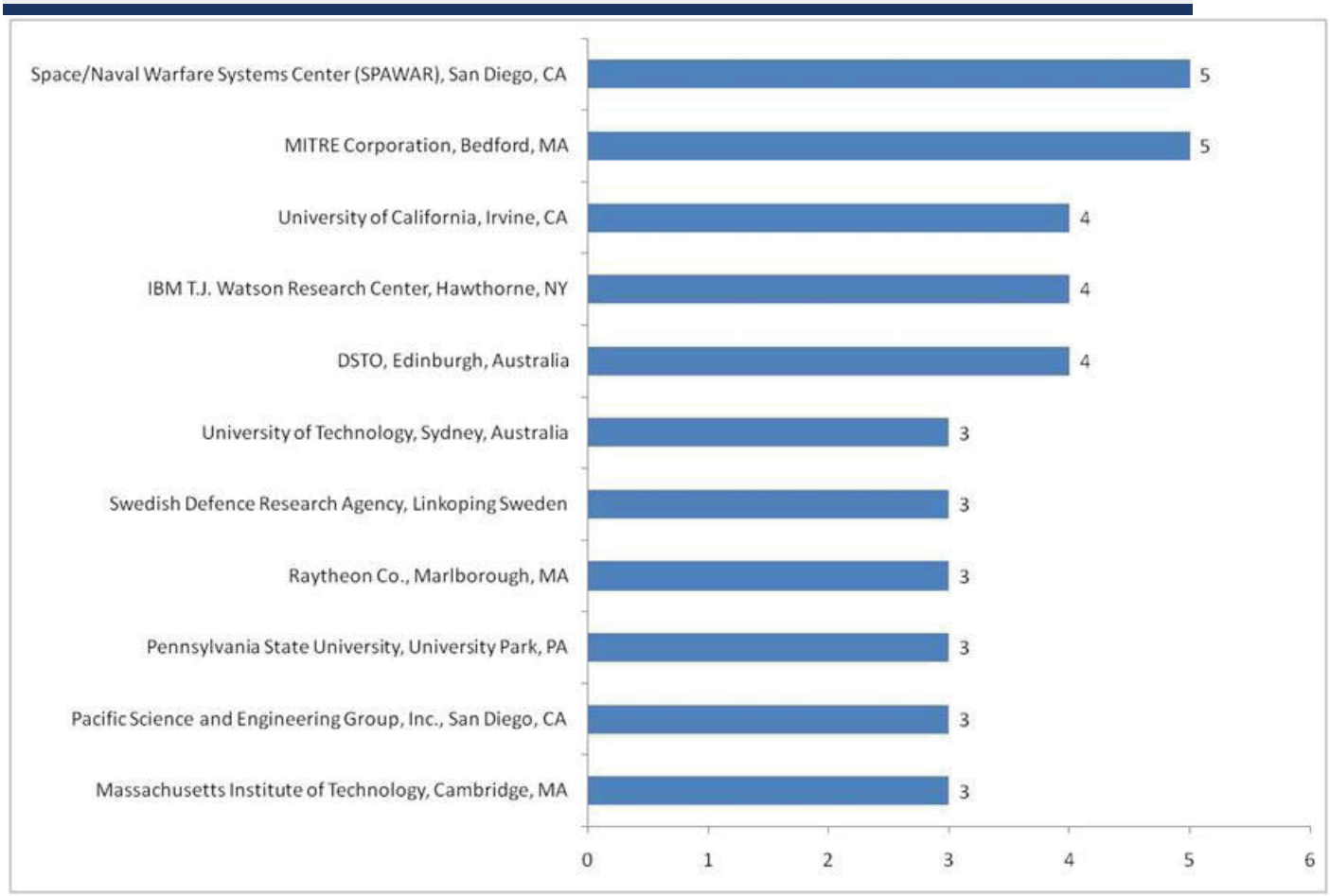


Figure 16. SEARCH & COP Organizations, 3 or more publications

Canadian expertise as reflected in the SEARCH files is slight. Only DRDC Valcartier appears in the SEARCH & LOG file, and for SEARCH & COP, DRDC also appears, as well as -- with one article each -- Natural Resources Canada (for an article on Canada's geospatial data infrastructure) and the University of Toronto (human robot interaction). Three companies also contributed one article each in the SEARCH & COP file:

- Humansystems Inc. of Guelph, ON: a report on a visual aid based on uncertain information for maritime situational awareness.[59]
- General Dynamics Canada: a SPIE report on content based image exploitation for situational awareness.[60]
- CAE Professional Services, Kanata, ON: on a context control model used to identify SA requirements for the tactical commander.[61]

The table below shows the numbers of publications for each topical group for each organization and so represents expertise for the top organizations from a merged LOG/COP file. For each organization, the top value in each row is highlighted in blue (if values are 3 or more).

Table 5. Organizations and Expertise - SEARCH & LOG merged with SEARCH & COP

Organization Name	Information search & retrieval	Situation awareness and COP	Networking & communication	Decision support	Logistics	Software & programming	Knowledge based, KM and info services	Databases	Mission planning	Algorithms	Analytics	Internet/Web	Human factors/ergonomics	Geospatial, geographic & maps	Semantics, ontologies, XML, metadata	Business/enterprise processes	Integration & legacy systems	Decision support sys/tools	Data/information fusion	Acquistns/procuremnt	Queries	Maintenance, repair, health management	Surveillance	Quality assurance & standards	Data mining	Data storage & warehousing
Naval Postgraduate School, Monterey, CA	11	3	9	6	4	6	9	6	3	2	4	3			2	4	3	2		4	1	4		1	2	3
DSTO, Edinburgh, Australia	4	3	5	1	2	3	3	2	1	1	2	1	3		3	1	2	1	3		2	1	4	1	2	
MITRE Corporation, Bedford, MA	2	3	3			2	3	2			2	1		1			2									
Space/Naval Warfare Systems Center, San Diego, CA	2	4	1	1		1	2	2				1	2		3		1			2					3	
DRDC Valcartier, QC	2	2	1	3	2	2		1	2	1	1	1		2				3	1						1	
IBM T.J. Watson Research Center, Hawthorne, NY	4	1	2	1			1	1	1		2	1			2	1		1	2				3			
University of California, Irvine, CA	4	3		2		1		2		1		1		3							3					
USAF Institute of Technology, Wright-Patterson AFB, OH	3		2	1	2		1	2	1	1	1					1		1								

Organization Name	Information search & retrieval	Situation awareness and COP	Networking & communication	Decision support	Logistics	Software & programming	Knowledge based, KM and info services	Databases	Mission planning	Algorithms	Analytics	Internet/Web	Human factors/ergonomics	Geospatial, geographic & maps	Semantics, ontologies, XML, metadata	Business/enterprise processes	Integration & legacy systems	Decision support sys/tools	Data/information fusion	Acquistns/procuremnt	Queries	Maintenance, repair, health management	Surveillance	Quality assurance & standards	Data mining	Data storage & warehousing
Heilongjiang University, Harbin, China	3				3	2			3	3						1										
MIT, Cambridge, MA	1	1	1	1		1			1					1				1								
Pacific Science and Eng Group Inc., San Diego, CA		3												1												
Pennsylvania State University, University Park, PA		1	1	2									2					1								
Purdue University, West Lafayette, IN	2	1		3							2	1														
Raytheon Co., Marlborough, MA	1	3	3	1		1	2	2	1			2			1		1	1		1	1		1	3		1
Swedish Defence Research Agency, Linkoping, Sweden	3	1		1			1						1	2	1				1	1	1					
University of Technology, Sydney, Australia	1	2		1			1						1			2										

3.5.5 Conclusions: SEARCH

Search technologies in logistical systems are being used to determine the location and availability of assets, and to support decisions related to costs, performance, readiness, routing, and scheduling. In systems developed for the common operational picture, search capabilities relate more to tactical situations such as threat detection, and the data sources are more likely to originate with sensors (e.g., video or image data). SEARCH & COP data also have more content on geo-aware searches.

For both SEARCH & LOG and SEARCH & COP, modeling and simulation play an important role, as users exploit sometimes uncertain or incomplete data to make predictions and support decisions. The challenges imposed by searching massive, diverse and distributed data are also evident in both files, and semantic and related technologies are being used to enable queries, apply filters, provide intelligent context, and improve runtimes and network transmission.

Publication velocities for almost all groups in both files are erratic or in decline, and SEARCH & COP results outnumber SEARCH & LOG by almost 2 to 1. Overall, this is not an area that demonstrates a great deal of recent innovation. Instead, the picture seems to be one of improvements to existing software and systems rather than innovative breakthroughs or disruption.

U.S. defence agencies, universities, and companies dominate the lists of leading organizations. Canadian participation is slight.

3.6 Visualization

As already described in section 3.5, similarly to the Search files, supplemental searches were performed for visualization, with a focus on the common operational picture (COP), rather than merely logistics. In the following section VIZ & LOG refers to those visualization results where logistics was the limiting search string, while VIZ & COP refers to results where COP was the limiting search string.

Terms in the VIZ & LOG and VIZ & COP datasets were organized into groups using a common thesaurus.

For VIZ & LOG, 86 groups were created from subject terms in 256 records, covering 100% of the data.

For VIZ & COP, 81 groups were created from subject terms in 533 records, covering 97% of the data.

The ratio of approximately 1:2 (LOG:COP) should be considered when comparing the two sets of results. As with the SEARCH datasets, we may extract meaning from differences and similarities between the two sets of data. In some cases, terms/groups occurred in one dataset, but not the other, or showed significant differences in the two files.

VIZ & LOG shows evidence of some subject threads that may be considered a part of the search strategy; since logistics was specified, it is natural that logistics functions and circumstances such as maintenance and asset visibility appear in the data. Certain aspects, however, demonstrate relatively stronger presence in LOG than in COP.

For instance, we can see in Figure 17 below that mission planning is a key function for logistics, and that logistical data lend themselves to simulation and modeling for purposes of optimization, routing, planning and decision support. Logistics also appear to be tied more strongly to business enterprise systems, especially with regard to costs and performance evaluation.

The data for VIZ and COP are focused almost exclusively on tactical situations, although these may include emergency services. These data are stronger on topics such as ergonomics and human factors, collaborative environments, surveillance and threat detection.

Both files are characterized by discussions of networking and communications architectures to support visual interpretations, the application of visualization to decision support, and by the role of geographic data in military/emergency management visualizations.

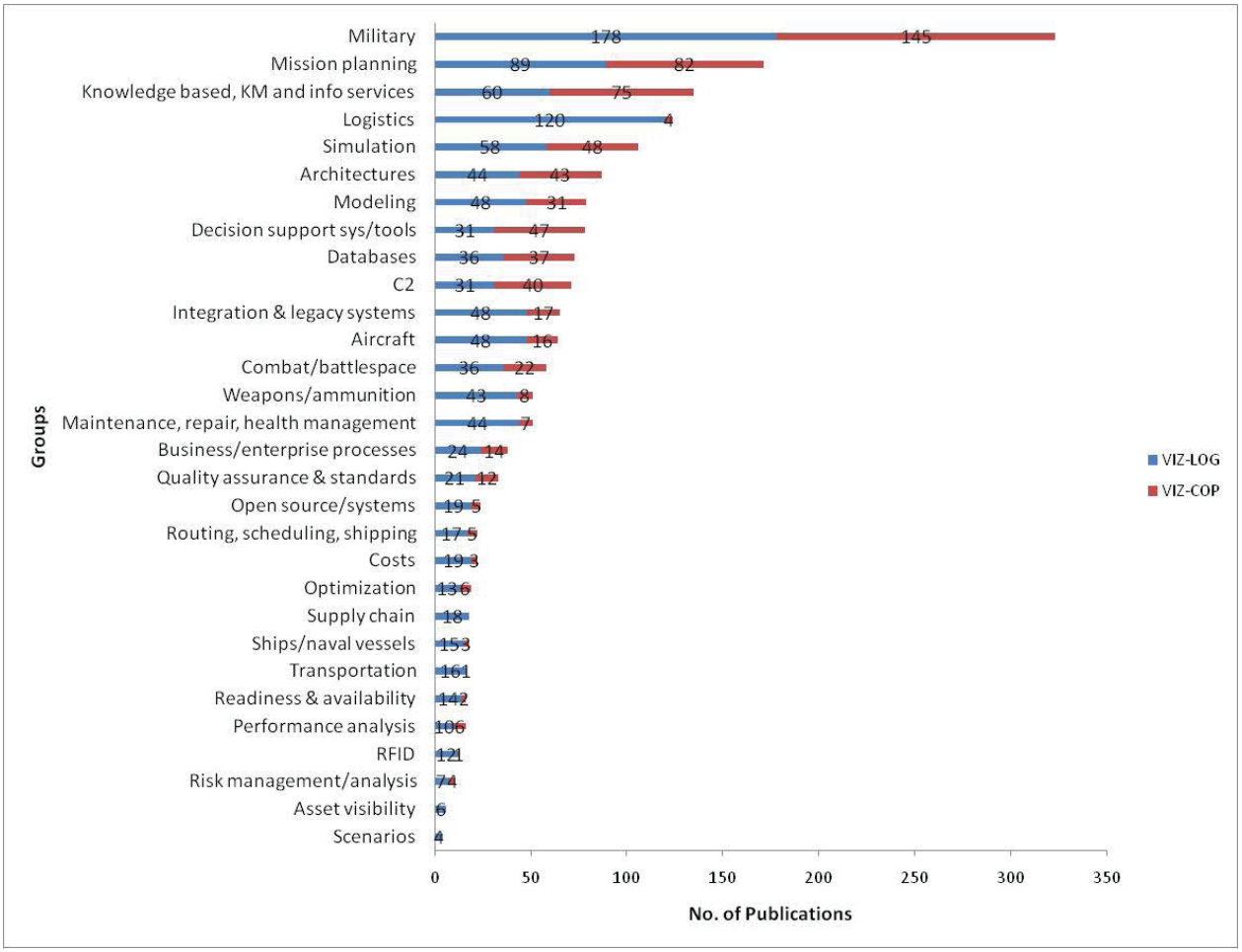


Figure 17. Subject Groupings with Higher or Disproportionate Strength in the VIZ & LOG dataset

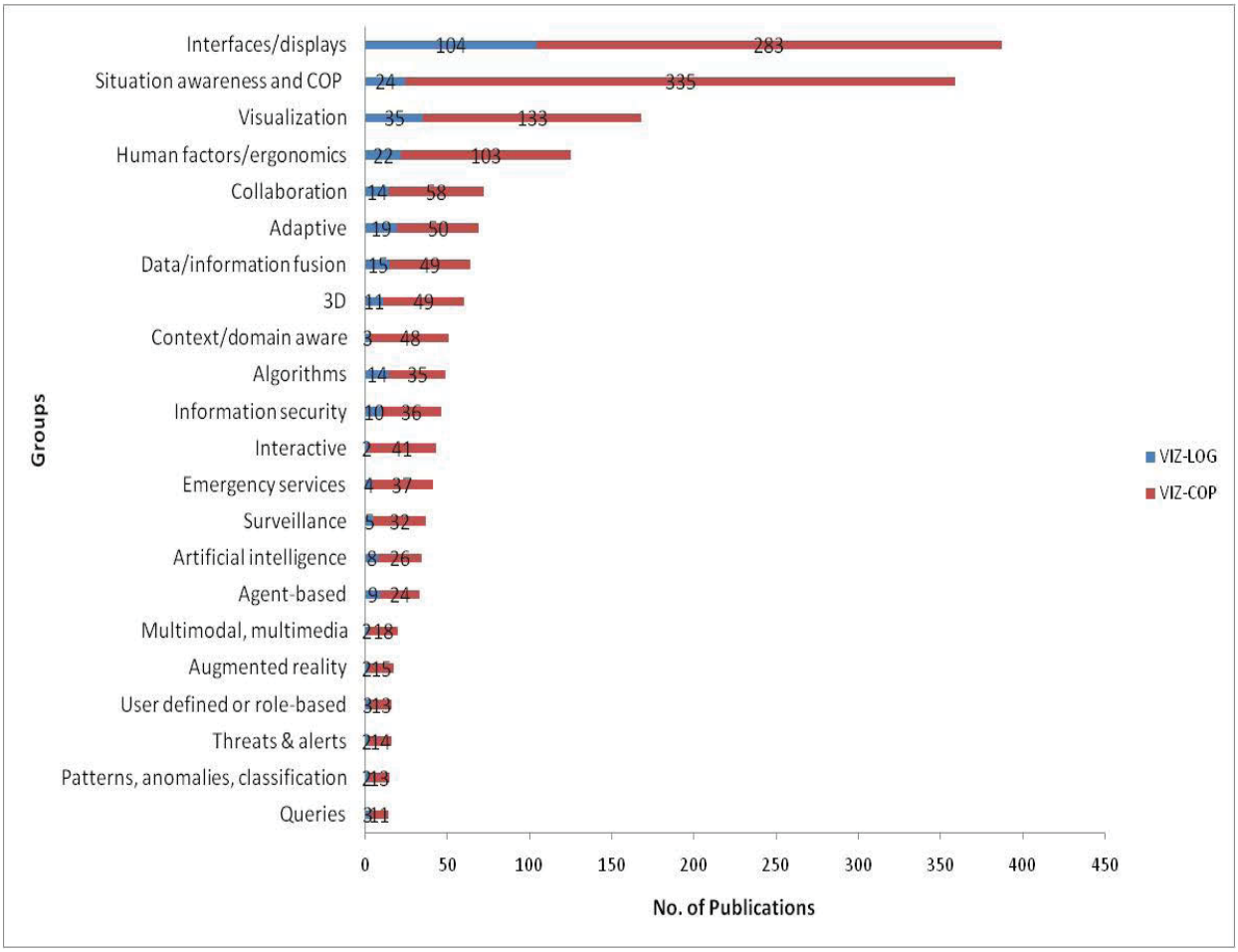


Figure 18. Subject Groupings with Higher or Disproportionate Strength in the VIZ & COP dataset

3.6.1 Visualization Topical Maps

VIZ & LOG

At the centre of the map (Figure 19), we see (in red) a strong connection between logistics and geospatial/geographic elements. This suggests that many of the visualizations performed for logistical functions are realized using geographic location information.

At right, in turquoise, another cluster demonstrates links between decision support, knowledge based information services, situational awareness and C2, and networks. Emergency services are also linked in this cluster, presumably because of their need for up to date logistical information in crisis management and dynamic situations where communications may be challenging.

At the bottom of the graphic (in green), while the volume of literature indicated by the node size is smaller, one sees the relationships between some “netcentric” technologies that support context aware

and user defined visualization, namely semantic technologies, web architecture, open systems and standards that enable interoperability.

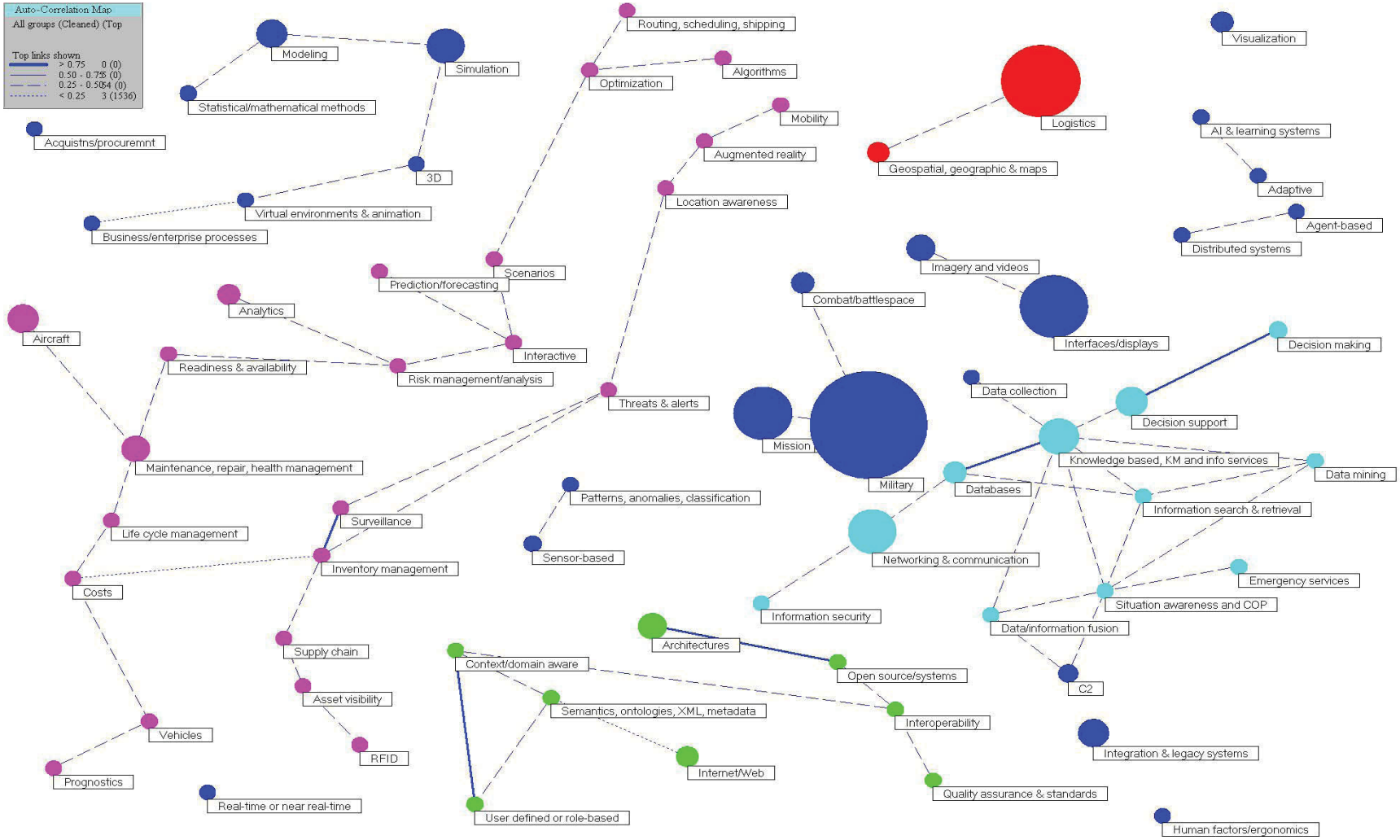
Finally, another cluster coloured in fuchsia and extending from top to bottom demonstrates that logistic functions such as asset visibility, supply chain, maintenance and lifecyle management, routing and scheduling are linked to algorithms and other analytic techniques that allow users to manage risk, optimize routes, predict inventory patterns and threats, and assess readiness.

VIZ & COP

In Figure 20, several small groups pertaining to logistics (Logistics, Maintenance, Routing, Readiness and availability, Acquisitions, Weapons/ammunition) are coloured red and are seen to be linked to each other or to risk management, virtual environments (e.g., as when maintenance is part of web-based training), internet/web, and military groupings.

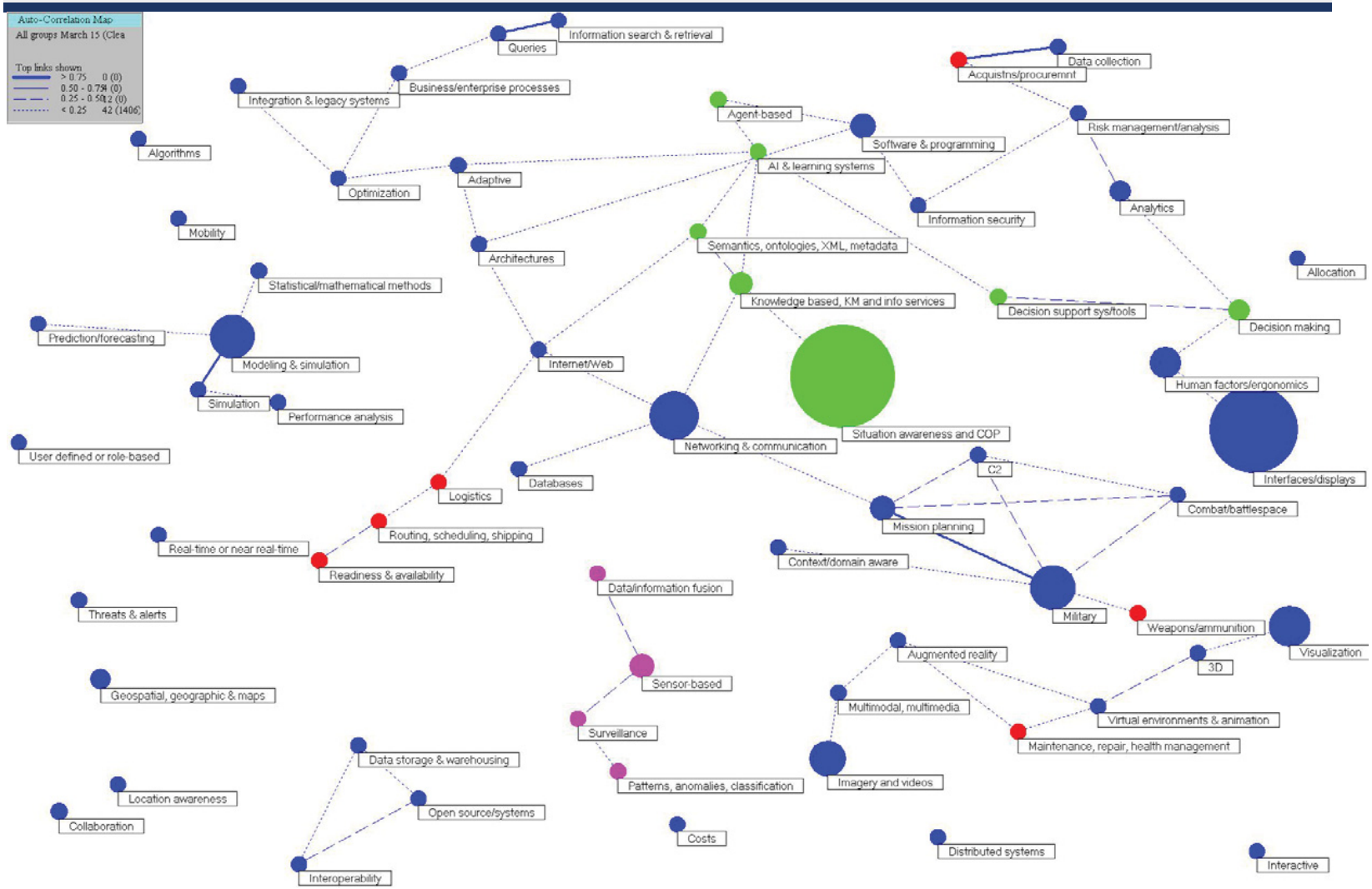
Green nodes show a close association between decision support and technologies such as AI/agents and semantic technologies.

In fuchsia we see that visual portrayals of patterns and anomalies appear to be derived from sensor information, reflecting the more “tactical” focus of these data.



- Logistics related to geospatial data
- Knowledge-based technologies and related
- Information search & retrieval
- Logistics systems functions and analytics

Figure 19. VIZ & LOG Topical Groups Map



- Logistics-related groups
- Decision support linked to AI/agents, semantics, KM
- Visual portrayals from sensor data

Figure 20. VIZ & COP Topical Groups Map

3.6.2 Drilling Down in Visualization

To ascertain what is being visualized and how this is accomplished, we crossed some key visualization groups with other groups. The tables below present co-ocurrence values for some of the more important or technology-specific groupings.

For the smaller dataset of VIZ & LOG, discussions often centre on graphical interfaces for modeling and decision support, especially those related to routing, (re)supply, maintenance, and asset visibility. Incorporation of geospatial information is also a common theme. Emphasis in the literature is placed more often on user needs and functions such as mission planning than on specific underlying technologies, however network architectures, integrated systems and semantics/ontologies are mentioned in passing.

In the VIZ & COP data, logistics content is negligible. Instead, the focus is on visualizations for tactical decision making, with an emphasis on geospatial and sensor-derived data and scenario modeling. Architectures and integration methodologies (such as ontologies) are in evidence as enabling technologies.

Table 6. VIZ & LOG: Sub-groups (total of 256 articles)

Group Name (total articles)	Functional/Technology Areas (No. of articles with ocurrences by group)	Remarks and References
Logistics (118)	• Interfaces/displays (54) • Mission planning (51) • Modeling & simulation (43) • Knowledge based, KM and info services (36) • Software & programming (34) • Decision support (29) • Geospatial, geographic & maps (27)	Examples include visualization of RFID workflows, demonstrations for logistics information and control, NATO solutions for multimedia visualization of massive military datasets including logistics content, and a review of visualization techniques for adaptive logistics applications.[62]
Interfaces/displays (103)	• Military (77) • Modeling & simulation (38) • Mission planning (36) • Imagery & videos (34) • Decision support (27) • Integration & legacy systems (23)	Examples include discussions of visual decision making tools based on inventory/maintenance data, with/without combat models,[63] as well as interfaces for disparate (legacy) systems and data.[64]
Geospatial, geographic & maps (34)	• Military (28) • Interfaces/displays (16) • Mission planning (13) • Modeling & simulation (12)	Various discussion of how GIS/map data can be integrated with RFID and other logistical data to help manage functions such as route optimization.[65]
Readiness and availability (14)	• Maintenance, repair, health management (10)	Discussion of graphical user interfaces used with readiness (modeling) tools, especially

Group Name (total articles)	Functional/Technology Areas (No. of articles with ocurrences by group)	Remarks and References
	• Mission planning (10) • Military (8) • Logistics (7) • Aircraft (6) • Interfaces/displays (6) • Modeling & simulation (5)	for aircraft.[66]
Visualization (34)	• Analytics (7) • C2 (7) • Combat/battlespace (7) • Decision making (7) • Knowledge based, KM and info services (7) • Situation awareness & COP (7) • AI & learning systems (6)	Results include a presentation on information display weakness for situational awareness, real-time logistics simulation driven by discrete events, the integration of logistics simulations for multi-phased deployments, and ontology-based scheduling and visualization.[67]

TABLE 7. VIZ & COP Sub-groups (total of 533 articles)

Group Name (Total articles)	Correlations: Functional/Technology Areas (No. of articles with ocurrences by group)	Remarks and References
Situation awareness and COP (335)	• Interfaces/displays (197) • Networking & communication (113) • Modeling & simulation (99) • Visualization (95) • Imagery & videos (80) • Decision support (81) • Human factors/ergonomics (75) • Sensor based (51)	Articles gathered in this grouping run the gamut from treatments of SA enabling network architectures to discussions of visual analytics/correlations and usability factors. Also included is DRDC publication on the COP21 Portal.[68]
Interfaces/displays (283)	• Networking & communication (88) • Modeling & simulation (84) • Imagery & videos (80) • Human factors/ergonomics (74) • Decision support (59) • Software & programming (53) • Sensor based (42)	Through the interface, hardware and software combine to produce strategic visualizations for a COP. Good design (human factors) is also key to adoption and effectiveness. Visual simulations are also freqently used tools for battlefield decision making. Semantic web technologies have also been used to identify relationships between objects/data and to enable situation awareness. Interoperability also comes under discussion in this grouping.[69]
Visualization (133)	• Networking & communication (46) • Decision support (38) • Imagery & videos (35) • Modeling & simulation (32) • Analytics (30) • Misison planning (30) • 3D (24)	Discusses the challenges of designing and deploying the real-time visualization tools required by today's tactical environments. Interfaces for fused data are also discusssed.[70]
Geospatial, geographic & maps (66)	• Situation awareness & COP (4) • Interfaces/displays (30) • Networking & communication (26) • Modeling & simulation (17) • Adaptive (12) • Data/information fusion (12)	Discusses geo-aware systems, their uses and requirements. The application of GIS data in emergency management systems is also included here.[71]

3.6.3 Visualization Publication Velocities

Both volume and velocity are greater for VIZ-COP than for VIZ-LOG. The COP data cover a wider range of subtopics and functions, however, any of which might be driving the upward growth (see below). Logistics, in fact, might be considered a subset of the more voluminous COP data.

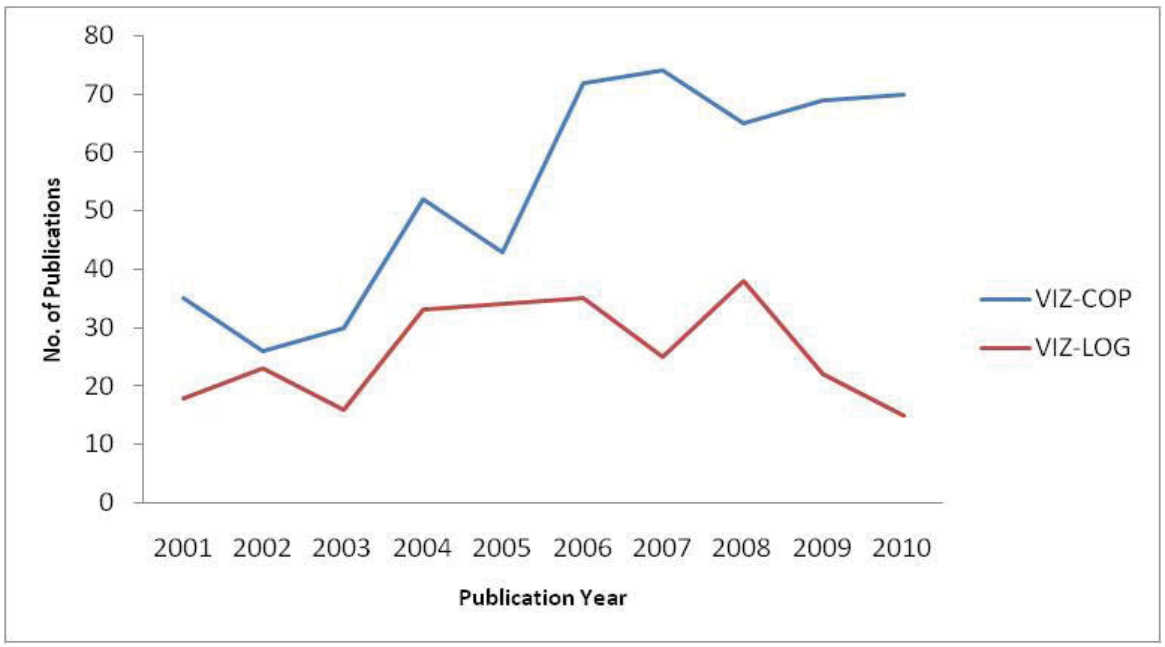


Figure 21. Velocity of Publication Compared, VIZ-COP vs. VIZ-LOG

For subjects in VIZ-LOG, the only groups with rising curves also have mixed past performance and low overall numbers. As with the Search analyses, functionality associated with vehicles and visualization of equipment health status appear to be of greatest logistical interest, based on the trajectories seen here.

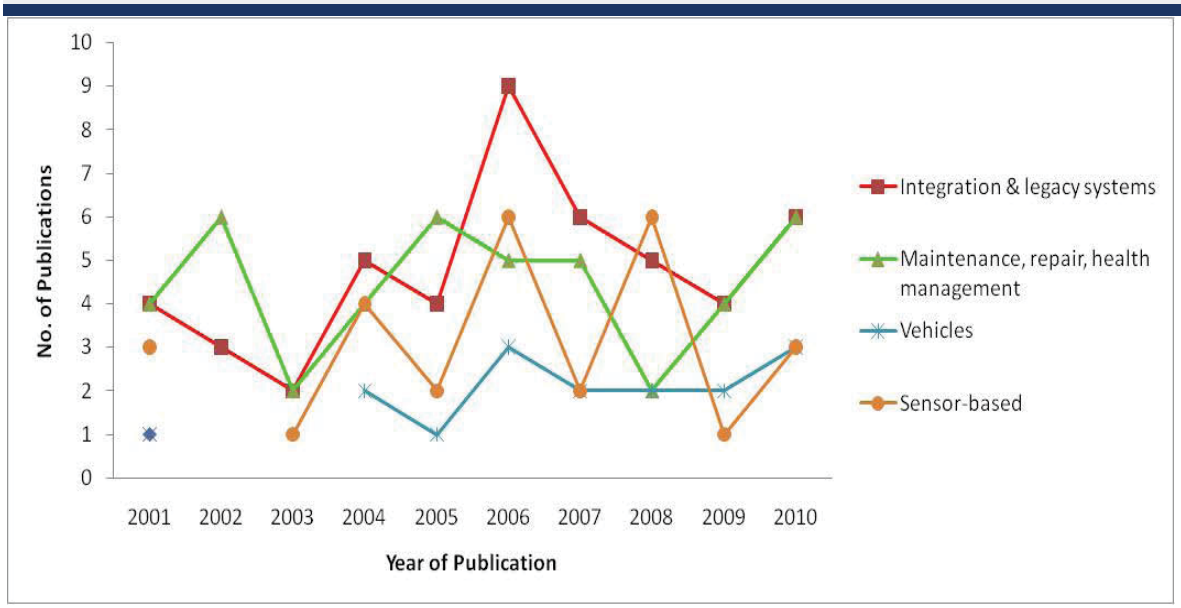


Figure 22. VIZ-LOG: Velocity of Publication, Ascendant Groups

Compared to VIZ-LOG, VIZ-COP data has more ascendant velocity curves. Velocity data for some of the more active groups is shown below in Figures 23 and 24. The growth topics for this file speak to the importance of a real-time visual perspective for tactical situations and surveillance. The role of visual elements in modeling, simulation and analytics is also apparent. Once again, semantic technologies are cited, though the number of publications is few (34 in all, with a maximum of 6 in 2006).

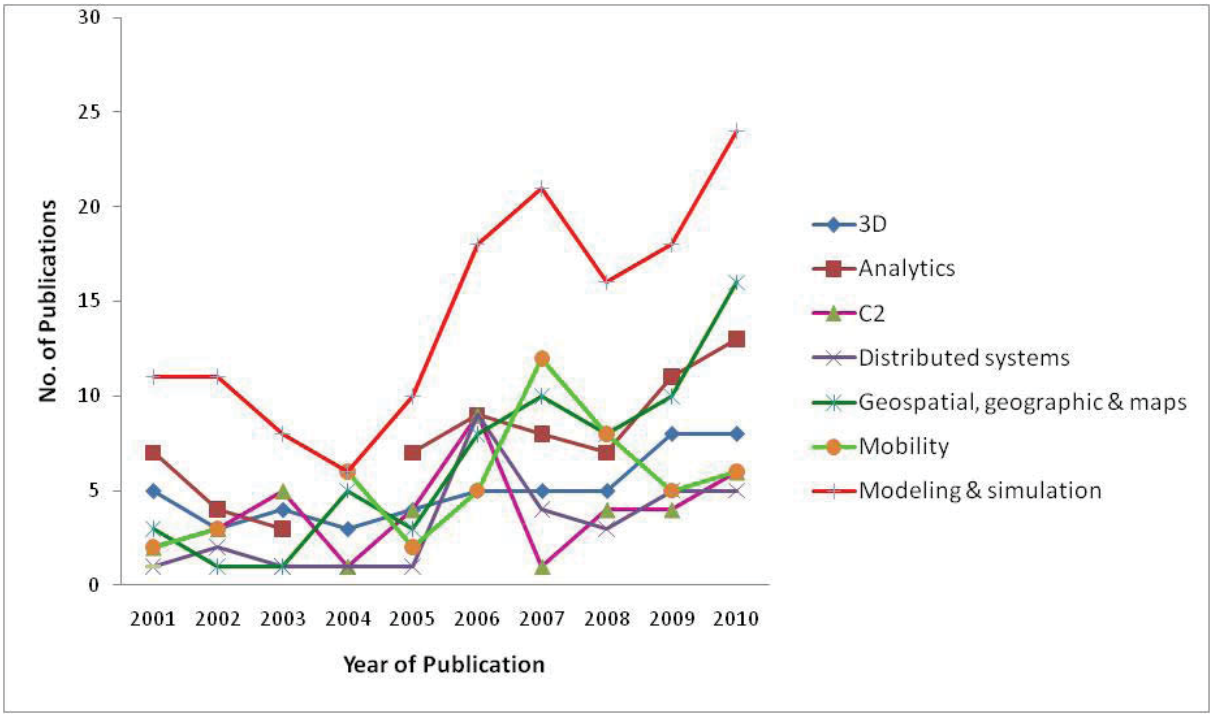


Figure 23. VIZ-COP: Velocity of Publication, Part One

In Figure 24, we see strong performance over time for 133 items gathered in the Visualization group, which offers examples of visual presentation and analysis.[72] The *User defined* group is much smaller, comprising only thirteen titles, but includes several articles on the design and management of user defined interfaces in networked, collaborative environments, another title on the use of personas and scenarios as interface design tools, and a study on how human-centric interface reconfiguration can reduce erroneous interpretation in situational awareness.[73]

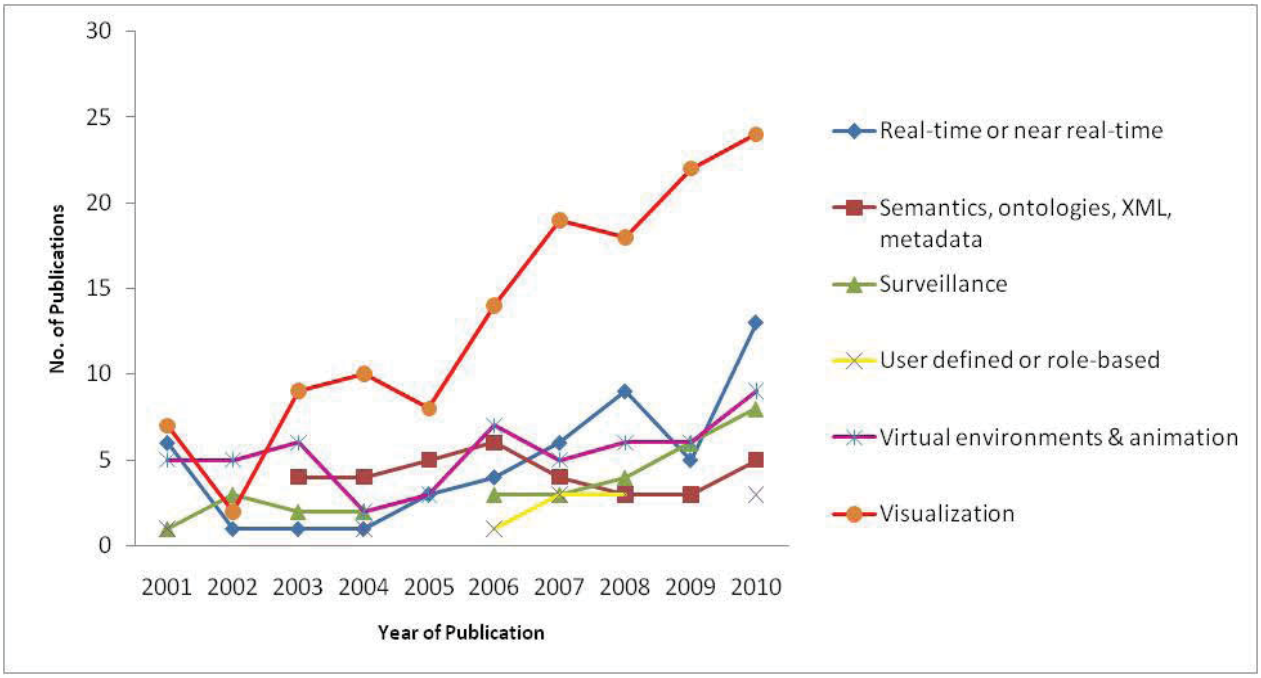


Figure 24. VIZ-COP: Velocity of Publication, Part Two

3.6.4 Visualization Organizations

Many of the top publishing organizations for visualization were also found in the Search data. U.S. government affiliations, especially for military agencies, are common. Several players (the US Air Force Laboratory at Wright Patterson Air Foce Base, the Space and Naval Warfare Systems Center at San Diego, and Carnegie Mellon University) also cross over between the VIZ-COP and VIZ-LOG datasets.

In addition, some of the organizations found below, such as Boeing and Raytheon, appear in the patent results. This suggests that common elements and interests exist between platforms that are purely logistic and those that address the wider common operating picture, and supports the contribution of logistical data to overall awareness. It also attests to the fact that visualization solutions have entered the commercial realm and are reasonably mature in terms of reliability.

In comparing VIZ-LOG and VIZ-LOG (Figures 25 and 26), one sees a mixture of large and small organizations, commercial and academic players. An international perspective is also evident on both lists.

VIZ-LOG data for Canada originates with a much smaller subet. DRDC is responsible for three publications in the time frame surveyed, while L.J. Hollick and Associates (Ottawa) and Memorial University account for one article each.

VIZ-COP data for Canada is shown below in Figure 27. Further details on the expertise of these organizations is found in Appendix 5.4.1.

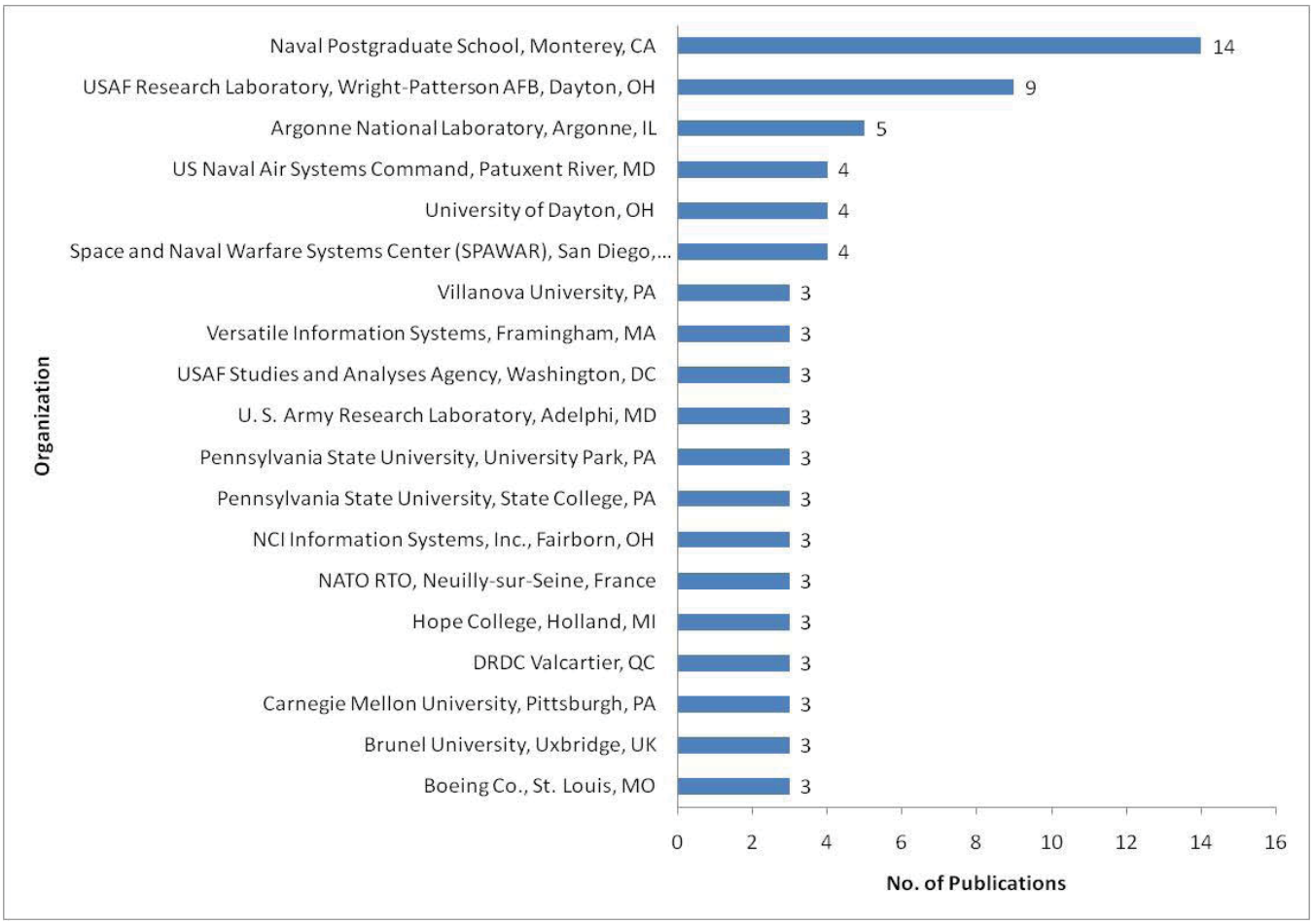


Figure 25. VIZ-LOG Organizations: 3 or More Publications

Figure 26. VIZ & COP Organizations: 4 or More Publications

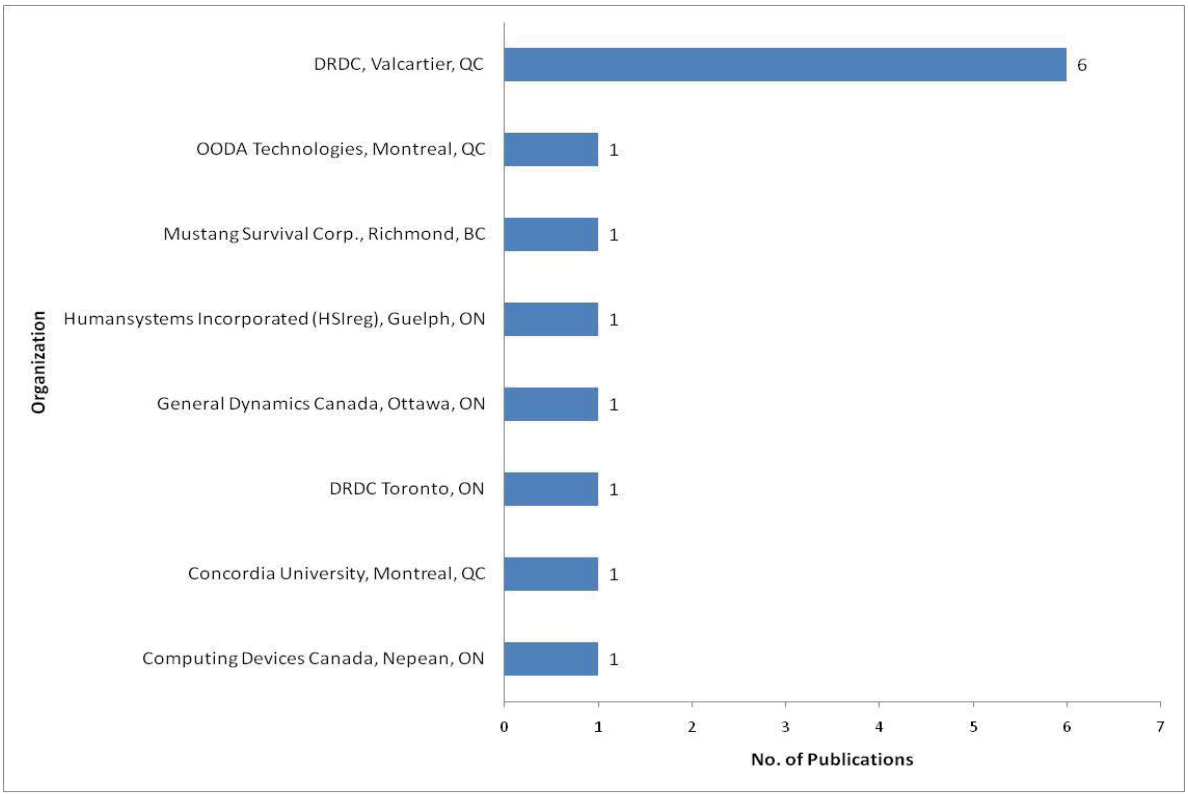


Figure 27. VIZ-COP Organizations: Canadian Origin

3.6.5 Conclusions: Visualization

Visualization is a hot topic for both logistics and the broader common operational picture. Visual techniques – and in particular, those based on geospatial and geographic data – are being used to inform real-time status reports, risk management, decision making, and simulation and modeling with regard to optimization of routes and resupply. Although the analyses do not disclose much detail for specific underlying technologies, several basic approaches, such as those based on semantics, ontologies, artificial intelligence and standards are common themes for both data sets. The COP data make few references to logistics applications, referring instead to more purely tactical situations. The COP data also include more content on the ergonomics and cognitive basis for effective visualization. The lesser volume for LOG and the slighter logistics content in the COP data both suggest that logistics visualization is less prevalent and a relatively new addition to the common operational picture. The presence of large defence companies in the COP data attest to commercial maturity.

3.7 Patents

The patent search strategy used the same strings as the literature search, but inclusion of the "military" search words limited results to such an extent that this strategy was deemed too counterproductive. For patents, it is likely that companies active in the area of logistics visualizations and the common operational picture develop their applications for generic use, and then adapt them for the customer base (military, transportation, etc.). For this reason, we opted to conduct the final patent search by specifying logistics or common operational picture terms (see Appendix 5.1.1: Columns 1 or 2 from original search in combination with other concepts sought (columns 4, 5, or 6). As will be seen, some patents that are military in nature were retrieved nonetheless.

We also extended the frame of reference backwards by several years to include applications from 1993 to present, and retained some non-military applications (such as commercial maritime transportation, the oil and automotive industries, and agriculture) in the results if they shared features (such as complexity, dynamism, a global reach, and a requirement for decision support or visualization) with defence logistics. Logistics management or COP solutions for emergency management were also retained in the results.

It should also be noted that software is primarily protected by copyright legislation and not by patents in most countries. Results from the patent dataset are therefore less likely to describe software code and more likely to cover hardware, programming concepts applied in a novel way (e.g., fleet optimization achieved through modeling), new industries served, or other aspects of technological solutions.

The final dataset for patents comprises 212 patent families. These families group substantive equivalents for which application has been made in several jurisdictions. The 212 families represent 443 patent applications. While the numbers for patents are considerably lower than those retrieved for the technical and scientific literature, we believe that the results provide a representative selection of applications and players, and that these numbers are also consistent with the generally lower volumes for patents versus other publications. The limitations posed by the fact that many solutions involve

software and programming (and are therefore more likely to be covered by copyright) would also have a dampening effect on final numbers.

3.7.1 Patent Subject Analyses

Patent documents were classified into 46 subject classes based on a review of titles, abstracts, claims and background descriptions. These classifications were assigned to each patent family and are not mutually exclusive.

Figure 28 below maps these subject classifications and their relationships to each other. As described earlier, the size of each node indicates the relative number of underlying documents, and the heavier the weight of connecting lines, the stronger the correlation. Isolated nodes do co-occur with other topical nodes, but the application (Vantage Point) has in this case determined which relationships to portray on the (statistical) basis of the most meaningful relationships.

In the map, we see in the red nodes that decision support is most often linked to geographic data and transportation decisions such as optimized routes and scheduling.

The green nodes describe links in the patent literature between availability and maintenance information, most frequently for aircraft.

At the centre of the map, a series of interconnected nodes in fuchsia demonstrate links between intelligent techniques (artificial intelligence, agents, algorithms, modeling and simulation) and predictive outcomes (risk assessment, alerts, patterns and anomalies) for situational awareness and emergency management.

Dynamic capability (turquoise nodes) is linked to rules, metadata (semantics, ontologies, etc.) and a net centric environment.

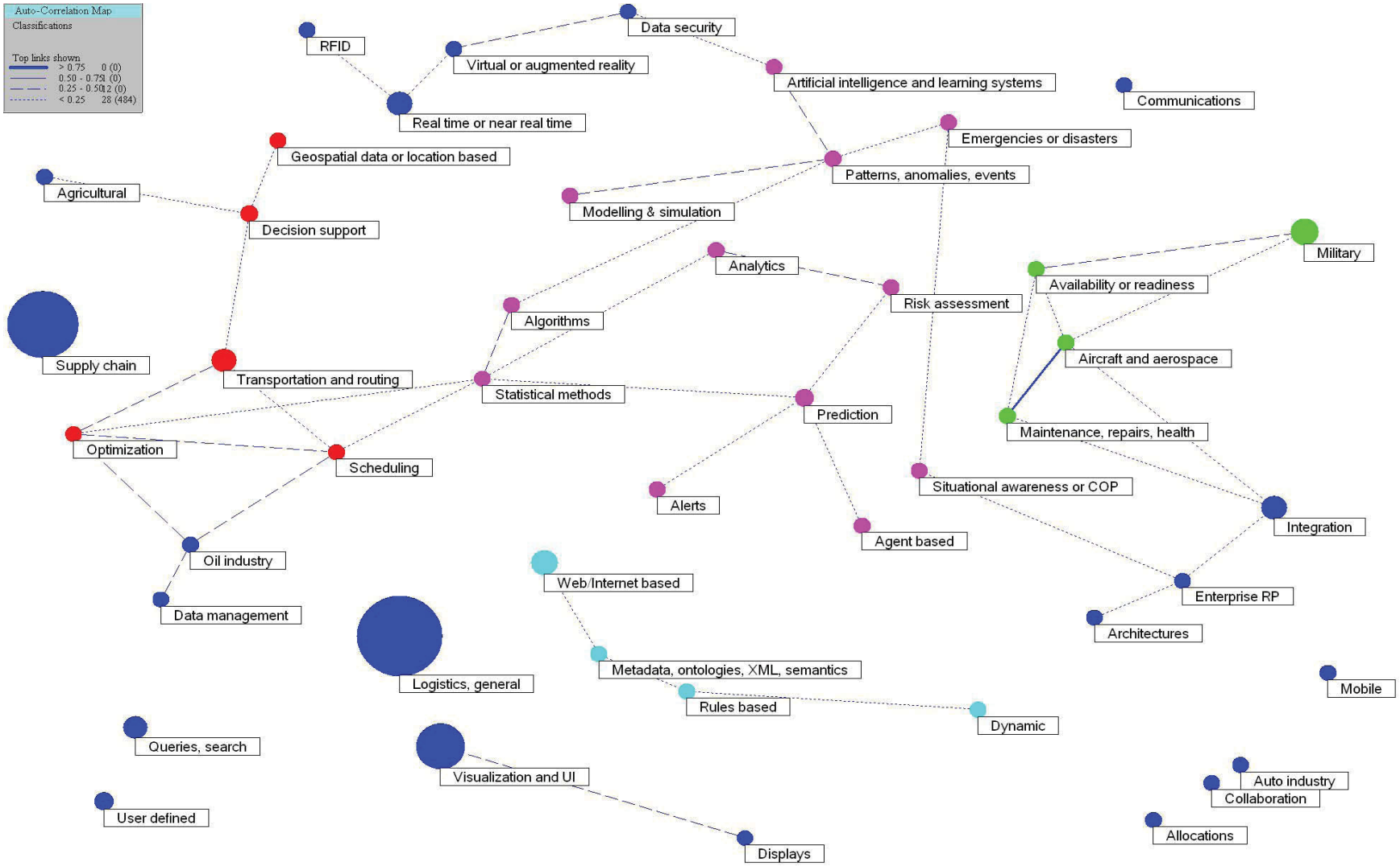


Figure 28. Patent Classification Map

3.7.2 Subject Trends in Patenting Activity

On such a small number of patents, it is difficult to ascertain research trends. The graphic below portrays velocity of patent applications in some of the more numerous categories for this dataset. For the period 1993 to 2008, even for these better populated subject categories, some intermittency is seen, as activity may rise or fall or be entirely absent in a given year. For subject categories with smaller results, this effect is even more exaggerated.

It is difficult to make conclusive statements based on these results but one can see a general upward trend over the last decade and for some subject areas, such as integration and visualization, interest has been sustained for the time period surveyed.

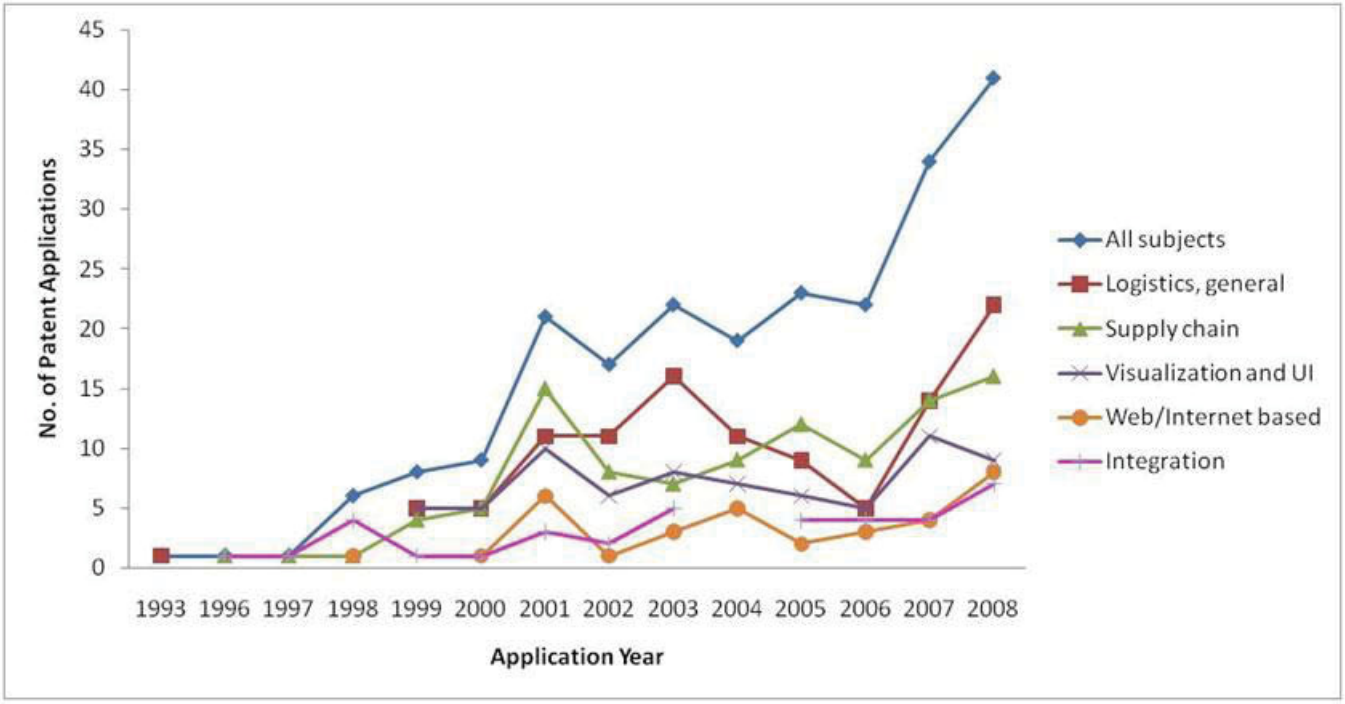


Figure 29. Velocity of Patenting Activity, All vs. Selected CoROSP Subjects, 1993 to 2008[3]

3.7.3 Major Players

The patent assignments for our dataset reveal the presence of several defence companies also identified in our market literature scan as active in logistics integration and situation awareness. Defence companies included at the top of the assignee list include global players: Boeing, Raytheon, Lockheed Martin, and Northrop Grumman.

[3] The years 2009 and 2010 are excluded from the graphic, due to the approximate eighteen month "silent period" (an embargo on publication) between the time of application and publication.

Also at the top of the list is SAP, whose product line extends beyond military markets to logistics and enterprise intelligence generally. SAP was also named in the market literature as a worldwide leader in defence logistics and a contractor for several major systems such as the Global Command Support System (GCSS). Several Chinese, Taiwanese, and Korean assignees are also featured for non-military applications.

Ranked second in the list is JDA Software, formerly known as Manugistics.[74] In an article from *Military Logistics Forum* dated February 1, 2011, JDA is named as a contractor with the U.S. Defense Logistics Agency (DLA), specifically for software to manage planning of supply and demand.[75] The same article also notes that the DLA is building common logistics interfaces based on SAP's service oriented architecture, with integration overseen by Accenture (not a major player on our assignee list) and using a data exchange format now under development.

A complete list of patent documents with information on assignees, priority dates, subject classifications, and hyperlinks to full text is included in the attachment to this report: filename: CoROSP patents.xls. It is highly recommended that the client review and obtain copies of patent documents since they often reveal very detailed technical information often not found in scientific journal articles.

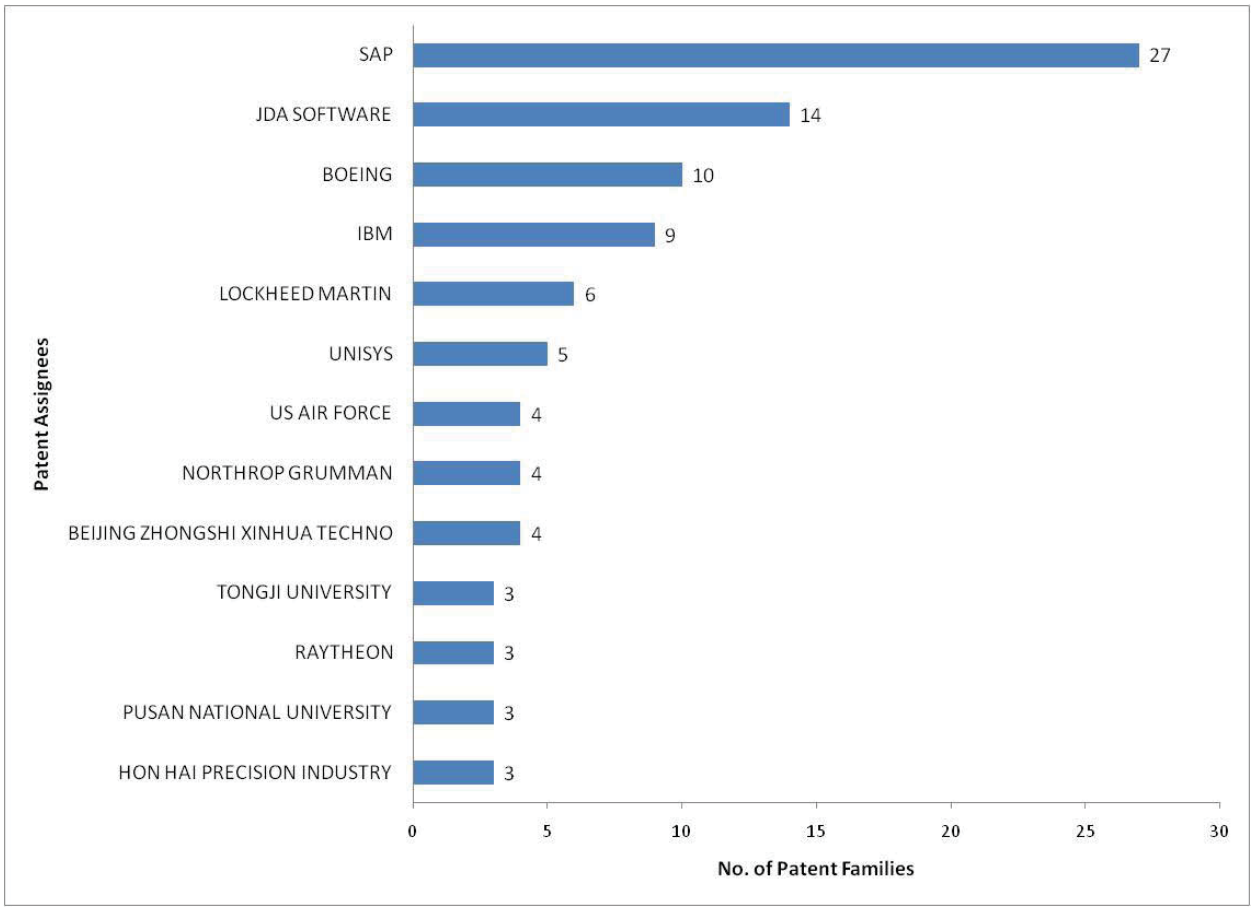


Figure 30. Top Patent Assignees, 3 or More Patent Families

3.7.4 Patent Assignees and Areas of Expertise

Table 8 below present the top patent assignees (3 or more families) and their areas of patenting interest or expertise. With the exception of the classification for Situational awareness or COP (column at far right), columns with low values of 1-2 only have been removed. The top value for each assignee is coloured in blue if the value is 3 or greater.

The table demonstrates the breadth of expertise found in large companies such as SAP, IBM, Boeing, JDA Software and Lockheed Martin, as well as strong patenting activity on the part of the US Air Force. Of all of the sub-topics represented in this field, *Visualization and user interfaces (UI)* appears to have garnered the most interest when it comes to patentable solutions. *Integration* is also a focus for several players, as are *Transportation and routing* and *Maintenance, repairs, and health.*

Table 8.Patents: Assignees and Expertise

Assignee Name	Logistics, general	Supply chain	Visualization and UI	Military	Web/Internet based	Integration	Real time or near real time	Transportation and routing	Queries, search	User defined	Prediction	Decision support	Modeling & simulation	Geospatial data or location based	Maintenance, repairs, health	Architectures	Alerts	Availability or readiness	Rules based	Aircraft and aerospace	Dynamic	Statistical methods	Algorithms	Situational awareness or COP
SAP	19	11	10		4	2	2	3	6	4	4	2		3		5	4	2	3		3	4	3	
JDA SOFTWARE	6	14	7		1	1	1	1	2	2	1	1	1			1	1	1	1				1	
BOEING	2	2	3	5		6			2	1		2	1		8	1	1	3		5				1
IBM	1	7				3		1	1	2	1	1	4			1					1			1
LOCKHEED MARTIN	3		1	5			1			2		1	1	2		1			1					1
UNISYS	5		4						5	4											1			
BEIJING ZHONGSHI XINHUA TECHNO	2	3			1			3	1			3		3								1	1	
NORTHROP GRUMMAN				1		1	1	1	1				1		1			1		1				
US AIR FORCE		2	1	4	3	4	1				2	1	1			2	1			1		1		
HON HAI PRECISION INDUSTRY	3		1					2	1					1		1								
PUSAN NATIONAL UNIVERSITY	2							2				1											1	1
RAYTHEON		1		3	1						2		1		1				1		1			1
TONGJI UNIVERSITY		3				1																		

3.7.5 Conclusions: Patents

The patent dataset is not sufficiently large to conclusively identify subject trends over time, but it does demonstrate that more generic logistics solutions (as opposed to those specified for the defence sector) have entered commercial markets. These applications are addressing problems typical of logistics operations such as transportation and routing, a need for total asset visibility in real or near real time, and prediction of availability based on maintenance patterns. Most solutions are web-based, and many incorporate customized user interfaces and sophisticated visual elements, especially geographical mapping. Analytics for risk management, prediction, and alerts are evident, as are decision making supports.

Search results for patents suggest that a few large companies such as SAP, Boeing, IBM and others dominate the intellectual property landscape in the same way that they dominate markets. Their patenting activity may be used as an indicator of features that are sought in the commercial sphere, many of which may also be useful in a military context.

3.8 Technology Readiness Levels

Table 9 summarizes our assessment of the Technology Readiness Level (TRL) for selected emerging technologies where we had enough data to make an assessment. When interpreting these ratings, one must keep in mind that the readiness is assessed in relation to the papers and patents that were gathered for this search, and so they are measured in the context of logistics systems only. For example, while analytics may be far more mature in other domains, within the narrow purview of this study analytical technologies are judged to be at TRLs 4-5. The methodology is described in Appendix 5.6 and complete data are provided in the attachment CoROSP TRL data.xls.

Table 9. Technology Readiness Levels

Technology Name	Derived Technology Readiness Level			
	Experimental (1-3)	Practical (4-5)	Prototype (6-7)	Product (8-9)
Decision Support				
Decision Making (general)	•			
Modeling	•			
Simulation		•		
Analytics		•		
Planning		•		
Decision Support Systems/Tools		•		
Mathematical/Statistical Analysis	•			
Prediction/Forecasting	•			
Information Search & Retrieval				
Search & Retrieval (general)		•		
Queries		•		
Semantics, ontologies, XML, metadata		•		
Visualization				
Visualization		•		
Interfaces/Displays		•		
Geospatial, geographic & maps		•		
Logistics and Operational Functions				
Supply Chain			•	
Maintenance, repairs, health management		•		
Mission Planning		•		
Situation Awareness and COP		•		

4 CONCLUSIONS

4.1 Primary conclusions

Generally, we can conclude that while there is much research being conducted on predictive analytics, decision support, visualization, and search technologies within the military logistics domain, implementation of these technologies is far behind. Neither does it appear that any country has been completely successful in fully linking systems designed primarily for logistics with those intended to support command and control in the field. Rather, it seems on the evidence that the two systems are running in parallel, with some rudimentary attempts at functional linkages. The main challenges that may be impeding this progress are problems of data integration of legacy systems and interoperability for coalition forces, and the difficulties associated with designing a common and unifying interface for heterogeneous data and decision scenarios. Key enabling technologies in data integration and information fusion are semantics, ontologies and web services. A review of the STIA Assessment *Integration and Management of Multi-Source Information – Literature Survey* (SDA 07-001/013) produced by CISTI in Feb. 2011 is recommended for further details on trends in this area.

The main logistics requirements that are dominating areas of study are mission planning, asset visibility and condition based maintenance, particularly for aircraft and vehicles. There is also a significant amount of discussion related to cost cutting, cost-effectiveness and business planning. There are many synergies between ROSP and enterprise resource planning for other markets and industries and it has been observed that this is a much more commercial market than is the case for most defence technologies. Several large global firms such as SAP, Lockheed Martin, IBM, and Oracle control the majority of market share and it appears that many logistics systems developed for commercial markets are being adapted for military purposes since these COTS solutions do not often have the full functionality required by military applications.

The data clearly show that decision making, decision support tools and predictive analytics are significant research thrusts within this domain, and that modeling and simulation techniques and tools are key enabling technologies in this area. On the visualization side, key enabling technologies are geographic information systems and mapping capabilities to show assets in transit as well as battlespace visualizations within a geographic context.

Based upon comparisons of search technologies in the logistics domain versus search technologies in the tactical situational awareness domain, it appears that the implementation of search technologies are more advanced for the tactical side than for the logistics side. This same conclusion was reached for visualization technologies and visual analytics. According to Frost & Sullivan, “no one comprehensive integrated defence logistics software solution exists in any marketplace in any country”.[76] Thus, a fully integrated common operational picture system that provides a logistical and a tactical point of view remains a challenge, however many countries are embarking on modernization programs and implementing systems that begin to merge these two domains.

4.2 Areas for further study

This study concentrated on technology areas as they apply to military logistics systems and the common operating picture. However, since the technologies may be applied to other industries and in other domains,

further research that does not limit the application area may be warranted for more in-depth analysis. Further study in the following four areas are recommended.

User-defined Interfaces
There was not a significant amount of literature on user-defined or role-based interfaces from our search, however there may be significant literature identified if one were to look beyond logistics or COP applications.

Performance Metrics
While performance metrics were identified as a key requirement for effective sense and respond logistics systems, very few documents that specify what these metrics should be were identified. This may be because these requirements are not publicly available, particularly for countries other than the United States. Further research to identify these requirements through other searches and personal contacts is recommended.

Predictive Analytics
Predictive analytics are a growing area of interest in many domains, such as business intelligence and healthcare for clinical decision support. Further exploration of analytics applied to other domains is recommended. Review of the STIA Assessment *Future Intelligence Analysis Capabilities* (SDA 07-001/012, Feb. 2011) may also provide useful information.

Information Search and Retrieval
This topic was the least discussed in the context of logistics and situational awareness, however this is a vast area of research in computer science and knowledge management. Further data gathering on search technologies is recommended, however, the client will need to define the key technical challenges and criteria for searching in a CoROSP architecture in order for the search to be effective.

5 APPENDICES

5.1 Methodology

5.1.1 Searches

Several searches were conducted in various databases, particularly *INSPEC, Ei-Compendex, Scopus NTIS* and *Aerospace and High Technology Database*. Results were limited to the last 10 years. Additional manual searches were performed in the databases listed in section 5.2 below.

The table below shows groups of concepts, which were combined in multiple variations using database-specific syntax to obtain relevant references.

Search concepts:

1: Logistics	2: Common Operational Picture	3: Military	4: Decision support	5: Visualization	6: Information retrieval
Logistics Supply chain Inventory Total asset visibility Transformational logistics Adaptive logistics Sense and respond logistics Materiel support Materiel management	Operational support picture Operational support awareness Situation* awareness Common operat*picture Situational understanding	Military Defense Defence Combat Warfighter Battle* Air Force Navy Naval Army Warfare Soldier Armed Forces Brigade Platoon	Decision support Decision making Decision aids Prediction Forecasting Modeling Simulation Readiness analysis Risk assessment Risk analysis Performance analysis Readiness monitoring Deviation detection What-if analysis Scenarios Trend analysis Diagnosis Diagnostics	Visualization Visual analytics Dashboards Portals Visibility User displays User interfaces Graphical tools User defined picture	Information retrieval Data retrieval Queries Query Search Information search

In addition, a search on logistics systems known to be of interest was also conducted, using the following search string:

"Global Combat Support System" or GCSS or "Battle Command Sustainment Support System" or BCS3 or "Common Logistics Operating Environment" or CLOE or "Logistics Innovation Agency" or "Adaptive Logistics Project" or "Net-Centric Decision Support Environment" or NDSE or "Logistics Network Enabled Capacity" or

LogNEC or "Future Logistics Information System" or FLIS or "Management of Materiel in transit" or MMiT or "Military Integrated Logistics Information System" or MILIS or "Situational Awareness Logistics Tool"

5.1.2 Analysis

All references were downloaded into VantagePoint software for analysis. VantagePoint allows us to create various groupings, matrices, graphs, cross-correlations and statistical analyses to analyze the data and draw conclusions about topics and subtopics and to profile the activities of the major players.

The visualization software TouchGraph was used for cluster analysis of the keywords and then thesauri were created to analyse the relationships between topics in VantagePoint.

Author names and author affiliations were cleaned to harmonize variant forms and spellings and group together departments from the same institutions.

Keywords, identifiers (akin to author-supplied keywords) and phrases and words from titles were merged together to facilitate subject analysis, resulting in over 13,000 terms. These were cleaned and edited to harmonize variant spellings, acronyms and similar meanings. These terms were then classified into broader groups and used in various graphs and matrices found in this report.

5.2 Sources Consulted

Scientific & Technical Literature:

- *Scopus*
- *INSPEC*
- *EiCompendex*
- *Aerospace and High Technology Database*
- *NTIS*
- Defense Technical Information Center (DTIC) – *Technical Reports Collection*
- DSTO – *Scientific Publications*
- NATO Research & Technology Organisation - *Scientific Publications*

Patents:

- *Orbit Fampat database* (worldwide patents and patent applications)

5.3 Attachments

The following documents are provided as attachments to this report.

Title & Description	Filename
Review of commercial systems	CoROSP systems.xls
Review of operational requirements	CoROSP requirements summary.xls
Patent results	CoROSP patents.xls
Evaluations, Reports, and Lessons Learned (recommended sources)	CoROSP recommended sources.doc
Technology Readiness Levels matrix	CoROSP TRL data.xls
List of articles from the master database	CoROSP all papers.xls

5.4 Major Players and Authors data

Table 10. Top 15 publishing organizations.

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
US Naval Postgraduate School, Monterey, CA, USA[110][4]		Housel, T. J. [4]; Mun, J. [4]; Brown, G. G. [2]; Clemens, Richard A. [2]; Curl, Gregory A [2]; Dell, R. F. [2]; Diaz, Andres [2]; Dillard, J. T. [2]; Doerr, Kenneth [2]; Griffin, Kristina K. [2]; Grooms, James W. [2]; Hoecherl, Joseph A. [2]; Kang, Keebom [2]; Odell, C. [2]; Pavlik, David E [2]; Robey, R. [2]; Yardley, Thomas E [2]	Mission planning [43]; Decision making [42]; Modeling [40]; Acquisitions/procurement [32]; Analytics [31]; Combat/battlespace [27]; Costs [26]; Simulation [25]; Software & programming [24]; Statistical/mathematical methods [23]	Decision making [41]; Logistics [24]; decision support systems [20]; Optimization [16]; logistics support [15]; Acquisitions [14]; Naval engineering [14]; Computer programs [13]; Simulation [13]; Marine Corps [12]; Modeling [12]; Military procurement [10]; Navy [10]; Tools [10]; Weapon systems [10]	2001 - 2010

[4] Numbers in square brackets represent the number of references in the dataset pertaining to that element. For example, US Naval Postgraduate School has 110 publications in the dataset. In all other columns, the numbers in square brackets represent the number of publications in the dataset for that element, attributed to the organization in the first column. For example, of the US Naval Postgraduate School's publications, 4 of them are authored by Housel, T.J.

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
US Air Force Institute of Technology (AFIT), Wright-Patterson AFB, OH, USA[62]		Gemas, David L [2]; Johnson, A.W. [2]; Kierpiec, Wendy S [2]; Miller, J. O. [2]	Mission planning [27]; Decision making [24]; Statistical/mathematical methods [23]; Modeling [22]; Analytics [18]; Acquisitions/procurement [13]; Aircraft [13]; Combat/battlespace [13]; Decision support sys/tools [12]; Costs [11];	Decision making [24]; Logistics [15]; Logistics management [11]; Air Force [9]; decision support systems [9]; Mathematical models [9]; Scheduling [8]; Acquisitions [6]; Decision analysis [6]; Logistics planning [6]; logistics support [6]; Supply Chain Management (SCM) [6]; Computer simulation [5]; Modeling [5]; Operational readiness [5]; systems engineering [5]	2001 - 2010
US Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH, USA[28]	University of Dayton, OH, USA [4]; NCI Information Systems, Inc., Fairborn, OH [2]	Faas, P. D. [4]; Bachmann, S. [2]; Bennett, A. M. [2]; Curtis, C. [2]; Dukes, A. W. [2]; Galster, S. M. [2]; Kancler, D. E. [2]; Militello, L. G. [2]; Nelson, W. T. [2]; Quill, Laurie [2]; Ritter, J. A. [2]	Decision making [11]; Simulation [10]; Aircraft [9]; Human factors/ergonomics [9]; Maintenance, repair, health management [7]; Collaboration [6]; Real-time or near real-time [6]; Analytics [5]; Interfaces/displays [5]; Mission planning [5];	Decision making [11]; Computer simulation [5]; Logistics [5]; Maintenance [5]; Situational awareness (SA) [5]; Information systems [4]; User interfaces [4]; Aircraft [3]; Architecture [3]; Command and control (C2) [3]; Human Factors [3]; Military aircraft [3]; Simulation [3]; Supply Chain Management (SCM) [3]; Weapon systems [3]	2001 - 2010

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
Department of Defense, Washington, DC, USA[18]		Granetto, Paul J [2]; Marsh, P. A. [2]	Decision making [8]; Mission planning [8]; Acquisitions/procurement [5]; Finance/budgeting [5]; Networking & communication [5]; Combat/battlespace [4]; Information security [4]; Analytics [3]; Business/enterprise processes [3]; Data collection [3]	Decision making [8]; Information systems [5]; Logistics [4]; Military capabilities [4]; Acquisitions [3]; Auditing [3]; IT Management [3]; Military procurement [3]; Operations [3]; Resource management [3]; Test and evaluation [3]; Architecture [2]; Business processes [2]; Combat Support [2]; control [2]; Data acquisition [2]; Data management [2]; Detectors [2]; Guidance [2]; human resource management [2]; Information Security [2]; Interoperability [2]; Leadership [2]; Logistics planning [2]; logistics support [2]; Military modernization [2]; Military planning [2]; Military requirements [2]; Operational effectiveness [2]; Planning Programming and Budgeting (PPB) [2]; Policies [2]; Real-time [2]; systems engineering [2]; Technology Assessment [2]; Technology Transfer [2]; Weapon systems [2]	2002 - 2010

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
Pennsylvania State University, University Park, PA, USA[17]		Reichard, K. M. [7]; Banks, J. [6]; Crow, E. C. [5]; Gautam, N. [4]; Kumara, S. [4]	Maintenance, repair, health management [10]; Costs [8]; Integration & legacy systems [6]; Mission planning [5]; Prognostics [5]; Analytics [4]; Combat/battlespace [4]; Readiness & availability [4]; Sensor-based [4]; C2 [3]; Decision support sys/tools [3]; Distributed systems [3]; Finance/budgeting [3]; Geospatial, geographic & maps [3]; Modeling [3]; Networking & communication [3]; Performance analysis [3]; Real-time or near real-time [3]; Supply chain [3]	Diagnostics [4]; Maintenance [4]; maintenance engineering [4]; Condition monitoring [3]; Cost Reduction [3]; decision support systems [3]; Ground Equipment Study [3]; Ground Support [3]; health management [3]; Integration [3]; logistics support [3]; Marine Corps [3]; Military vehicles [3]; Operational availability [3]; Adaptive logistic controller (ALC) [2]; autonomic logistics [2]; C2 systems [2]; Condition-Based Maintenance (CBM) [2]; Control systems [2]; cost benefit analysis [2]; costs [2]; customer satisfaction [2]; Embedded systems [2]; End Items [2]; Integrated systems [2]; Logistics [2]; Mission Planning [2]; real-time systems [2]; Return On Investment [2]; Total cost of ownership (TCO) [2]	2001 - 2008

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
Argonne National Laboratory, Argonne, IL, USA [15]		Macal, C. M. [7]; Van Groningen, C. N. [6]; Braun, M D [5]; North, M. J. [5]; Blachowicz, D. [4]; Widing, M. A. [4]	Modeling [11]; Simulation [11]; Discrete Event Simulation (DES) [6]; Agent-based [5]; Transportation [5]; Geospatial, geographic & maps [4]; Mission planning [4]; Decision making [3]; Decision support sys/tools [3]; Interfaces/displays [3]; Software & programming [3]	agent-based modeling and simulation (ABMS) [5]; Discrete Event Simulation (DES) [5]; Simulation [5]; Transportation [5]; Decision making [3]; decision support systems [3]; Deployment [3]; interacting agents [3]; Logistics [3]; logistics data processing [3]; Multi-agent systems (MAS) [3]; Supply Chain Management (SCM) [3]; army logistics simulation [2]; consumer market [2]; deductive reasoning [2]; electronic laboratories [2]; inductive reasoning [2]; Java [2]; Mathematical models [2]; Modeling [2]; Tutorials [2]; User interfaces [2]	2002 - 2009

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
Defence Science and Technology Organisation (DSTO), Edinburgh, Australia[15]	University of South Australia, Adelaide, Australia [2]	Kuster, Egon [5]; Bender, A. [4]; Pincombe A. [2]; Triantafyllidis, Aaron [2]	Integration & legacy systems [5]; Modeling [4]; Networking & communication [4]; Decision making [3]; Mission planning [3]; Software & programming [3]; Agent-based [2]; Business/enterprise processes [2]; Collaboration [2]; Data mining [2]; Decision support sys/tools [2]; Geospatial, geographic & maps [2]; Information search & retrieval [2]; Interfaces/displays [2]; Internet/Web [2]; Maintenance, repair, health management [2]; Prediction/forecasting [2]	Logistics information systems [6]; Decision making [3]; Joint operations [3]; Computer network architecture [2]; Data mining [2]; decision support systems [2]; Future Logistics Information Environment [2]; IBM Business Integration Modeler Advanced Edition [2]; Logistics [2]; Military operations [2]; Multi-agent systems (MAS) [2]; Situational awareness (SA) [2]	2004 - 2010

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
Rand Corporation, Santa Monica, CA, USA[15]		Tripp, R. S. [4]; Lynch, Kristin F [3]; Amouzegar, M. A. [2]; Drew, John G [2]; Galway LA [2]; Kerchner, R. [2]; Mills, Patrick [2]; Peltz, Eric [2]; Williams, W. A. [2]	Mission planning [9]; Combat/battlespace [7]; Allocation [6]; Decision support sys/tools [6]; Maintenance, repair, health management [5]; Aircraft [4]; Decision making [4]; Modeling [4]; Costs [3]; Networking & communication [3]; Readiness & availability [3]; Statistical/mathematical methods [3]	decision support systems [5]; Decision making [4]; Distribution [4]; logistics support [4]; Project Air Force [4]; Spare Parts [4]; allocation [3]; Repair [3]; theatre Level Operations [3]; aircraft maintenance [2]; Airlift Operations [2]; closed loop systems [2]; Combat Effectiveness [2]; Communication networks [2]; costs [2]; Execution Capabilities [2]; Inventory management [2]; Iraqi War [2]; Joint Expeditionary Movement System [2]; Logistics management [2]; Logistics planning [2]; Materiel [2]; Mathematical models [2]; Military training [2]; Networks [2]; Operational readiness [2]; Resource management [2]; Weapon systems [2]	2001 - 2009

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
University of Arkansas, Fayetteville, AR, USA[14]		Cassady, C. R. [6]; Rossetti, M. D. [5]; Pohl, E. A. [4]; Mason, Scott J [3]; Rainwater, C. [3]; Schneider, K. [3]	Modeling [11]; Maintenance, repair, health management [9]; Statistical/mathematical methods [9]; Aircraft [8]; Decision making [7]; Mission planning [6]; Analytics [5]; Performance analysis [5]; Simulation [5]; Supply chain [5]	Mathematical models [8]; aircraft maintenance [6]; Decision making [6]; Supply Chain Management (SCM) [5]; Computer simulation [4]; Logistics [4]; Spare Parts [4]; allocation [3]; Maintenance management [3]; Missions [3]; Scheduling [3]; Selective Maintenance [3]; Air Force [2]; decision support systems [2]; Failure [2]; Heuristic methods [2]; Impact [2]; Military [2]; Mission Profiles [2]; object-oriented framework [2]; Optimization [2]; Performance (Engineering) [2]; Prognostic capabilities [2]; Radio frequency identification (RFID) [2]; Reliability [2]; Repair [2]	2003 - 2008

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
US Army War College, Carlisle Barracks, PA, USA[14]			Decision making [8]; C2 [5]; Mission planning [5]; Combat/battlespace [4]; Costs [4]; Requirements/needs [4]; Acquisitions/procurement [3]; Collaboration [3]; Networking & communication [3]; Readiness & availability [3]	Decision making [8]; Acquisitions [3]; Defense system [3]; military commanders [3]; National Security [3]; Cooperation [2]; Cost Overruns [2]; Data management [2]; Impact [2]; Logistics planning [2]; logistics support [2]; Management planning and control [2]; Military requirements [2]; Operational readiness [2]; Recapitalization [2]; Scheduling [2]; Transformations [2];	2001 - 2010
US Government Accountability Office, Washington, DC, USA[14]		Coffey, C. [2]; DiNapoli, T. [2]	Decision making [12]; Acquisitions/procurement [8]; Weapons/ammunition [8]; Costs [4]; Combat/battlespace [3]; Mission planning [3]; Requirements/needs [3]; Analytics [2]; Business/enterprise processes [2]; Finance/budgeting [2]	Decision making [11]; Weapon systems [6]; Defense system [5]; Defence logistics [4]; Acquisitions [3]; Contract administration [3]; Defense Acquisitions [3]; Logistics management [3]; Military procurement [3]; Accountability [2]; Growth(General) [2]; Information systems [2]; Investment [2]; Military requirements [2]; planning [2]; Weapon Systems Acquisition [2]; Weapons Systems Support [2]	2001 - 2009

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
US Military Academy, West Point, NY, USA[14]		Crino, S.T. [3]; Feliciano, M.M. [2]; Hurst KB [2]; Klein, N. A. [2]; Kwinn Jr. M. J. [2]; Warner, S.S. [2]	Modeling [8]; Decision making [7]; Simulation [6]; Combat/battlespace [4]; Analytics [3]; Decision support sys/tools [3]; Weapons/ammunition [3]; Agent-based [2]; Algorithms [2]; Allocation [2]; Interfaces/displays [2]; Prediction/forecasting [2]; Software & programming [2]	Decision making [7]; Computer simulation [5]; military computing [5]; decision support systems [3]; Logistics [3]; military systems [3]; systems decision process [3]; agent-based modeling and simulation (ABMS) [2]; feasibility study [2]; MK-19 weapon system [2]; Modeling [2]; Multi-agent systems (MAS) [2]; recruitment [2]; Simulation [2]; User interfaces [2]; Warehousing [2]; weapons [2]	2001 - 2009

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
US Naval War College, Newport, RI, USA[13]		Spencer, Michael A. [2]	Mission planning [7]; Decision making [5]; C2 [4]; Combat/battlespace [4]; Collaboration [3]; Weapons/ammunition [3]; Integration & legacy systems [2]; Networking & communication [2]; Readiness & availability [2]; Risk management/analysis [2];	Decision making [5]; logistics support [5]; Military operations [5]; C2 systems [4]; Military planning [4]; Joint military activities [3]; Weapon systems [3]; Combat forces [2]; Crisis Management [2]; Deployment [2]; Lessons learned [2]; Logistics Common Operating Picture (LCOP) [2]; Manoeuvres [2]; Military capabilities [2]; Network centric warfare (NCW) [2]; operational necessity [2]; Operational readiness [2]; Protection [2]; Situational awareness (SA) [2]; Transformations [2]	2001 - 2007

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
US Army Command And General Staff College, Fort Leavenworth, KS, USA[12]		Sachariason, Thomas E. [2]	Mission planning [10]; C2 [6]; Combat/battlespace [6]; Collaboration [4]; Decision making [3]; Adaptive [2]; AI & learning systems [2]; Decision support sys/tools [2]; Algorithms [1]; Imagery and video [1]; Interfaces/displays [1]; Networking & communication [1]; Optimization [1]; Performance analysis [1]; Requirements/needs [1]; Software & programming [1]; Supply chain [1]	Logistics [5]; Army Battle Command System (ABCS) [4]; Battle Command Sustainable Support System (BCS3) [4]; Joint military activities [4]; Battlefields [3]; Combat Service Support [3]; C2 systems [3]; Logistics planning [3]; military commanders [3]; Training [3]; Adaptive Systems [2]; Afghanistan Conflict [2]; Army Equipment [2]; Army Personnel [2]; Asymmetric Warfare [2]; Contemporary Operating Environment (COE) [2]; Command Post Of The Future [2]; Control systems [2]; decision support systems [2]; Distribution-Based Logistics [2]; Familiarization [2]; Field Use [2]; Force protection [2]; Iraqi War [2]; Lessons learned [2]; Logistics management [2]; military decision making [2]; Military operations [2]; Military planning [2]; Training Assessment Module [2]; Transformations [2]; Underutilization [2]	2001 - 2010

Organization Name	Co-Authoring Organizations	Top Authors	Top Subject Groups	Top Keywords	Publication Years
US Army Research Laboratory (ARL), Aberdeen Proving Ground, MD, USA[12]		Cushing, M. J. [2]	Modeling [6]; Decision making [5]; Maintenance, repair, health management [5]; Mission planning [5]; Analytics [4]; C2 [3]; Prognostics [3]; Weapons/ammunition [3]; Acquisitions/procurement [2]; Algorithms [2]; Costs [2]; Data collection [2]; Human factors/ergonomics [2]; Knowledge based, KM, info services [2]; Life cycle management [2]; Networking & communication [2]; Risk management/analysis [2]; Software & programming [2]	Decision making [5]; Logistics [4]; Maintenance [4]; Reliability [4]; Prognostics [3]; Systems analysis [3]; Algorithms [2]; Army Research [2]; C2 systems [2]; condition based maintenance [2]; control [2]; Design engineering [2]; Human performance [2]; Materiel [2]; Mathematical Tool [2]; mechanical failure [2]; Military operations [2]; Military planning [2]; Missions [2]; US Army Materiel Systems Analysis Activity [2]; Weapon systems [2]	2001 - 2010

Table 11. Authors with six (6) or more publications

Author Name	Affiliation(s) of Author	Co-Authors	Top Subject Groups	Top Keywords	Publication Years
Zhang, Liu[10]	Ordnance Engineering College, Shijiazhuang, China [4]	Yu, Yongli [3]; Li Shiying [2]; Nie Chenglong [2]; Zhang, Yong [2]	Modeling [6]; Combat/battlespace [4]; Maintenance, repair, health management [4]; Simulation [4]; Mission planning [3]; Supply chain [3]; Discrete Event Simulation (DES) [2]; Inventory management [2]; Software & programming [2];	Combat unit [2]; Discrete Event Simulation (DES) [2]; Inventory management [2]; Inventory models [2]; maintenance engineering [2]; Materiel [2]; Materiel support [2]; Military operations [2]; military systems [2]; Modeling [2]; Repairable spare parts [2]; Simulation [2]; Support systems [2]	2007 - 2010
Kang, Rui[9]	Beijing University of Aeronautics and Astronautics, China [6]; Beihang University, Beijing, China [3]	Guo Linhan [3]; Qu, Lili [3]; Kang Xiao ming [2]; Long J. [2]	Modeling [8]; Analytics [6]; Statistical/mathematical methods [4]; Aircraft [3]; Maintenance, repair, health management [3]; Algorithms [2]; Decision support sys/tools [2]; Integration & legacy systems [2]; Mission planning [2]; Simulation [2]	Logistics [4]; Reliability [4]; Support systems [4]; Development phase [3]; Evaluation models [3]; Materiel [3]; materiel support plan [3]; Modeling [3]; Plan evaluation [3]; Ranking of alternatives [3]	2007 - 2010

Author Name	Affiliation(s) of Author	Co-Authors	Top Subject Groups	Top Keywords	Publication Years
Kuster, Egon[7]	Defence Science and Technology Organisation (DSTO), Edinburgh, Australia [5]; Defence Science and Technology Organisation (DSTO), Canberra, Australia [2]	Roff, A. [2]; Triantafyllidis, Aaron [2]	Collaboration [4]; Networking & communication [4]; Architectures [2]; Integration & legacy systems [2]; Modeling [2];Queries [2];	Joint military activities [4]; Logistics information systems [4]; Architecture [2]; Coalition Theatre Logistics architecture [2]; Computer network architecture [2]; Future Logistics Information Environment [2]; IBM Business Integration Modeler Advanced Edition [2]; Information systems [2]; Joint logistics [2]; Logistics [2]; XQuery Engine Prototype [2]	2004 - 2006
Macal, C. M.[7]	Argonne National Laboratory, Argonne, IL, USA [7]	North, M. J. [5]; Love, R. J. [2]; Van Groningen, C. N. [2]	Simulation [7]; Modeling [6]; Agent-based [5]; Decision making [3]; Supply chain [3]; Decision support sys/tools [2]; Discrete Event Simulation (DES) [2];	agent-based modeling and simulation (ABMS) [5]; Simulation [5]; Decision making [3]; interacting agents [3]; Multi-agent systems (MAS) [3]; Supply Chain Management (SCM) [3]; army logistics simulation [2]; Computer simulation [2]; consumer market [2]; decision support systems [2]; deductive reasoning [2]; electronic laboratories [2]; inductive reasoning [2];	2004 - 2009

Author Name	Affiliation(s) of Author	Co-Authors	Top Subject Groups	Top Keywords	Publication Years
Reichard, K. M.[7]	Pennsylvania State University, University Park, PA, USA [7]	Banks, J. [4]; Crow, E. C. [4]; Rogan C. [2]	Maintenance, repair, health management [5]; Prognostics [4]; Costs [3]; Readiness & availability [3]; Analytics [2]; Finance/budgeting [2]; Life cycle management [2]; Mission planning [2]; Sensor-based [2];	Operational availability [3]; Condition monitoring [2]; Cost Reduction [2]; health management [2]; logistics support [2]; maintenance engineering [2]; Mission Planning [2]	2005 - 2008
Banks, J.[6]	Pennsylvania State University, University Park, PA, USA [6]	Reichard, K. M. [4]; Crow, E. C. [3]	Maintenance, repair, health management [6]; Costs [4]; Prognostics [4]; Analytics [3]; Finance/budgeting [3]; Mission planning [3]; Readiness & availability [3]; Vehicles [3]; C2 [2]; Combat/battlespace [2]; Knowledge based, KM, info services [2]; Life cycle management [2]	Cost Reduction [3]; health management [3]; logistics support [3]; Maintenance [3]; Military vehicles [3]; Operational availability [3]; Condition monitoring [2]; Control systems [2]; cost benefit analysis [2]; financial assessment [2]; Logistics [2]; maintenance engineering [2]; Mission Planning [2]; Return On Investment [2]	2005 - 2008

Author Name	Affiliation(s) of Author	Co-Authors	Top Subject Groups	Top Keywords	Publication Years
Cagle, Ron[6]	Gracar Corp., Dayton, OH USA [3]; University of Dayton, OH, USA [2]	Gallimore, J. J. [5]; Matthews, Elizabeth [5]; Gruenke, Jessica [4]; Quill, Laurie [4]	Decision making [4]; Maintenance, repair, health management [4]; C2 [3]; Human factors/ergonomics [3]; Real-time or near real-time [3]; Aircraft [2]; Collaboration [2]; Combat/battlespace [2]; Integration & legacy systems [2]; Location awareness [2]; RFID [2]	Decision making [4]; control SSLC2 [3]; Flightline Maintenance [3]; Information systems [3]; Logistics [3]; Logistics Command [3]; smart Systems [3]; Agile Combat Support (ACS) [2]; Command and control (C2) [2]; Feedback [2]; Human Factors [2]; Integrated Flightline Data [2]; logistics support [2]; Maintenance decision making [2]; Radio frequency identification (RFID) [2]; Real Time Location System [2]; Simulation [2]; user Feedback [2]	2006 - 2008
Cassady, C. R.[6]	University of Arkansas, Fayetteville, AR, USA [6]	Pohl, E. A. [3]; Rainwater, C. [3]; Schneider, K. [3]; Mason, Scott J [2]; Mendoza, A. [2]; Nachtmann, H. L. [2]; Ormon, S. [2]; Pohl, L. [2]	Maintenance, repair, health management [6]; Modeling [6]; Statistical/mathematical methods [6]; Decision making [5]; Aircraft [4]; Mission planning [4]; Allocation [2]; Analytics [2]; Decision support sys/tools [2]; Optimization [2]; Performance analysis [2]	Mathematical models [6]; Decision making [5]; aircraft maintenance [4]; Maintenance management [3]; Selective Maintenance [3]; allocation [2]; Impact [2]; Mission Profiles [2]; Missions [2]; Optimization [2]; Performance (Engineering) [2]; Prognostic capabilities [2]; Reliability [2]; Spare Parts [2]	2003 - 2005

Author Name	Affiliation(s) of Author	Co-Authors	Top Subject Groups	Top Keywords	Publication Years
Chilov, Nikolai[6]; Levashova, Tatiana[6];Smirnov, Alexander [6];Pashkin, Michael [6]	Russian Academy of Sciences, St Petersburg, Russian Federation [6]	Levashova, Tatiana [6]; Pashkin, Michael [6]; Smirnov, Alexander [6]; Krizhanovsky, Andrew [2]	Knowledge based, KM, info services [6]; Agent-based [5]; Data/information fusion [4]; Acquisitions/procurement [3]; Decision making [3]; Distributed systems [3]; Networking & communication [3]; AI & learning systems [2]; Decision support sys/tools [2]; Information search & retrieval [2]; Internet/Web [2]	Knowledge logistics (KL) [5]; Intelligent agents [4]; Decision making [3];F fusion-Based Knowledge Logistics [3]; knowledge acquisition [3]; decision support systems [2]; Distributed computer systems [2]; Health service logistics [2]; information fusion [2]; intelligent systems [2]; Knowledge based systems [2]; knowledge management system [2]; Knowledge representation [2]; Logistics [2]; Multi-agent systems (MAS) [2]; Network centric environment [2]; OOTW intelligent support [2]; Operations Other Than War (OOTW) [2]	2003 - 2005
Faas, P. D.[6]	US Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH, USA [4]	Cagle, Ron [2]; Gallimore, J. J. [2]; Matthews, Elizabeth [2]; Quill, Laurie [2]; Seyba J. [2]; Young I. [2]	Maintenance, repair, health management [4]; Aircraft [2]; Decision making [2]; Geospatial, geographic & maps [2]; Human factors/ergonomics [2]; Modeling [2]; Performance analysis [2]; Real-time or near real-time [2]; Simulation [2];	Logistics [3]; aircraft maintenance [2]; Decision making [2]; Flightline Maintenance [2]; Human Factors [2]	2003 - 2007

Author Name	Affiliation(s) of Author	Co-Authors	Top Subject Groups	Top Keywords	Publication Years
Li, Shiying[6]; Yu, Yongli[6]; Zhang, Yong[6]	Ordnance Engineering College, Shijiazhuang, China [3]	Li, Shiying[6]; Yu, Yongli[6]; Zhang, Yong[6]	Combat/battlespace [3]; Modeling [3]; Algorithms [2]; Networking & communication [2]; Prediction/forecasting [2]; Simulation [2];		2007 - 2010
Quill, Laurie[6]	University of Dayton, OH, USA [4]; Gracar Corp., Dayton, OH USA [2]; US Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH, USA [2]	Cagle, Ron [4]; Gallimore, J. J. [4]; Gruenke, Jessica [3]; Matthews, Elizabeth [3]	Maintenance, repair, health management [4]; Decision making [3]; Human factors/ergonomics [3]; Simulation [3]; Aircraft [2];Collaboration [2]; Combat/battlespace [2]; Integration & legacy systems [2]; Location awareness [2]; Real-time or near real-time [2];	Decision making [3]; Information systems [3]; Logistics [3]; Agile Combat Support (ACS) [2]; Computer simulation [2]; Computer supported cooperative work [2]; Flightline Maintenance [2]; Human Factors [2]; Integrated Flightline Data [2]; logistics support [2]; Maintenance decision making [2]; Radio frequency identification (RFID) [2]; user Feedback [2]	2002 - 2007
Van Groningen, C. N.[6]	Argonne National Laboratory, Argonne, IL, USA [6]	Braun, M D [5]; Blachowicz, D. [4]; Widing, M. A. [4]; Love, R. J. [2]; Macal, C. M. [2]; Simunich, K. L. [2]	Discrete Event Simulation (DES) [4]; Simulation [4]; Transportation [4]; Geospatial, geographic & maps [3]; Modeling [3]; Software & programming [3]; Analytics [2]; Integration & legacy systems [2]; Mission planning [2];	Transportation [4]; Logistics [3]; army logistics simulation [2]; Computer simulation [2]; Deployment [2]; Java [2]; logistics data processing [2]	2002 - 2004

Author Name	Affiliation(s) of Author	Co-Authors	Top Subject Groups	Top Keywords	Publication Years
Vincent, Patrick J.[6]	Northrop Grumman Information Technology, Fairborn, OH, USA [6]	Allen, Christopher S. [2]; Hicks, Graydon K. [2]; Jacobs, John T. [2]; Snyder, David B. [2]; Wampler, Jeffrey L. [2]	Decision support sys/tools [3]; AI & learning systems [2]; Asset visibility [2]; Decision making [2]; Mission planning [2]; Networking & communication [2];	logistics support [3]; Air Force [2]; Artificial intelligence [2]; Concept designs [2]; Decision making [2]; decision support systems [2]; expert systems [2]; Logistics [2]; Logistics Decision Support Tool (LDST) [2]; Logistics management [2] ;logistics Reachback [2]; Missions [2]	2002 - 2006

5.4.1 Identification of Expertise: Visualization

The tables below cross the top (including Canadian) organizations from the VIZ-COP and VIZ-LOG datasets with expertise (as evinced through subject matter in groups). While the highest rated subject groups may differ in the LOG vs. COP perspective, we have attempted to include common and important groups for purposes of comparison. For each organization, the highest value is shaded in blue, provided its value is three or higher.

It should be noted that organizations such as the Naval Postgraduate School in Monterey, California, are educational institutions publishing graduate theses, and should not be considered as equivalent to R&D agencies such as the US Air Force Research Laboratory.

It may also be of interest that the Pacific Northwest National Laboratory, identified in the VIZ-COP table, is home to the U.S. National Visualization and Analytics Center.[77] The lab has developed numerous visual tools for the U.S. military, some of which have been commercialized (for example, Future Point Systems' Starlight[78] visual information system).

TABLE 12. VIZ-LOG : Organizations & Expertise

Organization	Logistics	Interfaces/displays	Mission planning	Modeling & simulation	Knowledge based, KM and info	Software & programming	Aircraft	Decision support	Integration & legacy systems	Architectures	Imagery and videos	Maintenance, repair, health mgt.	Databases	Combat/battlespace	Geospatial, geographic & maps	Internet/Web	Decision making	Statistical/mathematical methods	Business/enterprise processes
Argonne National Laboratory, Argonne, IL	4	3	1	5	1	2			1	1	2		2		3				1
Boeing Co., St. Louis, MO		2			1		1				2	1							
Brunel University, Uxbridge, UK				3		1				3									
Carnegie Mellon University, Pittsburgh, PA	1	1	1		2	1	1	1		2		1	1				1		1
DRDC Valcartier, QC	1	1	2		1	1		3		1			1	2			1		
Hope College, Holland, MI		3									3								
NATO RTO Neuilly-sur-Seine, France	2	3	2	1	3	2		2	2				2				1		
Naval Postgraduate School, Monterey, CA	5	9	9	9	7	6	3	6	2	6	8	2	4	5		3	3	3	4
NCI Information Systems, Inc., Fairborn, OH	1	2			2	2	3					3	1						
Pennsylvania State University, State College, PA	3	1	1	1	1	1	1	1	1			3				1	1		
Pennsylvania State University, University Park, PA	2	1	1	1	1	1					1	2	1			1		1	
Space and Naval Warfare Systems Center (SPAWAR), San Diego, CA	3	2	2		1	1	2		3	2	1				1				
University of Dayton, OH	2	3	1	1	1	3	4					4			1			1	

Organization	Logistics	Interfaces/displays	Mission planning	Modeling & simulation	Knowledge based, KM and info	Software & programming	Aircraft	Decision support	Integration & legacy systems	Architectures	Imagery and videos	Maintenance, repair, health mgt.	Databases	Combat/battlespace	Geospatial, geographic & maps	Internet/Web	Decision making	Statistical/mathematical methods	Business/enterprise processes
US Air Force Research Laboratory, Wright-Patterson AFB, Dayton, OH	4	4	5	2	2	1	3	3		1		4	1		1		2		
US Air Force Studies and Analyses Agency, Washington, DC	3	2	2	1		1	2				1			2				2	
US Army Research Laboratory, Adelphi, MD	1				1	1		1					1	1			1		
US Naval Air Systems Command, Patuxent River, MD	1		1	1	1		4					3		1	1				
Versatile Information Systems, Framingham, MA	2	3			3	1				1	2					3			
Villanova University, PA	3	1	1	1	3	1		2			1						1		1

TABLE 13. VIZ-COP: Organization & Expertise

Organization	Situation awareness and COP	Interfaces/displays	Modeling & simulation	Visualization	Imagery and videos	Decision support	Human factors/ergonomics	Mission planning	Knowledge based, KM and info services	Analytics	Geospatial, geographic & maps	Collaboration	Internet/Web	AI & learning systems	Data/information fusion	Context/domain aware	Simulation	Decision support sys/tools	Real-time or near real-time
Arizona State University, Tempe, AZ	5	5	1		1	1	2	1				1				4			
Carnegie Mellon University, Pittsburgh, PA	2	2	1	2	1	1	1			1	1	2		2	1				1
Charles River Analytics Inc., Cambridge, MA	4	3	2		1	2	2		3	1	1			1	2		1		
Computing Devices Canada, Nepean, ON	1																		
Concordia University, Montreal, QC	1																		
DRDC Toronto, ON	1							1	1				1	1		1			
DRDC Valcartier, QC	6	4	2	1	1	2		4	3				2	1	2	1	1	2	1
DSTO, Edinburgh, Australia	2	2		1	1	2	2	2						2	1	1		1	
General Dynamics Canada, Ottawa, ON	1				1											1			
Georgia Institute of Technology, Atlanta, GA	1	3	1				1				1						1		1
Humansystems Incorporated (HSIreg), Guelph, ON	1			1	1		1												
Korea University, Seoul, South Korea	4	3	4		1	1	1					1	2				1		
Massachusetts Institute of Technology, Cambridge, MA	6	1	1	2		1	1	1		3	2	1	1				1		
Mustang Survival Corp., Richmond, BC	1	1	1					1									1		

Organization	Situation awareness and COP	Interfaces/displays	Modeling & simulation	Visualization	Imagery and videos	Decision support	Human factors/ergonomics	Mission planning	Knowledge based, KM and info services	Analytics	Geospatial, geographic & maps	Collaboration	Internet/Web	AI & learning systems	Data/information fusion	Context/domain aware	Simulation	Decision support sys/tools	Real-time or near real-time
OODA Technologies, Montreal, QC	1	1	1						1						1				
Pacific Northwest National Laboratory, Richland, WA	6	4	2	3	1	2	3		1	2	3	2				1			3
Purdue University, West Lafayette, IN	3		2	4	1	3		1		3									
Raytheon Company, Marlborough, MA	2	2	1	1	1	2		2	2			1	1	1				2	
SA Technologies, Inc., Marietta, GA	3	2	2			2	2	1		1		1				1	2	1	
Sandia National Laboratories, Albuquerque, NM	3	3	1		1	1		2			1			1		1		1	1
Space and Naval Warfare Systems Center (SPAWAR), San Diego, CA	4	4			1	1		1	1					1	1				
University of Illinois, Urbana-Champaign, IL	14	8	6	7	5	4	5	3	2	4	3		3	1		1	5	1	2
University of Skövde, Sweden	3	2	3	3	3		1		1	3	1				2				
University of Southern California, Los Angeles, CA	3	3	1	1	1		2			2	1	1		2		1			
University of Virginia, Charlottesville, VA	3	5		1	1	4	1	1	1	1				1				4	
USAF Research Laboratory, Rome, NY	4	5	3	4		4	1	3	1	2		1	1	2	3		2	2	
USAF Research Laboratory, Wright-Patterson AFB, Dayton, OH	11	10	5	2	1	3	3	3	4	3	1	5		2	7	2	3	1	1
Virginia Polytechnic Institute and State University Blacksburg, VA	3	2	2	2	1	1		1			1					1	1	1	1

Organization	Situation awareness and COP	Interfaces/displays	Modeling & simulation	Visualization	Imagery and videos	Decision support	Human factors/ergonomics	Mission planning	Knowledge based, KM and info services	Analytics	Geospatial, geographic & maps	Collaboration	Internet/Web	AI & learning systems	Data/information fusion	Context/domain aware	Simulation	Decision support sys/tools	Real-time or near real-time
Wright State University, Dayton, OH	4	3	1		2	1	1		1	1					2				1

5.5 Canadian Papers

The following table lists 20 papers in the master dataset authored by Canadians.

Table 14. Papers authored by Canadians.

Author(s)	Affiliation(s) of Author(s)	Title	Source	Pub Year
Li G.; Luo J.	Carleton University, Ottawa, ON, Canada	Shock model in Markovian environment	Naval Research Logistics. vol 52(3) (pp 253-260), 2005. Date of Publication: April 2005.	2005
Bulgak A. A.; Khataie A. H.; Segovia J. J.	Concordia University. Montreal, QC, Canada	Advanced decision support tool by integrating activity-based costing and management to system dynamics	PICMET '10 - Portland International Center for Management of Engineering and Technology, Proceedings - Technology Management for Global Economic Growth. (pp 2387-2390), 2010.	2010
Forsyth, D.; Leemans, D. V.	Crosscurrents Research and Policy Consulting, Toronto, ON, Canada; National Research Council Canada, Ottawa, ON, Canada	Bayesian approaches to using field test data in determining the probability of detection	Materials Evaluation. vol. 62, no8, pp. 855-859	2004
Berger, J.; Boukhtouta, A.; Ghanmi, A.; Martel A	DRDC-Ottawa, ON, Canada	A framework for the design of a military operational supply network	Proceedings of the 2009 IEEE Symposium on Computational Intelligence for Security and Defense Applications (CISDA). IEEE. 2009, pp. 9.	2009
Campbell GB; Ghanmi, A.; Gibbons TA	DRDC-Ottawa, ON, Canada	Modeling and simulation of multinational intra-theatre logistics distribution	2008 Winter Simulation Conference (WSC). IEEE. 2008, pp. 1157-63	2008
Pagotto J.; Walker R. S.	DRDC-Ottawa, ON, Canada	Capability engineering - Transforming defence acquisition in Canada	Proceedings of SPIE - The International Society for Optical Engineering. Battlespace Digitization and Network - Centric Systems IV. vol 5441 (pp 89-100), 2004.	2004

Author(s)	Affiliation(s) of Author(s)	Title	Source	Pub Year
Gouin, Denis; P. Evdokiou	DRDC-Valcartier, QC, Canada	Showcase of Visualization Approaches for Military Decision Makers.	Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", Halden, Norway, 10-13 September 2002. Published in NATO RTO-MP-105.	2004
Berger, J.; Boukhtouta, A.; Sahi A.	DRDC-Valcartier, QC, Canada	A network centric operational framework for information sharing and decision support	Proceedings of the 4th IASTED International Conference on Advances in Computer Science and Technology, ACST 2008. (pp 19-24), 2008.;	2008
Boukhtouta, A.	DRDC-Valcartier, QC, Canada	Decision support planners for military operations	Recent Advances in Computers, Computing and Communications. Recent Advances in Computers, Computing and Communications. (pp 50-57), 2002.	2002
Gouin, Denis	DRDC-Valcartier, QC, Canada	The Electronic Battle Box	Multimedia Visualization of Massive Military Datasets; 01 Aug. 2002. pp. 4-1 - 4-6. 2002; STAR. Vol. 40. 20 Sept. 2002	2002
Berger, J.; Boukhtouta, A.; Ghanmi, A.; Guitouni A; Jabeur K	DRDC-Valcartier, QC, Canada	A Hybrid Genetic Algorithm for Rescue Path Planning in Uncertain Adversarial Environment	2010 IEEE Congress on Evolutionary Computation. IEEE. 2010, pp. 8.	2010
Pellerin R	Ecole Polytechnique de Montreal, QC, Canada	Development and integration of a simulation-based repair and overhaul execution strategy in ERP systems	International Journal of Value Chain Management, vol.2, no.4, 2008, pp. 436-49.	2008
Howe T.; Ruwanpura J. Y.	General Dynamics Canada, Calgary, AB, Canada; University of Calgary, AB, Canada	The land forces equipment support model	Proceedings of the IASTED International Conference on Modeling and Simulation. Proceedings of the Fifteenth IASTED Internatinal Conference on Modeling and Simulation. (pp 36-41), 2004.	2004
Aube G.; Gignac N.	Institut National de la Recherche Scientifique, Quebec, QC, Canada; Université de Sherbrooke, QC, Canada	Homeland security and national defence: Emerging Geo-information technologies from the geospatial industry	55th International Astronautical Congress 2004. vol 2 (pp 1070-1073), 2004.; International Astronautical Federation	2004

Author(s)	Affiliation(s) of Author(s)	Title	Source	Pub Year
Hollick LI	Ludwig Hollick & Associates, Inc., Ottawa, ON, Canada	Achieving shared accountability for operational availability attainment	2009 Annual Reliability and Maintainability Symposium. IEEE. 2009, pp. 6.	2009
Cater NE; O'Reilly T	Memorial University, St. John's, NL, Canada	Promoting Interoperable Ocean Sensors The Smart Ocean Sensors Consortium	OCEANS 2009. IEEE. 2009, pp. 6.	2009
Yawei Liang	Royal Military College of Canada, Kingston, ON, Canada	Using extend simulation tool to study the logistic requirements of the standing contingency task force	2008 International Conference on Service Systems and Service Management (ICSSSM 2008). IEEE. 2008, pp. 1-6.	2008
Gao, Y.; Li Shiying; Liu S.	Ryerson University, Toronto, ON, Canada; University of Calgary, AB, Canada	Emergency management systems using event-driven GIS	Proceedings of the 31st AMOP Technical Seminar on Environmental Contamination and Response	2008
Bordenave, Charles; Gendreau, Michel; Laporte, Gilbert	Universite de Montreal, QC, Canada	A branch-and-cut algorithm for the nonpreemptive swapping problem	Naval Research Logistics. Vol. 56, no. 5, pp. 478-486. Aug. 2009	2009
Berman O.; Sapna K. P.	University of Toronto, ON, Canada	Optimal service rates of a service facility with perishable inventory items	Naval Research Logistics. vol 49(5) (pp 464-482), 2002.	2002

5.6 Technology Readiness Levels

Table 15 describes the way that we have broken down the Technology Readiness Levels into four (4) groups instead of nine (9), and the indicators we used to judge if categories of technologies can fit into one category or another.

The data for the TRL assessment is provided in an attachment to this report: CoROSP TRL data.xls

Table 15. Technology Readiness Level criteria

Modified TRL Level	Includes TRL Levels	Types of Organizations Expected	# of publications/ # of patents	Publication treatment codes	Keywords in identifiers
1- Experimental	1-3	Universities, public labs	High number of publications, low number of patents	Theoretical Mathematical Experimental	Basic research Experiment Experimental Speculative Theoretical Analytic study Analytical study Basic properties Computer simulation Mathematical models Numerical simulation Controlled study
2-Practical	4-5	US Army Research Laboratory Government Labs Private Labs	High number of publications, more patents than experimental	Practical Applications	Applications Applied research Practical Low fidelity Integration Bread board Ad hoc Integrated components Laboratory integration High fidelity Simulation Virtual prototype
3- Prototype Stage	6-7	US Army ARDEQ Companies, esp. their research labs	High number of publications, high number of patents	Applications New Developments	Prototype Prototypical Representative model Testing Simulated operational environment Demonstration Demonstrated readiness Reduced-scale test Scale-model experiment Test bed

Modified TRL Level	Includes TRL Levels	Types of Organizations Expected	# of publications/ # of patents	Publication treatment codes	Keywords in identifiers
4- Product stage	8-9	Companies (predominantly)	Lower number of publications, high number of patents		Co. Company Corporation Product Product design Developmental test Developmental evaluation Weapon system Mission Operational test Operational environment Operational evaluation Patent

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More than 1,700 scientific publications and 238 patents were analysed for this report. Analyses were based on text analysis and the co-occurrence of words in the metadata of the documents to identify important research fronts in the domain of military logistics, with specific emphasis on decision support, predictive analytics, search and retrieval, visual analytics and user interfaces. The main logistics requirements that are dominating areas of study are mission planning, asset visibility and condition based maintenance, particularly for aircraft and vehicles. There is also a significant amount of discussion related to cost cutting, cost-effectiveness and business planning. There are many synergies between ROSP and enterprise resource planning for other markets and industries and it has been observed that this is a much more commercial market than is the case for most defence technologies. Several large global firms such as SAP, Lockheed Martin, IBM, and Oracle control the majority of market share and it appears that many logistics systems developed for commercial markets are being adapted for military purposes since these COTS solutions do not often have the full functionality required by military applications.

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Logistics, operational support picture, information management, decision support, optimization

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