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STIA Assessment

Future Intelligence Analysis Capability

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National Research Council (NRC) Canada

Defence Research and Development Canada – Valcartier

Contract Report
DRDC Valcartier CR 2012-246
October 2011

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IMPORTANT INFORMATIVE STATEMENTS

The scientific or technical validity of this Contract Report is entirely the responsibility of the Contractor and the contents do not necessarily have the approval or endorsement of the Department of National Defence of Canada.

Abstract

To address the questions posed in the project mandate, we collected data from three complementary information streams: market research, scientific and technical literature, and patent grants and applications.

Results indicate this is an active and competitive space, with both commercial and military participants. Private enterprise has made significant contributions in the form of the key technologies underpinning business intelligence architectures and analytical methods. The intelligence community has adapted that functionality to its own purposes, and advanced capability in areas such as data governance and grids, security, visualization, interoperability, and the exploitation of specific types of intelligence data (sensor/signals, geospatial, visual, HUMINT).

Résumé

Pour répondre aux questions posées dans le mandat du projet, nous avons recueilli des données à partir de trois sources d'information complémentaires : études de marché, documentation scientifique et technique, et brevets approuvés ou demandés.

Les résultats indiquent qu'il s'agit d'un milieu actif et compétitif, avec des participants commerciaux et militaires. L'entreprise privée a apporté des contributions significatives sous la forme de technologies clés qui sous-tendent des méthodes d'analyse et des architectures de renseignements d'affaires. La communauté du renseignement a adapté cette fonctionnalité à ses propres fins, et a perfectionné des capacités dans des domaines tels que la gouvernance et les grilles de données, la sécurité, la visualisation et l'interopérabilité, et l'exploitation de types précis de données de renseignement (capteurs/signaux, géospatial, visuel, HUMINT).

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STIA Assessment

Title: **Future Intelligence Analysis Capability**

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Prepared for: Stéphane Paradis

Prepared by: Brenda Brady, Technical Information Analyst

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2 SUMMARY

To address the questions posed in the project mandate, we collected data from three complementary information streams: market research, scientific and technical literature, and patent grants and applications.

Results indicate this is an active and competitive space, with both commercial and military participants. Private enterprise has made significant contributions in the form of the key technologies underpinning business intelligence architectures and analytical methods. The intelligence community has adapted that functionality to its own purposes and advanced capability in areas such as data governance and grids, security, visualization, interoperability, and the exploitation of specific types of intelligence data (sensor/signals, geospatial, visual, HUMINT).

Analysis of the data reveals what appears to be a natural progression from supporting technologies to analytical applications. In the earliest stages, there has been an effort to eliminate or integrate data systems and silos, accompanied by initiatives to build networked structures -- frequently distributed grids -- for shared applications and intelligence. In some cases, these may create truly integrated enterprise systems; in others, middleware or other services are at work to provide a layer that links disparate sources and systems, granting functional integration even when the data and systems are still dispersed and independent. Efficiencies have also been achieved in leaner methods of data warehousing, data reduction, and automated processes, such as tagging of legacy or unstructured information.

Data fusion has also been a matter of early concern, and techniques have been developed – if not necessarily perfected – to reduce errors and uncertainty that are exaggerated when data is propagated or fused. The need to merge sensor-derived data has driven much of the development in this area, but as time has gone on, other data types have entered the fusion equation.

Key technologies based on semantics, ontologies, and taxonomies, all of which support data fusion, retrieval, classification and analysis, have been the object of considerable research and commercialization. Standards and schema developed by the U.S. Departments of Defense and Justice have made significant contributions in this regard.

With such basic enablers in place, research has moved on to second generation technologies, such as those for feature extraction, search, interpretation, pattern recognition, link analysis, and prediction. Certain challenging areas, such as those related to interpretation of non-textual and multi-domain data, continue to attract research attention and funding. Multifunctional technologies, such as visualization methodologies, are of strategic interest, as are ways to automate basic processes.

The need for speed, mobility, and interoperability are also emergent. With diverse users in multiple locations, and with differing security clearances and job profiles, complex methods of data sharing, collaboration, access and data security are of high interest. The network of data fusion centers, developed in the United States to assist criminal investigations and anti-terrorism efforts, and ongoing coalition campaigns in Afghanistan and Iraq have done much to advance critical data collection and sharing initiatives, but this is still a hot area for development. Military officials and the strategic plans of key agencies also continue to stress the need for smarter means of dissemination. The Internet and service oriented architecture are key elements for all aspects.

Our results support an evolutionary hypothesis, with research efforts moving from core and enabling technologies through analytical methods and dissemination techniques. The literature, market and patent surveys all demonstrate that technology for collection, storage, and integration is slightly more mature, while solutions related to interpretation, security and dissemination are less fully developed but well established in the testbed/demonstration phase.

Many technologies are already available commercially, since many defence contractors are also active in the business intelligence space and thanks to programmes to encourage technology development and transfer, as sponsored by government agencies. Defence requirements are different, but cross-fertilization between the two domains (military/commercial) has benefited both.

The approach for this project was broad, and the intent was to gain a birds' eye view of intelligence analysis capabilities. Our results describe general trends and support general hypotheses, such as the importance of data fusion, systems integration, multisource intelligence, semantic interoperability, agent-based analytics and in all things, netcentricity.

Our findings also describe the recent history of intelligence analysis, and demonstrate changing patterns of research focus. While the results cannot predict the future of analytics, and while they are in no way linked to official policies and priorities of the Defence Research and Development Canada, our assessment suggests future directions for research, especially those categorized as "Emergent Technologies". Important topic areas for consideration in the near and far term include semantic and agent-based analytics and predictive tools, visualizations of all types, technologies that can automate basic processes, exploitation of service oriented architecture and cloud computing, multimedia analytics, support for mobile applications, the use of open source literature, better multilingual capabilities, and a variety of techniques to support improved and secure collaboration and dissemination.

For more focused views in areas DRDC deems critical in the near term, we recommend additional future research in regard to available technologies and expertise.

A summary of results for the key questions of the mandate follows:

Key technologies:

> These may be categorized as Core, Tasking, Collection, Processing, and Dissemination. They include communications and data management architectures as well as technologies for systems integration, data fusion (primarily sensor based, but also apply to geospatial/temporal and other data sources), semantic interoperability, complex event processing, and analysis.

Commercial and deployed technologies:

> Almost all of the key technologies are approaching maturity, and are available as commercial and/or government off the shelf technologies. Large contracts to firms such as IBM, Raytheon, General Dynamics, Northrop Grumann and others have supported integration and fusion initiatives, and technology transfer programmes on the part of large intelligence agencies have done much to promote commercial innovation in areas of strategic interest, such as visualization. U.S. data fusion centers are a well-documented example of technology development for the full intelligence cycle (communications through analysis).

Emergent technologies:

> Smarter and more versatile analytics (agent based, multimedia, predictive, modeling and simulation) visual, audio, agents, predictive); visualization and virtualization; social media-based (e.g., for collaboration and analysis); open source INT; mobility solutions; automation of processes; service oriented architecture; cloud computing; information governance and assurance; multilevel security and cryptography.

Drivers:

Increasing collection and volume of data; proliferation of threats; counter-terrorism initiatives; continuing campaigns and joint operations; requirements for interoperability.

Barriers:

Proliferation of threats and data; stovepiped assets and legacy systems; cultural issues related to integration and sharing; lack of policy/guidance; entrenched competition on the part of large contractors; regulatory environment for military information and technology; bandwidth issues; shortage of analysts; shortage of language skills; diverse domains.

Key players:

United States: Department of Defense, including research labs, Defense Information Services Agency, Defense Advanced Research projects Agency (DARPA); Intelligence Advanced Research projects Agency (IARPA); U.S. Department of Justice; National Security Agency; In-Q-Tel (Central Intelligence Agency venture capital firm).

Other National and International: DRDC; Swedish Defence Research Agency; National University of Defense and Technology (China); NATO.

Commercial: mixture of large global firms (Lockheed, Raytheon, General Dynamics, Northop Grumann, Boeing, IBM Cognos, etc.) and smaller niche market companies. Many of the smaller companies have been the source of recent innovations.

3 BACKGROUND

Intelligence analysts are faced with a number of technical and logistical challenges with regard to analysis. Particular challenges are presented by the exploitation of vast amounts of multisource data and by the identification of appropriate methods of information collection, extraction (discovery), synthesis, processing, dissemination and presentation.

The present survey will characterize recent technological developments in the area of information management and exploitation for all source intelligence on the part of defence and security organizations, with a goal of assisting DRDC with S&T program formulation, planning and investment activities in support of future intelligence analysis capability.

While the assessment will summarize related developments in the field of business intelligence (as derived from a brief survey of market literature), the focus of the analysis will be on trends, tools and underlying technologies for intelligence data collection and analysis conducted by the defence and security organizations.

Results of this Strategic Technical Information Analysis (STIA) assessment will provide DRDC managers and researchers with a solid, evidence-based perspective for their state of the art review. The findings will also identify leading organizations and corporations active in this field and will suggest potential research and development directions and areas of expertise that may be required in the near and long term.

4 KEY QUESTIONS

1- What are the key technologies for multisource intelligence management, processing and analysis in support of defence and civil intelligence for defence and security organizations? What are the current and emerging trends of research and application in these areas?

2- How do they relate (in brief, based on market research) to similar products developed for other disciplines (e.g., business intelligence)?

3- Who are the major and active players in academia, industry and government R&D worldwide? Who is doing what?

4- Which of the military or public security intelligence technologies have reached maturity, i.e., which have been commercialized?

5- Which barriers and drivers to adoption are suggested by the findings of the scientific and market research literature review?

5 Overview of Review and Market Literature

5.1 Business and Military Intelligence Analytical Functionality

It is frequently the case that technologies developed by the military migrate to commercial markets. In the case of intelligence analytics, however, the opposite pattern has often been observed: intelligence technologies developed first by business have been adopted, adapted and refined by the military.

This migration has been assisted by large vendors such as IBM, SAP, and Oracle, who frequently serve both markets, as well as by technology transfer programs sponsored by governments. In the latter category, in the United States, funding from agencies such as the Defense Advanced Research Projects Agency (DARPA), the Intelligence Advanced Research Projects Agency (IARPA), the Small Business Innovation Research Program, and In-Q-Tel (a venture capital firm sponsored by the Central Intelligence Agency) have all jump-started private sector innovation related to the needs of intelligence analysis.

The functionality offered by business intelligence platforms addresses problems common to both domains, such as how to manage large and varied amounts of available data and how to exploit it for purposes of performance analysis and strategic planning. The table below lists functionality advertised in product literature from some of the major business intelligence vendors (IBM Cognos, SAP, SAS), but which also applies to any domain, including defence and security intelligence, that is knowledge centric. In many cases, vendors who offer business intelligence products also provide a defence and security edition of their basic toolkit.

Table 1: Common Features of Business Intelligence Solutions

Typical Functionality: Business Intelligence Solutions
Data Warehousing (Collection & Management)
Data integration (from legacy sources or of multisourced data, via fusion, middleware, web services)
Exploitation of unstructured data (such as email messages or voice recordings) as well as structured
Metadata application & exploitation (including domain based ontologies) to enable search and analysis
System integration with enterprise tools
Single portal access to distributed data, and for distributed users (using techniques and methods such as service oriented architecture, cloud computing)
Sophisticated query tools (such as those supporting natural language processing, guided or faceted search)
Analytical tools (such as multidimensional online analytical processing or OLAP)
Generation of forecasting and alerts (predictive analytics based on rules or on intelligent, dynamic algorithms)
Visualization & guided analysis (including analytic dashboards, scorecards, or key performance indicators, and performance analyses)
Web and desktop reporting
Collaboration tools
Security & access management (role based access using secure networks)
Support for mobility (such as applications for smartphones)

5.2 Trends in Business Intelligence

To identify current trends in business intelligence (BI) offerings – and to create a list of topic areas that might also apply military intelligence functionality -- we consulted a number of market literature reports and recent review articles. These are listed in the bibliography (Appendix 12.2) which accompanies this report.

One such review, published by Hewlett Packard in 2010, provides a “top trends” list that is largely echoed in other publications and opinion polls. In the review, the top trends are identified as follows:[1]

- Increased data governance (regulations, standards, information assurance policies)
- Enterprise wide data integration
- Promise of semantic technologies (to reconcile and normalize meaning across varied data types and sources)
- Expanding use of advanced analytics
- Narrowing of the gap between operations & warehousing: BI is now better integrated into decision making (i.e., less stand-alone BI)
- Growing impact of complex event processing (complex link and pattern analysis)
- Growing importance of all-source integration and more use of unstructured data

- Integration of social computing (exploitation of dynamic conversations, increased collaboration on the part of users and the customer base)
- Growing interest in cloud computing
- Other miscellaneous trends: real-time BI, predictive analytics, mid-market emergence, visualization, mobile users & applications, end user empowerment, open source (do it yourself BI) solutions. [2]

5.3 Business Intelligence: Prominent Players

According to the market literature, the global business intelligence vendor landscape is dominated by a few large vendors, including IBM Cognos, SAP BusinessObjects, Oracle Hyperion, SAS, and Microsoft. The Business Intelligence archive at IT World Canada also suggests that these companies dominate in Canada, although our study did not uncover any market literature that reported separately on the Canadian situation. It is worth noting, however, that most of IBM's BI functionality rests on software developed by the Canadian firm Cognos (acquired by IBM in 2007). Many of the BI contracts awarded to Canadian government agencies, as listed in the MERX database, have been awarded to IBM Cognos.

Several smaller niche companies, such as Tibco Spotfire, Qlikview, Actuate, Denodo Technologies, and others also offer BI and data integration solutions. Many products from vendors large and small have also been adapted for the public sector. According to the Spotfire company website, for instance, their software is used by over 65 U.S. government agencies for functions such as intelligence, communications, incident tracking, logistics, risk management, sharing and collaboration.

5.4 Military Intelligence Overview: Key Technologies, Trends, Players

For this brief overview of military intelligence products, players, drivers and challenges, we consulted sources and documents as listed in Appendices 12.1.3 and 12.2.1.

Most of the data retrieved describes U.S. policies and practice; very little information was found to be publicly available for Canada and its coalition partners. Indeed, the availability of authoritative public (unclassified) information from all sources on this sensitive topic was found to be a significant constraint to analysis for this project, a sentiment that is echoed by Frost and Sullivan in its analyses: "A substantial amount of the total market information and the vast majority in the intelligence segment is not accessible because of security classifications."[3] General trend analyses can be derived from our results, but detailed discussions of technical solutions and specific roadmaps that outline a technology strategy were found to be virtually non-existent.

5.4.1 Military vs. Business Intelligence: Where Do Differences Exist?

The product, patent and scientific literature on military intelligence/analytics software, as well as guidelines published by U.S. fusion centres, and solicitations from DARPA, IARPA and others, suggest that differences between the defence and business communities – and therefore differences in product functionality -- relate to file type, scale, security, currency, and regulatory requirements. These may be summarized as follows:

- Context: more related to tactical (battlespace) and logistical operations as well as threat forecasts (e.g., counter-terrorism) than to business (performance) problems
- Network, data and user security requirements are greater and more complex
- Greater interoperability and sharing requirements related to inter-agency and international joint operations
- Greater use of geographic (spatial), temporal, and sensor data
- More numerous and varied sources and file types that require management and integration: video, image, audio, open source, ELINT, MASINT, HUMINT, etc.
- Greater need for data hygiene and management of (quality) issues related to uncertainty and error, e.g., related to fused sensor data
- Greater need for temporal analyses & streamed data, real time reports
- Greater potential complexity: event & entity relationship discovery and analysis, anomaly detection
- Larger scale and wider distribution of data and operations
- Large and distributed number of different legacy systems that need to be integrated
- Multiple language requirements
- More regulations, standards, and governance requirements

5.4.2 Key Existing Technologies and Systems

For military and security intelligence tools, *many* enabling technologies and military systems are implicated, end to end. The literature repeatedly notes that stovepiped systems persist, although efforts have been underway for at least a decade to integrate and expand access to data and applications.

One web source classifies existing US military intelligence technologies as follows:[4]

- **Core:** architectures, interoperability/semantics, operating systems
- **Tasking**: collection management, interface technologies
- **Collection**: methods to collect and integrate different INT types, disciplines, communities
- **Processing**: conversion and correlation (exploitation/analysis) technologies
- **Dissemination**: networks, protocols, servers, access controls

A well-documented example of a complex, integrated, end-to-end system developed by the U.S. military (with the participation of many commercial players, including Raytheon, Lockheed Martin, and Northrop Grumann) is provided by the Distributed Common Ground System (DCGS), which fuses sensor data from multiple sources and offers a net-enabled capability for situational awareness and analysis. Although development of the DCGS began in 1998, its implementation is not yet complete: the US Air Force and Navy expect to have functional versions running by the end of fiscal years 2010 and 2013 respectively, while the Army's version will be delayed until 2016, and the Marines have not yet announced a completion date.[5] The latest edition (2009) of the *DCGS Commander's Handbook,* available at http://info.publicintelligence.net/commanders_handbook.pdf, provides a brief overview of components and functionality, and a recent article on the latest DCGS upgrade notes that the system is increasingly used to link intelligence data to tactical applications.[6] DoD has also developed an XML

schema to support information management for this and other defence analysis tools, as has the Defense Intelligence Agency.[7]

The U.S. Defense Department is also developing the Defense Intelligence Information Enterprise (D2IE), a unified ground processing, exploitation and dissemination architecture, which will allow users single sign-on and the ability to launch a single query against multiple databases.[8]

Another useful example of a full featured system is provided by the U.S. Department of Justice and its fusion center guidelines.[9] Seventy-two fusion centers (one for each state, plus 22 urban centers) have been created in recent years in order to promote better information sharing between law enforcement and some military and homeland security agencies, with an eye to preventing terrorist and other criminal activity. The fusion centers have made great strides in the development of standards for data description and exchange, as well as dissemination technologies.

Existing operational systems and infrastructure for the U.S. military are centrally provided by the Defense Information Systems Agency (DISA). Multinational information sharing of operational and intelligence data is currently enabled by the CENTRIXS system, incorporating the Combined Federated Battle Laboratories Network (CFBLNET). DISA's Global Information Grid provides the communications backbone and their Secure Mobile Environment for Portable Electronic Devices (SME-PED) , enabling usage of cellular phones and laptop computers, is also a critical tool for responsive C4ISR.

5.5 Drivers and Challenges for Intelligence Analytics

The overview documents (see Appendix 12.2) consulted for our search identified the following drivers and challenges to the development and adoption of intelligence analytics products -- some, such as the proliferation of information sources and types, constitute both a driver *and* a challenge.

5.5.1 Drivers

- Continuing deployments, and anti-terror campaigns, that rely heavily on intelligence data and analysis; OSINT and HUMINT are particularly important in this regard
- Proliferation of data of all types, especially as collected during campaigns in Afghanistan and Iraq
- Increased use of (sensor) data streams from unmanned systems, from soldier systems (uniforms and weapons). According to Frost and Sullivan, the use of such streamed data is forecast to increase exponentially by 2030.[10]
- Need to integrate and share data and applications -- not just as a means of saving money, but for strategic advantage
- Availability and acceptance of social media as a means to support collaborative efforts[11]
- Increased counter-terrorism efforts worldwide
- Proliferation of threats e.g., weapons of mass destruction and asymmetric threats
- Increased coalition campaigns (and therefore, a pressing need for interoperability)

5.5.2 Challenges

- The "widening spectrum of threat and challenges" posed by conventional and asymmetric warfare[12]
- Stovepiped assets and platforms (silos), accompanied by cultural and technical issues regarding sharing between agencies and branches[13]

- Proportion of data still housed in (untagged) legacy systems[14]
- Lack of policy and guidance regarding information sharing[15]
- Entrenched competition on the part of large firms[16]
- Regulations limiting foreign (non U.S.) providers, privacy[17]
- Technical and governance issues regarding data quality
- Proliferation of all types of data
- Bandwidth requirements for transmission of increasing amounts of (high resolution) data over network channels[18]
- Too much data, not enough analysts & cataloguers
- Need to automate tagging/classification and to find algorithms to identify patterns, trends, and threats, thus freeing up precious analyst time
- Need to improve methods of sharing and disseminating data (not just collection)
- Inadequate human intelligence, and difficulties of integrating HUMINT with other types of intelligence[19]
- Lack of user-friendly formats
- Need to balance the needs of security and information sharing (especially in multi-security level databases)[20]
- Comprehension and (automatic) concept extraction in multilingual environments; a lack of analysts with the necessary linguistic skills[21]
- Lack of interoperability for models and algorithms across diverse domains[22]

5.5.3 Emerging Military Intelligence Technologies: Trends and Forecasts

Technologies under development in the area of military or security intelligence are experiencing healthy growth and active interest. Frost and Sullivan has noted, for instance, that of all C4ISR segments, Intel has the largest budget/contract growth rate: a compound annual growth rate of 6.9% is forecast through 2015. This is likely due to the continued emphasis on counter-insurgency and anti-terrorism operations.[23]

To identify trends and developments in the field, we began by consulting general publications and review articles retrieved by our Internet/literature search. These documents, coupled with strategic goals and solicitations literature from IARPA, DARPA, and others inform this summary of emerging trends, and in our Vantage Point analyses of intelligence literature and patents, presented below, we will also assess the status of these trends in the data gathered for analysis. In some cases, trends and goals cited in the overview documents do not yet comprise a strong thread in the R&D literature, but given the timelines typical of research and publication --- and the suppression of some data due to its security classification ---- this should not discount the general validity of these topics as emergent themes.

The organization of IARPA research thrusts and their recent solicitations are typical of developments observed in the literature collectively. Agencies like IARPA are moving on from early stage efforts at data fusion and mining to second generation technologies for analysis and dissemination. Their current research goals and solicitation suggest where the intelligence community is headed – in other words, areas for mid to long term direction. In IARPA's mandate, this forward-looking perspective translates into three categories:

Smart collection: tools that improve the value and quality of the data collected (novel sources, sensor technologies with improved range/sensitivity/power, improved means to gauge trust and veracity of the data collected).

Incisive analysis: technologies that can handle large volumes of multisource information, use of virtual worlds, shared workspaces for greater insight and productivity, analysis of social/cultural/linguistic data, analysis of non-technical data, models of visual perception and cognition, predictive analytics for multiple domains, faster and/or

automated scanning technologies, meta or aggregated analyses, visual analytics, improved data models and algorithms for analysis.

Safe and secure operations: addressing data and communications security through novel means such as quantum cryptography or optical transmission systems; exploration of data exchange scenarios or data processing methods such as outsourced storage, publish/subscribe models.

Other perceived emergent areas (not in priority order since they are derived from multiple sources) include:

- **Increased use of commercial off the shelf (COTS) technologies/data (or COTS/GOTS combinations** from trusted firms, and an emphasis on **open architectures.** This includes increased use of commercial (satellite, geospatial) imagery, used both for military operations and for crisis response.[24] The Distributed Common Ground System and US DoD Global Information Grid/Command and Control System are but two examples of C4ISR architectures built largely on COTS solutions

- A move from platform-and-source-specific technologies to **multi-use technologies and applications**.[25]

- **More and better integration of data from disparate sources**. Multi-purpose fusion technologies are especially desirable, according to Frost and Sullivan. The U.S. Defense Intelligence Agency highlights multisource and multidomain data integration and exploitation ("all source analysis") as a priority in their information technology strategic plan,[26] and IARPA's Knowledge Discovery and Dissemination Program sets out similar goals (the participants listed on their website for the KDD proposers day provides an interesting portrait of academic and commercial activity in support of KDD activities). IARPA's Blackbook technology – a semantically based multisource visual analysis platform -- is an example of a full-featured tool under development. In a similar vein, a 2010 U.S. Air Force pre-solicitation, entitled Reasoning, Comprehension, Perception, and Anticipation in Multi-Domain Environments, addresses tools (such as automated knowledge extraction, reasoning and link analysis) that enable integration, exploitation and analysis in dynamic, multi-source, and multi-domain environments.

- **Collaborative enterprise**: horizontal integration of data is a recurrent theme in DIA's latest *Information Technology Strategic Plan*. [27]

- **Modernization of existing integration technologies**, enabling more capacity with large volumes of data, multi-type and multidimensional data, launching of queries against disparate databases, consolidation on a single desktop, and common database architectures. See, for example, the U.S. Air Force Research Laboratory's July 2010 solicitation on modernization of the Defense Intelligence Modernized Integrated Database Enterprise (currently based on COTS and GOTS software components).

- Movement from the traditionally strong INTEL focus on sensors to consideration of other data types --- but **sensor data will remain important** and will also increase in volume, as sensing technology improves and finds wider application. Sensor data gathered with autonomous vehicles will also increase.[28]

- **More streamed (live) data**: for instance, Lockheed Martin's Airborne Multi-INT Laboratory feeds real time intelligence data (video, imagery and communications) into the U.S. Army's Distributed Common Ground System.[29] Frost and Sullivan predicts robust live/streamed collection and analysis by 2025.[30]

- Development of increased **visual intelligence and visual source analytics**. One example of this is the DARPA Mind's Eye program, which will develop smart cameras (combining artificial intelligence and machine vision and the ability to detect and report) for intelligence gathering using unmanned

vehicles.[31] Other examples of visual analytics development include DARPA's Video and Image and Retrieval Analysis Tool (VIRAT) and its Persistent Stare Exploitation and Analysis System (PERSEAS) – the latter is scheduled for integration into the Distributed Common Ground System.[32] In a similar vein, IARPA's ALADDIN Program seeks to improve video extraction and search technologies for analytic purposes.

- **Increased bandwidth** to support transmission of large amounts of data, much of it characterized by high resolutions. Between July of 2009 and October of 2010, for instance, bandwidth on channels used by American forces in Afghanistan increased from just over 1,000 megabits per second (Mbps) to 8,000 Mbps.[33]

- **A need for speed and portability:** not only do intelligence analysts need good information, they need it quickly. Program's such as DARPA's MEDEX (Digital Media Exploitation) will develop fast algorithms suitable for the exploitation of digital multimedia (such as those found on computers captured in the field) in tactical situations where computational resources are at a premium.[34]

- More **open source data**, for example the use of open source data to examine social networks. Increased availability and awareness of open source intelligence is mentioned as a priority in the U.S. Defense Intelligence Agency's current strategic plan. A current U.S. Air Force solicitation, entitled *Revolutionary Intelligence and Influence Technologies*, calls for proposals on technologies to identify and understand threat networks using open source data (it is part of a larger project entitled Human Systems Technologies for Future Air Force Challenges). In this instance, English language named entity recognition software and machine translation packages will be adapted for other languages. In another initiative, the U.S. Air Force's National Air and Space Intelligence Center (Wright-Patterson Air Force base, Ohio), is creating an Open Source Research Center to offer training on the exploitation of OSINT sources, and the U.S. government's Open Source Center offers myriad sources that can be exploited by authorized users. The European Commission's Institute for the Protection and Security of the Citizen (Joint Research Centre) has also experimented with a desktop tool for the mining of open source data in law enforcement.[35]

- Use of **social media** such as wikis as a means of intelligence information and collaboration.[36]

- Exploitation of various data types (sensors, OSINT, etc.) for **social network analysis,** especially in law enforcement.[37]

- Novel methods such as the use of game theory and collaborative semantic wikis for **predictive analytics** in intelligence and security.[38]Predictive analytics is also a hot topic for business intelligence tools (see IBM/SPSS or SAS), and Pacific Northwest National Laboratory is leading a government initiative in this area.

- More emphasis on data-driven, machine to machine (**automated, intelligent) collection and analyses**. According to a recent article in the *C4ISR Journal*, the U.S. Department of Defense ISR Task Force is seeking technology that will automate data mining and extraction, in order to maximize analysts' time.[39] Automated imagery analysis is one technology of particular interest, per recent DARPA projects.[40] In another recent solicitation, the U.S. Air Force has called for development of technologies and enabling architectures to support automation of the collection of multi-source data from many platforms, accompanied by automated processing for assessment, cueing, and damage assessment. Funding for the project will be $24.5 million through 2012.[41] The project is entitled Synchronized Net-Enabled Multi-INT Exploitation. Technology to automate data mining and extraction is also a priority for the U.S. DoD ISR Task Force.[42]

- More emphasis on the integration of **cultural/language applications & expertise**. Linguistic abilities are identified as a gap in DIA's annual report, and initiatives such as IARPA's Babel program (to build speech recognition technology for a much wider range of languages than is currently supported) will build capacity in this area.

- **Cloud computing**: provision of cloud computing is cited as an opportunity for private firms by Frost and Sullivan in their 2009 report on U.S. DoD C4ISR services.[43] There is also some evidence that U.S. intelligence and defense agencies are pursuing this model. The Defense Information Systems Agency manages an internal (DoD) cloud environment called the Rapid Access Computing Environment (RACE; developed by Hewlett-Packard), for instance,[44] and the U.S. National Security Agency (NSA) has published a guidance document on information assurance in the cloud.[45] The NSA's own largely COTS-based cloud system began testing in 2009.[46] The NSA, the National Geospatial Intelligence Agency and the CIA have all publicly announced their intention of pursuing the cloud option[47] and a list of top cloud providers to government (including General Dynamics and Montreal's CGI Group) was published in a 2010 issue of Information Week. In other notes, in December 2010, the U.S. Army Communications and Electronics Command (CECOM) announced a $24.8 million contract with Data Tactics of Arlington, Virginia, for provision of cloud computing capability for intelligence and analysis.[48] Cloud computing for streamed video and images and HUMINT is also available through Raytheon's Green Thunder intelligence system (part of the Distributed Common Ground System), which is aimed at combat teams.[49]

- **Service oriented architectures**: as early as 2005, the Armed Forces Communications and Electronics Association (AFCEA) called for adoption of service-oriented architecture as a means of improving intelligence integration, analysis and dissemination.[50] Frost and Sullivan predicts that SOA will be an intelligence commonplace by 2030 and Florida-based firm Modus Operandi already has engineered SOA for intelligence as part of the Distributed Common Ground System.[51] SOA is also mentioned as part of the Defense Intelligence Agency's strategic IT plan, and a 2010 paper from the People's Liberation Army University of Science and Technology (China) also discusses SOA in an intelligence context. DRDC has also explored SOA as a means of addressing integration issues encountered in the Arctic.[52]

- **Multi-level, multi-party access (and security controls)** for a varied user community[53]

- **Mobility solutions**: The Defense Information Systems Agency is already supporting portable electronic devices for intelligence collection and interpretation, and Raytheon's One Force Tracker (an iPhone application that tracks red/blue forces on real time maps) was announced in late 2009.[54]

- **Fusion centres** (public security/military) and **international interoperability.** A recent policy document from the FBI describes the continuing need for standards, protocols, and cross-domain solutions that provide multi-level browsing capability while preserving security.[55] While fusion centres are obviously more common in law enforcement than for military intelligence, the Distributed Common Ground System is a move in this direction, and a recent document from the U.S. National Reconnaissance Office also calls for fused data centers that resemble the commercial IT model, and that could "provide extraordinary opportunity for the integration of mission data and applications, effective tipping and cueing, multi-INT data fusion, and hardware and software cost savings by capitalizing on mission commonality."[56]

- Increased requirements for **interoperability based on standards, XML and other metadata**.[57]

- Emphasis is turning increasingly towards **dissemination and collaboration technologies**. In an October 2010 briefing, for instance, the Marine Corps director of intelligence called for DOD's ISR Task

Force to reduce the urge to increase collection and "…to stop fielding what he calls 'stuff' and not overlook the need for processing, exploitation and dissemination tools" such as smart algorithms that can cut through large amounts of data and free up analysts' time."[58]This sentiment is echoed in a report from *C4ISR Journal*, which notes that while US$7 billion has been spent in recent years on sensors, collection systems and communications architectures, "very little has been spent on getting data down to the operational level" through improved methods of sharing and dissemination.[59]

5.5.4 Military Intelligence Technologies: Key Contractors

A table listing selected companies with technologies (products and service) in the areas of intelligence analytics appears in Appendix 12.4 to this report. Sources for the table include In-Q-Tel, corporate websites, solicitations and contract information for defense intelligence agencies. Many of the same companies in the table also appear in the patent literature explored later in this report.

The top ten intelligence contractors had 89.7% of U.S. market share, according to recent Frost & Sullivan reports on C4ISR goods and services markets.[60] For 2009, these top ten companies were:

- General Dynamics
- Lockheed Martin (broadest range of C4ISR products and services, per F&S)
- General Atomics
- Northrop Grumann (largest number of C4ISR contracts in 2009, per F&S)
- Honeywell
- Boeing
- BAH (now owned by the Carlyle Group)
- L-3 Communications
- Raytheon
- SAIC

Frost & Sullivan also note that, to date, the thrust for these contractors has been systems integration, procurement, and operations services.[61]

Our search was unable to find a separate market analysis for Canadian companies producing business or military intelligence products and services. A search of MERX (Canadian public tenders), Canadian Company Capabilities, and commercial literature indicates the presence of all of the major global C4ISR firms as listed above. Many of these large companies also maintain Canadian offices. Canadian presence and/or capabilities are indicated by blue highlighting in the table published in Appendix 12.3, however. Once DRDC has identified particular capabilities needed for future contracting, we suggest that additional focused searches be undertaken to identify Canadian capacity – niche or otherwise – in the areas of interest.

6 LITERATURE & PATENT ANALYSES

6.1 Methodology

To identify trends, correlations and players in answer to the key questions of the mandate, we conducted searches in scholarly and scientific literature as well as patents.

For the literature search, articles and conference proceedings were sourced from:

- SCOPUS: a multidisciplinary database; searches were limited to the physical sciences (including computer science)
- INSPEC and EI COMPENDEX: engineering databases, including electrical engineering
- NTIS (National Technical Information Service;): a database of publicly funded research
- NATO Research and Technology Organisation Publications database

For patents, we used the Questel Orbit database, which includes patent grants and applications for all major European, North American, and Asian patenting authorities.

It is important to note, however, that protection of most software is not provided by the instrument of patents, but by copyright. Unfortunately, copyright databases do not provide the same level of detail as is published in patent documents. Since many aspects of intelligence analysis are provided through software functionality, this must be considered a limitation for this project.

Keywords and other details of search strategy for both patents and the literature search are included in Appendix 12.1 to this report.

Data from both the literature search and patents were loaded into VantagePoint software for data mining and analysis.

6.2 Literature: Points of Analysis

For articles retrieved as part of the literature search, we examined velocity of publication for the entire dataset, as well as for topical subsets. Subject terms and groupings of those terms were also used to identify correlations and other relationships between topics in the literature. In addition, we used top affiliations (organizations) crossed with subjects in order to identify known expertise and research strengths.

Subject terms in the data -- both controlled vocabularies and uncontrolled terms -- were merged and cleaned, resulting in a list of 19,767 terms.

Sixty-five meaningful groups were created from these terms. These groups were determined using volume rankings within the list of terms, as well as emerging trends suggested by the review of market literature and summary articles.

It is important to note that not all groups are equal in size. The largest, *Military operations*, was attached to 1995 articles, while the smallest group, *Languages and translation*, had only 28 hits. Furthermore, not all terms were included in the 65 groups. The groups provide 98% coverage of the content in the literature dataset, however.

In cases where terms, not groups, were used for analysis, data were drawn from the top two hundred fifty terms.

6.3 Velocity of Publication: Literature

Velocity of publication is indicative of rising, falling, or sustained interest in a topic on the part of researchers. It can also be used to suggest the relative maturity of a topic, or emergent themes.

The overall velocity of publication for scientific and technical literature is shown below in Figure 1. For this graphic, we excluded articles with a publication date of 2010, since data for 2010 were incomplete at the time of our search.

The graphic portrays a pattern of steady growth. While collectively the topics covered appear to be relatively mature (the trajectory shows a modified S-curve, ascending, then leveling off in step-wise fashion), growth is still apparent: no final plateau or descent has been reached.

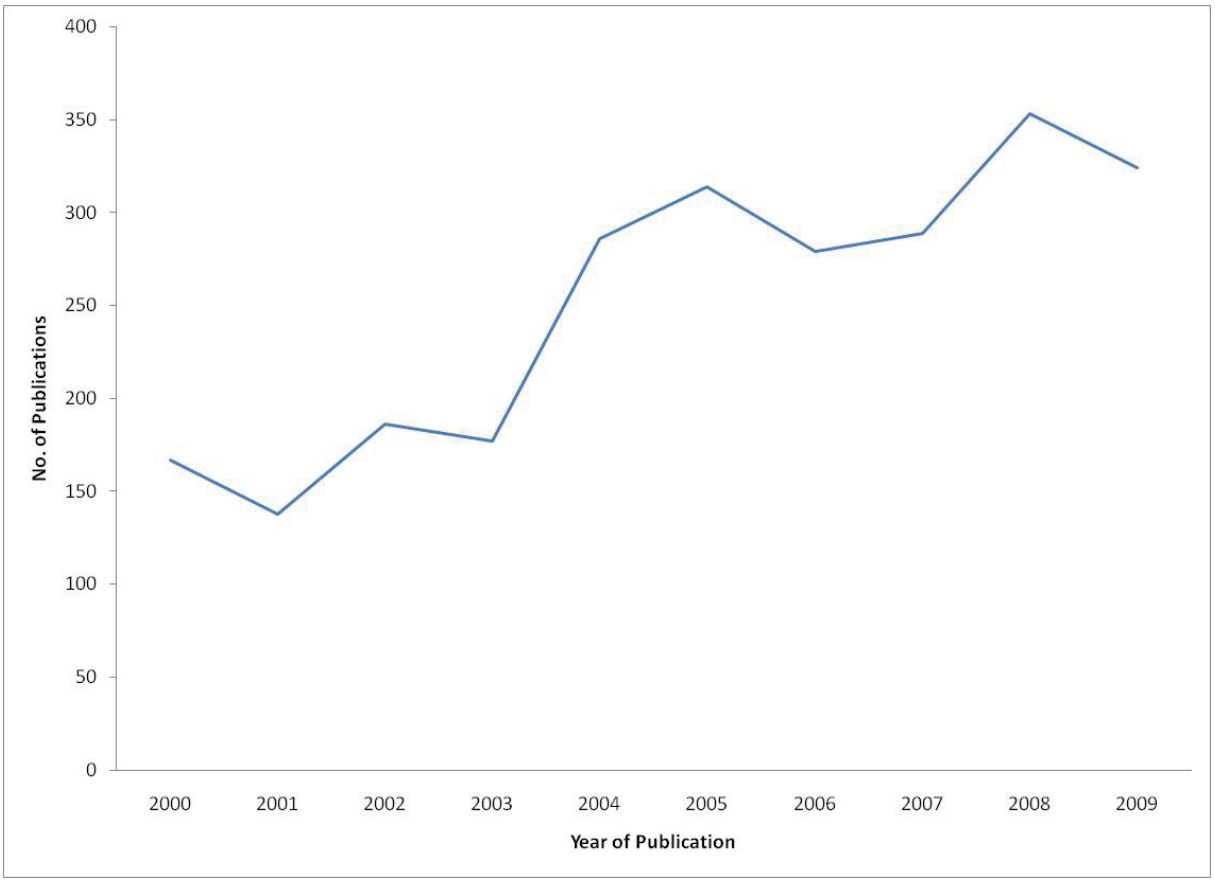


Figure 1: Literature: Velocity of Publication

We also plotted the velocity of publication for each of the sixty-five subject groups in the literature dataset, to identify trends and anomalies for sub-topics. For the sixty-five groups, thirty showed a rising velocity:

- Analysis and analysts
- Air force/aviation
- Architectures
- Communications
- Case studies
- Collaboration
- Decision making
- Data fusion
- Data collection/warehousing
- Data mining/NLP
- Human intelligence
- Information (knowledge) management
- Information dissemination/sharing
- Integration/Legacy systems
- Law enforcement/policing
- Marine and naval
- Measurement
- Logistics
- Networks
- Mobile devices
- Quality
- Planning
- Problem solving
- Situational awareness
- Risk management
- Surveillance & reconnaissance
- Terrorism
- Uncertainty
- Visualization & displays
- Virtualization

The rising velocity for these labels indicates continuing research interest in underlying data management topics (architectures, integration, quality, warehousing), as well as practical applications (situational awareness, problem solving, data sharing, collaboration), techniques and new technologies (data fusion, mobile technology, visualization, virtualization).

In the illustrations below, velocities are shown for selected groups: those with highest volumes and/or the most dramatic increases. These curves indicate subject areas of relatively higher interest, where researchers are concentrating their activity.

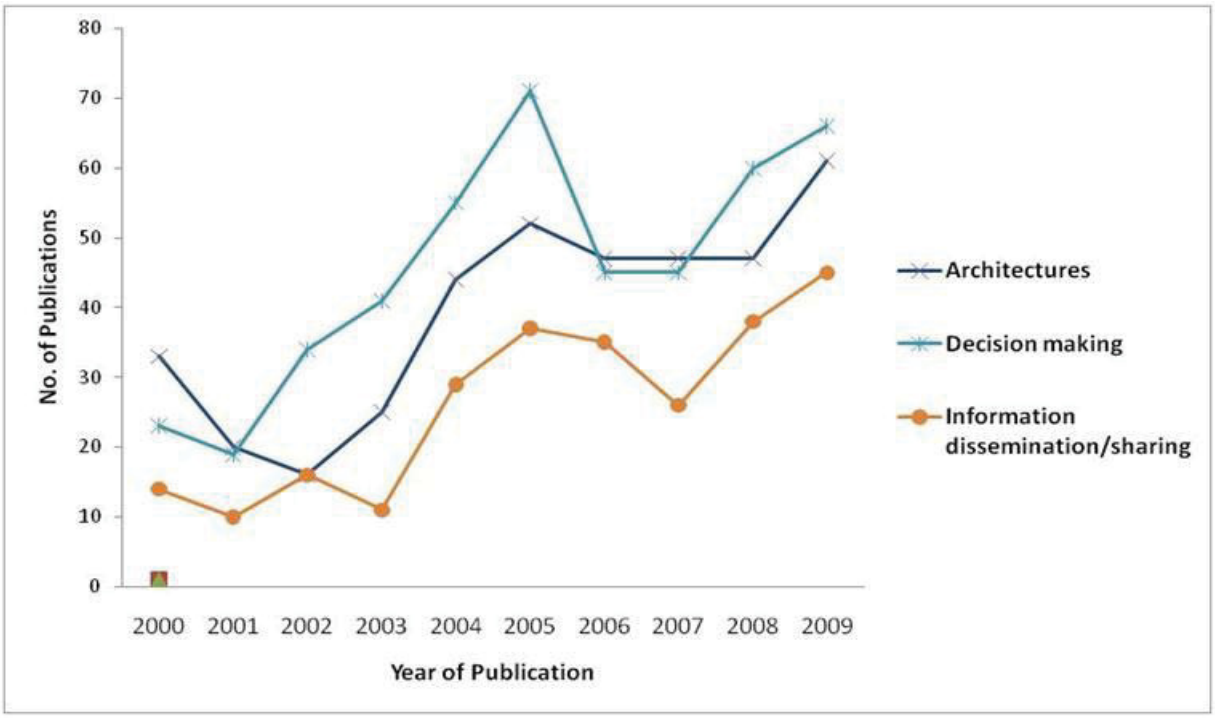


Figure 2: Literature: Rising Velocity, Group 1

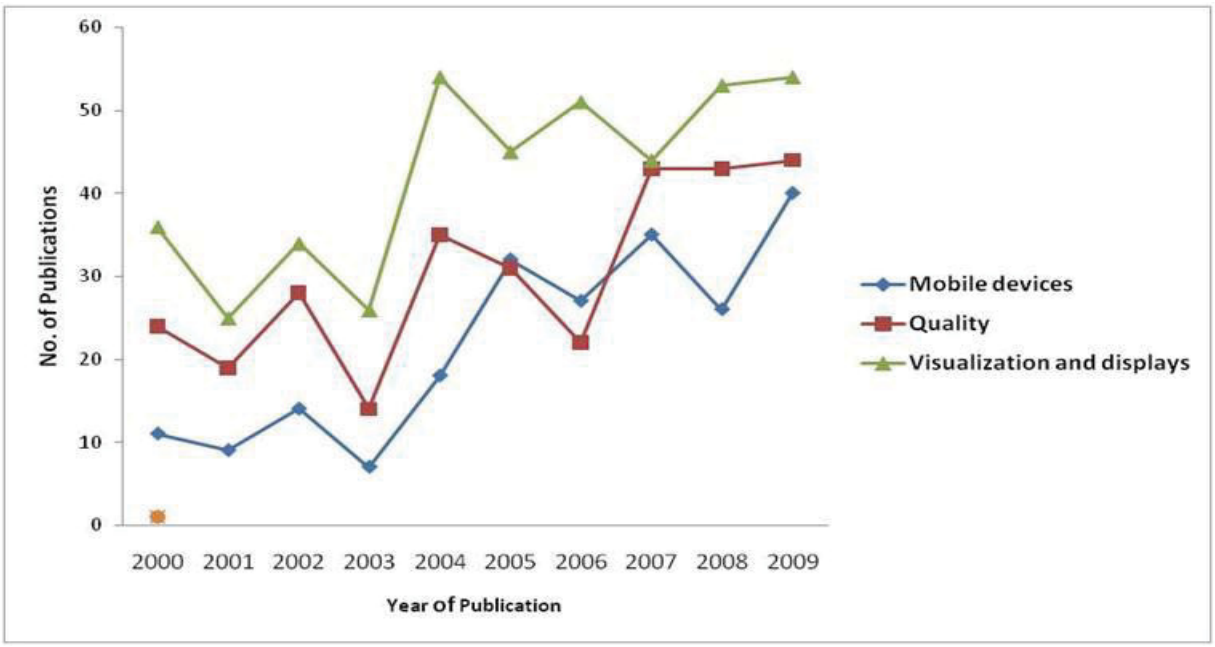


Figure 3[1]: Literature: Rising Velocity, Selected Groups

[1] *Quality* refers to various issues related to quality: data, image, quality of service, and so on.

Two groups within the data show trendlines which may be considered indeterminate or problematic. *Learning systems and AI*, for instance, includes articles that describe methods using genetic or evolutionary algorithms or other artificial intelligence tools to process intelligence data. After demonstrating strong growth in the period from 2000 to 2008, the trendline takes a sudden downturn. This may simply be indicative of a "natural" ebb and flow of interest that is typical of emergent trajectories: initial bursts of activity are often followed by a slackening in pace. Since no other competing technology appears to have replaced or overtaken artificial intelligence techniques, once could assume that this downward direction is not a major concern.

The other indeterminate group, *Collaboration*, demonstrates mixed performance, with a slight increase in the most recent period, but the smaller size of the underlying data makes it difficult to draw definite conclusions.

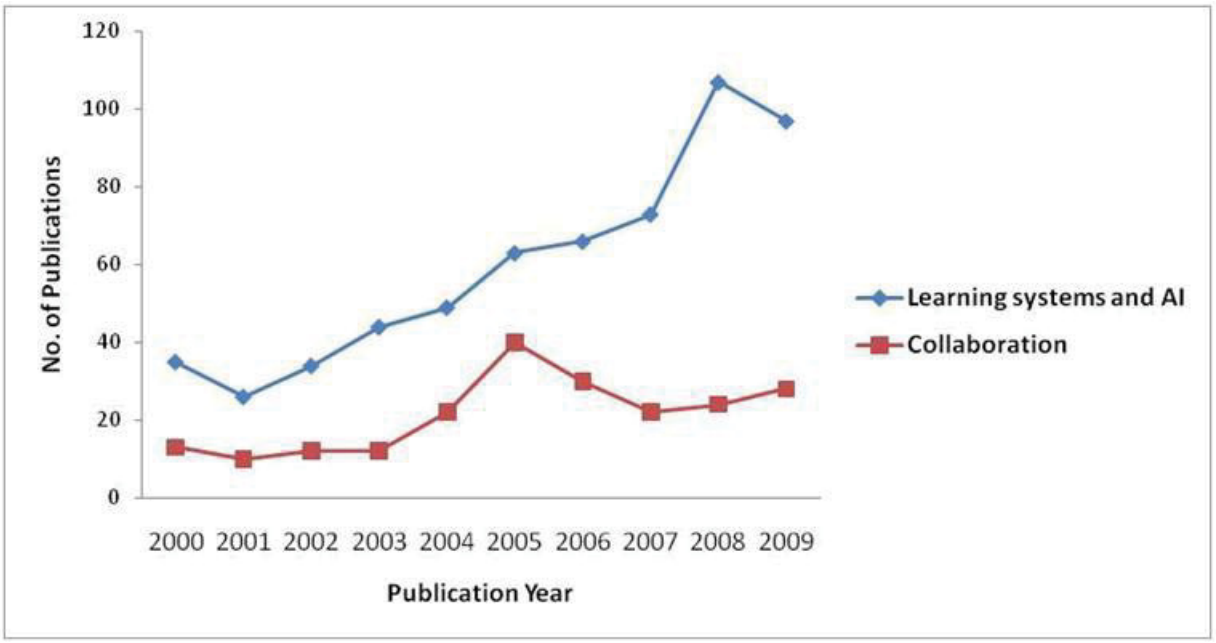


Figure 4: FIAC Literature: Topical Groups with Indeterminate Velocity of Publication

6.4 Mapping Patterns and Relationships Within the Literature

To examine patterns and relationships within the literature, we created maps of co-occurrences (correlations) between groups and terms, as well as lists of the most frequent occurrences.

In Figure 5, we present a map of groups within the FIAC literature, showing the most significant (greater than 15%) co-occurrences between the topical areas. Items with no significant correlation have been excluded from this map, for purposes of greater clarity.

The larger the node or bubble in the map, the greater the number of underlying publications. Heavier lines between the nodes indicate relatively higher correlations. Node size and connector weight are relative values, however, and are not tied to absolute numbers or ranges of numbers.

The map presents a birds' eye view of the entire dataset, from which one can make some very general conclusions.

For instance, the largest node, *Military operations*, is a group constructed on the basis of references to military applications or agencies. Unsurprisingly, the strongest correlations between this and other groups reflect a military context: interoperability and joint operations figure prominently, as do situational awareness, communications (and from thence, network architectures), and sensor data.

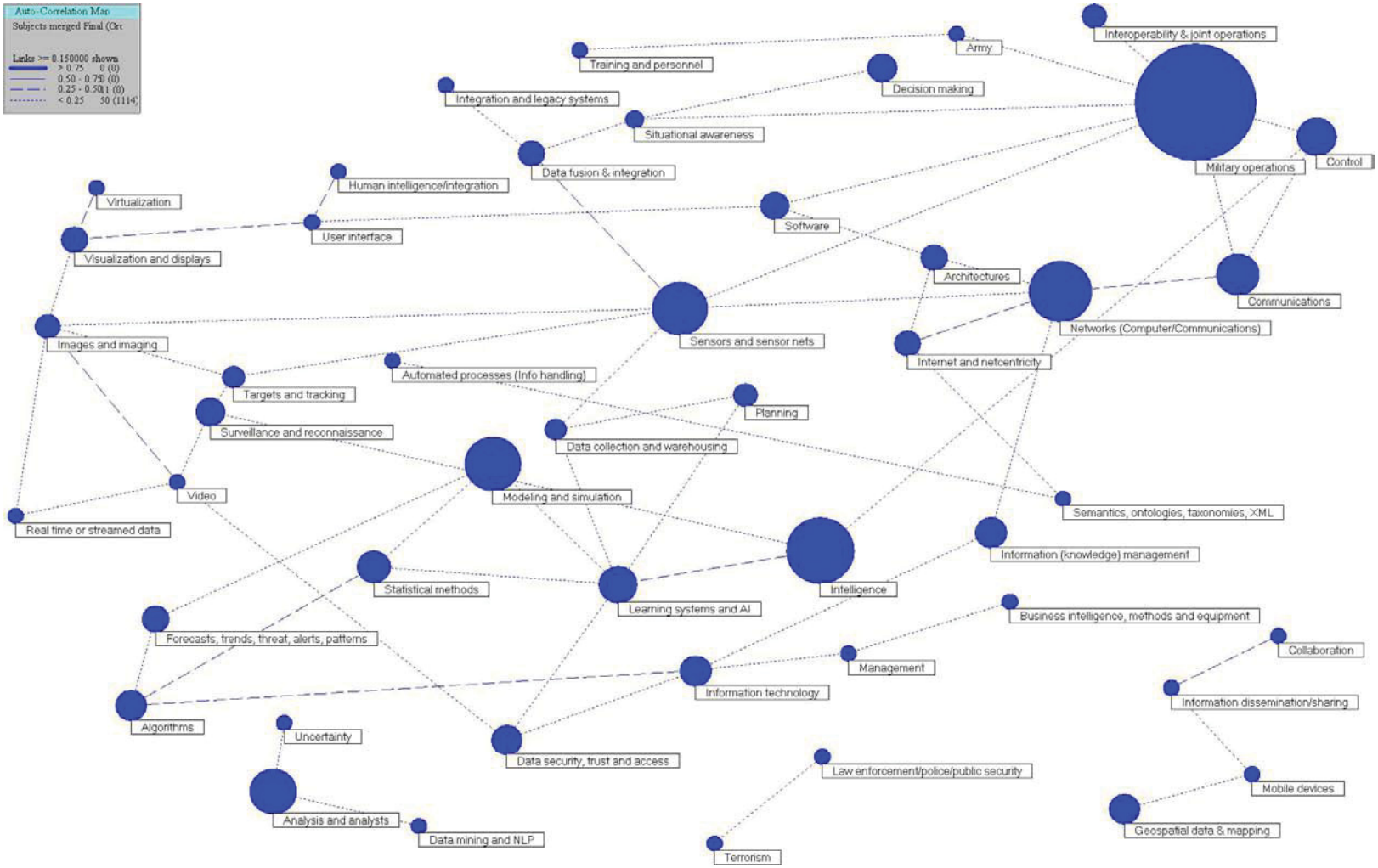
Sensors and sensor nets (mid-graphic) constitute a major thread in the literature, with strong correlations to data collection, images, fusion, and integration.

In another relationship of note, real time data, at left, correlates most highly with video/image data. Geospatial data is linked to mobile devices – and the latter also shows correlation with the information dissemination/sharing grouping.

Methods of sense-making are seen in the relationships between intelligence and learning systems (AI), statistical methods, algorithms (that is, algorithms that generate forecasts, trends, threat recognition, pattern analysis). Data mining/NLP, while linked to analysis and analysts, is not clearly linked to the algorithms/AI groupings. Semantic methods, however, correlate with automated processes for data processing and the extraction of meaning.

For the FIAC literature, terrorism (prevention and analytical tools) shows a correlation with law enforcement, policing and public security, with no substantial links to military operations.

Figure 5: Map of Co-occurrences, Literature: Groups



6.4.1 Ranking of Top Terms

A ranking of top terms (as opposed to groups of terms) within the data gives a slightly more granular view, but shows many of the same themes.

Sensors and sensor data, for instance, clearly have an important place in the literature, as do methods of sense making (artificial intelligence, modelling and simulation), applications (decision making, command and control, interoperability), and enabling technologies (netcentricity, data fusion).

Also of note is the absence from the top twenty of several key topics that were suggested in the initial literature review, topics such as dissemination and collaboration. In the ranked list of terms, the first reference to *information dissemination* is at 41st place (97 articles), for instance; *information sharing* is ranked 76thth place (68 articles), while *intelligence dissemination* is in 1439th place (only 4 articles). *Collaborative techniques* is ranked at 212th place (28 articles). These relatively low placements may indicate that techniques of collaboration and dissemination, while part of the strategic thrust of intelligence agencies, are not as advanced as early stage technologies such as data fusion and systems integration. In this case, supply may not have caught up to demand.

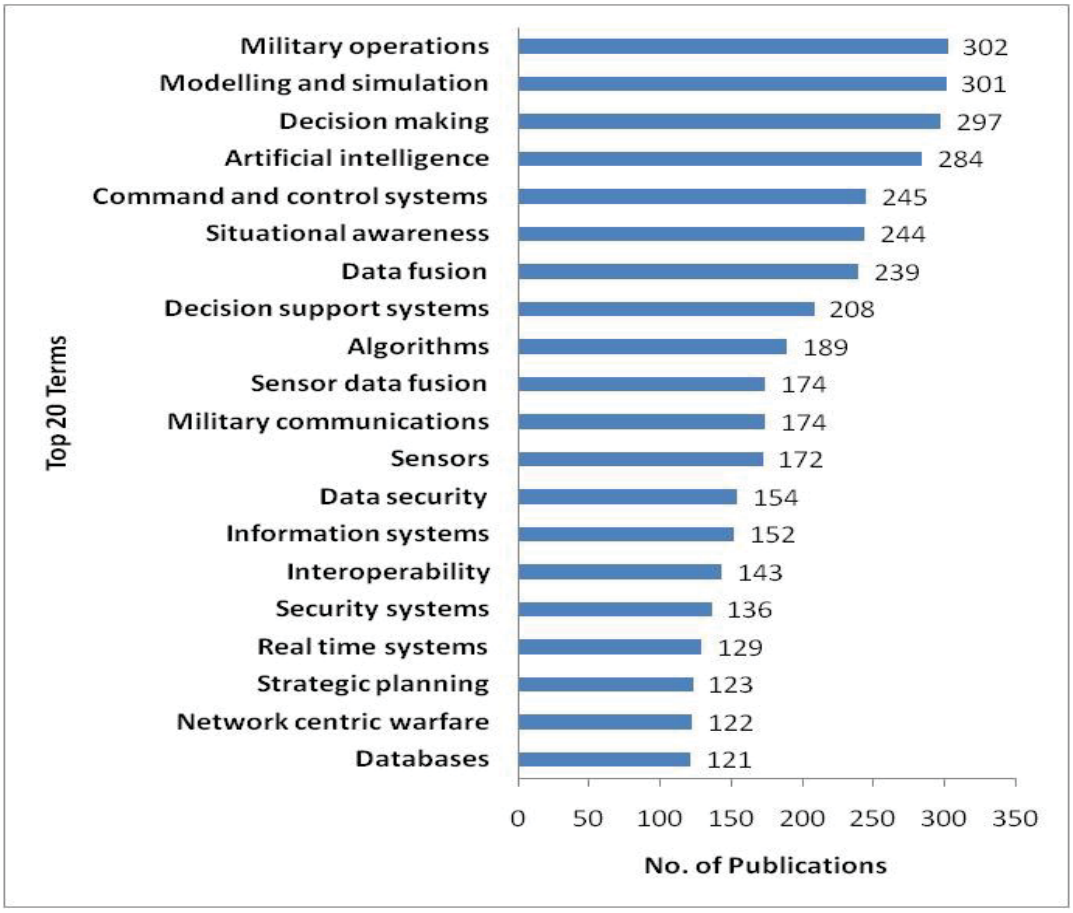


Figure 6: Literature: Top 20 Terms, 2000-2010

6.4.2 Correlations Between Top 250 Terms

In Figure 7, we see a map of correlations (values higher than 20 %) for the top 250 terms in the FIAC literature. Since the nodes in the map are for terms, not groups, it provides a slightly more detailed view of patterns within the data than Figure 5 (groups).

Items on the map are automatically clustered and coloured by the application (TouchGraph) according to semantic similarity. The number on the connecting line between nodes shows the correlation co-efficient.

Of particular note on this map is the prominence of *Service oriented architecture* (SOA), coloured orange at the top of the graphic. Although SOA is ranked at 126th place in the list of top 250 terms (44 articles), it has one of the highest correlation values on the map: in 48 instances, it is found in conjunction with *Information services*. SOA also links to *Network centric operations*, which is in turn linked to netcentric warfare, interoperability, etc. SOA is clearly seen, therefore, as a key technique underpinning information discovery and interoperability in a networked environment.

Also of interest in this graphic is the yellow cluster at right showing relations between video/image analysis topics, and with links to artificial intelligence, image processing, and algorithms. Indirect links occur from this yellow group to *Decision support* and *Decision theory* (pale orange), suggesting the role of image based data in decision making and planning.

Data fusion (purple, centre bottom) is related most frequently in the literature to *sensor* data fusion used for situational awareness.

Figure 7: Literature, Co-Occurrence Map, Top 250 Terms, 2000-2010

6.4.3 Chronological Differences in the Data (Top Terms and Correlations)

To ascertain shifts in trends in the data, we split results into two chronological slices, 2000-2004 and 2005-2010. Figure 8 shows rankings for the top 250 terms for the earlier period. In it, we see that the generic *Military operations* appears in a strong first place, while methods (*Modelling, Artificial Intelligence, Algorithms*) and applications (*Command and control, Battlefields, Planning*) occur lower in the ranking.

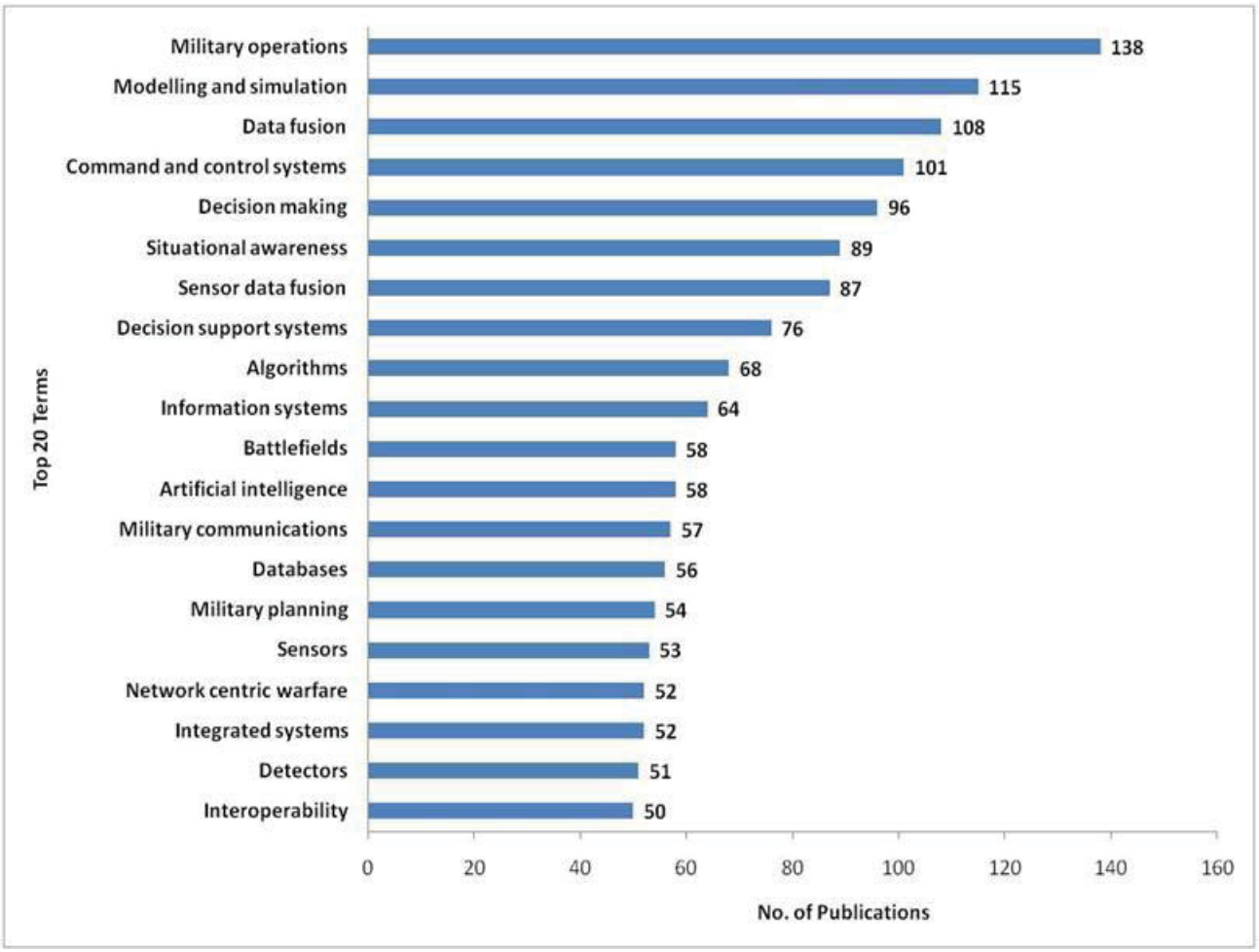


Figure 8: Literature: Top 20 Terms, 2000-2004

The TouchGraph correlation map for the top 250 terms, 2000-2004, demonstrated an unusually high number of co-occurrences between all terms, to the extent that we split the map into two views for greater legibility and ease of interpretation.

6.4.3.1 Early Period Maps

In Figure 9, we see correlations with values of 20-25 for the period 2000-2004; in Figure 10, labels with values of 26 or higher are shown, i.e., the "busiest" topics with the greatest number of sub-topical linkages.

In the first image (Figure 9), it is interesting to note the appearance of *Grid technologies* (linked to Information retrieval systems) and *Global information grid* at the top right. These terms, so prominent in the early data, slip in the rankings in later period, and in fact do not even figure in the map for 2005-2010 (Figure 10), since their correlation values dropped in the later period. *Network protocols* and *Data security* (Figure 9, top right*)* also experience the same fate (sliding rank, lower correlations) when early and late data are compared.

In the second graphic (Figure 10), correlations filtered to a value of 26 or higher show that *Data fusion* refers primarily to sensor data. Geospatial data are linked relates to information superiority.

Other topical areas with frequent correlations in the later data are security, cryptography, and access controls (light orange, top).

Figure 9: Literature, 2000-2004 : Correlation Map, Top 250 Terms, Part 1 (Values of 20-25%)

Figure 10: Literature, 2000-2004 : Correlation Map, Top 250 Terms, Part 2 (Values >25%)

6.4.3.2 Later Period List and Map

Shifting to views for the later (2005 to 2010) period, we note that *Military operations*, formerly in 1st place in the ranked list of top 250 terms (both in the overall list and for the early period, 2000-2004), has fallen to 5th place in the data for the later period, displaced by analytical processing methods (*Artificial intelligence, Modelling*) and specific functionalities (*Decision making, Situational awareness*). *Interoperability* has also moved up to 15th place, compared to earlier data (20th position).

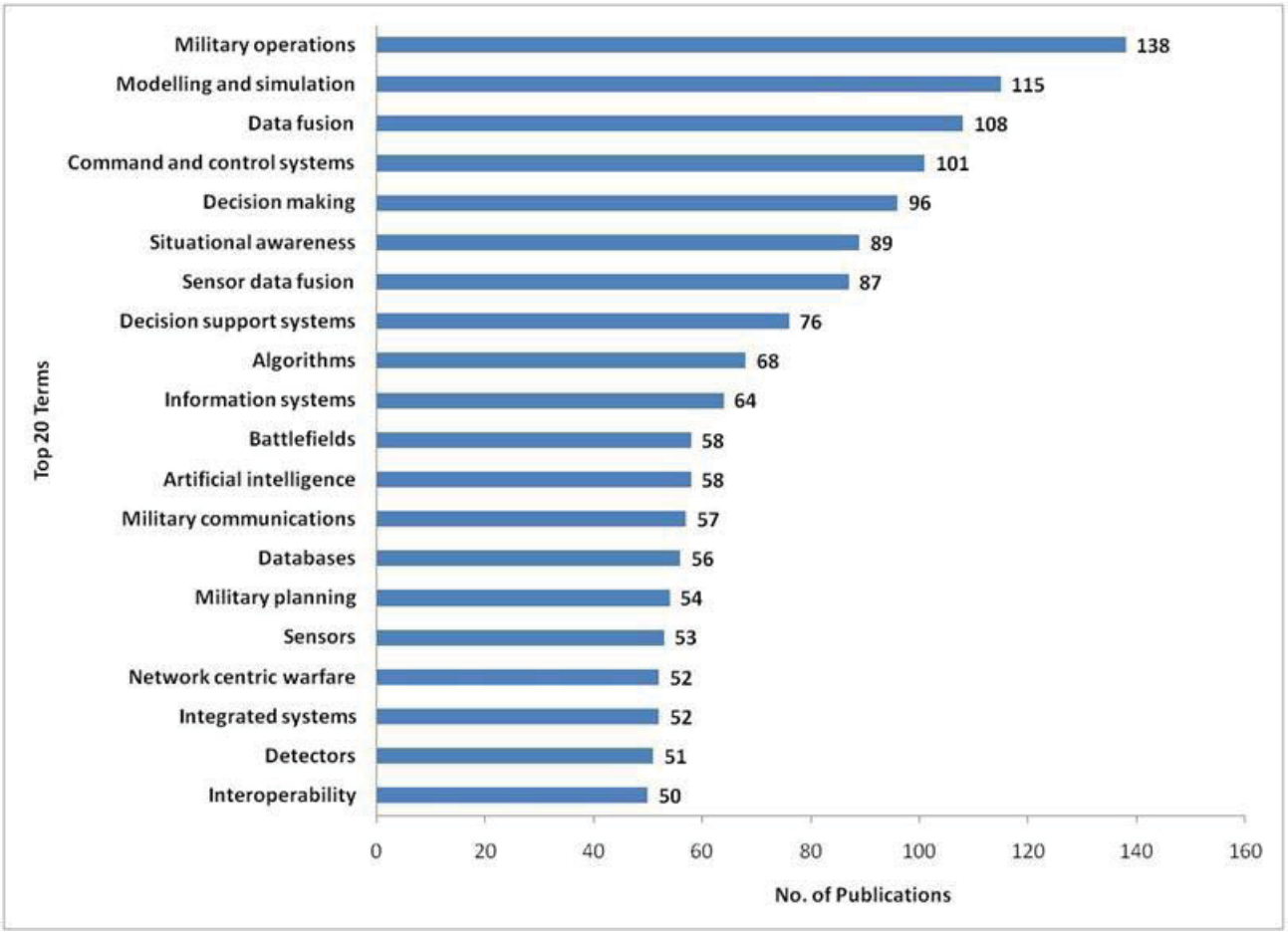


Figure 11: Literature, Top 20 Terms, 2005-2010

In the correlation map for 2005 to 2010 (Figure 12), visualization and display systems (red, upper left) assume a position of greater prominence, and are now linked to intelligence analysis.

The orange cluster immediately below it sees *Standards* and *Requirements* linked to NATO, indicating the role this organization has played in defining standardization. Below this, are lines linking *Collaborative techniques* with *Information exchange*, and *Joint military activities* (purple and pink clusters).

At the centre top (peach-coloured nodes), unmanned systems nodes are linked to reconnaissance and military intelligence: this is consistent with findings in the review literature, that autonomous systems will continue to play an important role in intelligence gathering.

Management and *Decision making* (teal, lower right) are repeatedly linked to *Artificial intelligence* and *Algorithms*, which in turn are linked to items in the purple cluster at right (*Video*, *Image processing, Feature extraction, Surveillance, Complex event processing, Pattern recognition*, etc. This suggests the strong role that graphical images will play in intelligence analysis systems.

Figure 12: Literature, Correlation Map, Top 250 Terms, 2005-2010: Values >20%

7 SUB-TOPIC EXPLORATIONS

Following our initial data review, additional detail was requested on the following topical groups within the literature: military operations, data fusion and integration, situational awareness, visualization and displays, query/search, and information technology.

In the section which follows, for each of these groups, we provide a short scope note, an examination of the top terms, examples of content in endnotes, and a publication velocity graph.

This section concludes with a brief look at certain topic areas (*Mobility, Cloud computing, Service oriented architecture, Open source data, Predictive analysis, Collaboration and dissemination*) which figure prominently in literature review trends, but which may not show similar importance in the publications data.

7.1 Military Operations

Given that the military context was specified in the search strategy, it is not surprising that articles that reference military, defence, army, navy, tactical, battlespace, and so on, are numerous in the dataset.

This group comprises 1995 articles for 2000-2010. It is the largest and probably the most diverse of the groups.

The velocity trend is generally upward, in step-wise fashion:

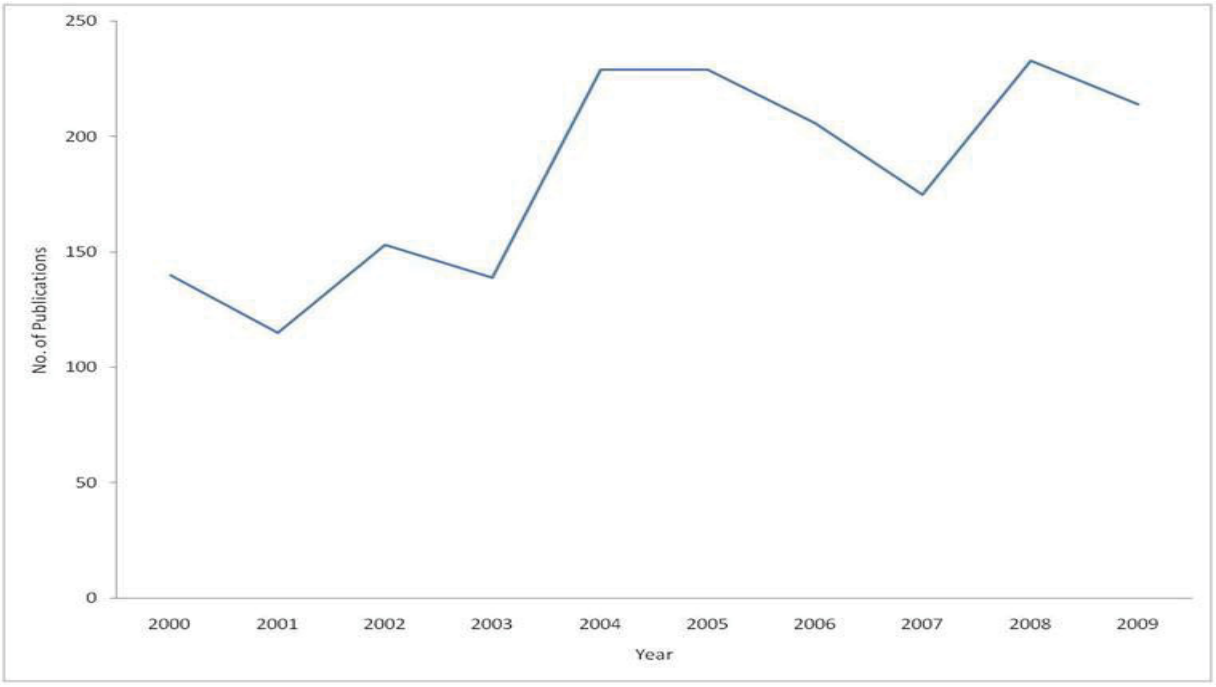


Figure 13: Publication Velocity, Military Operations (Group)

The graphic below lists major sub-topics for *Military Operations* -- in this case, only terms that describe more than 90 articles within the group are shown. Although the sub-topics at this level are quite general, some common themes do emerge: the application to tactical situations and surveillance, command and control, situational awareness and decision making; net-centricity; data fusion (especially for sensor data); and visualization.[62]

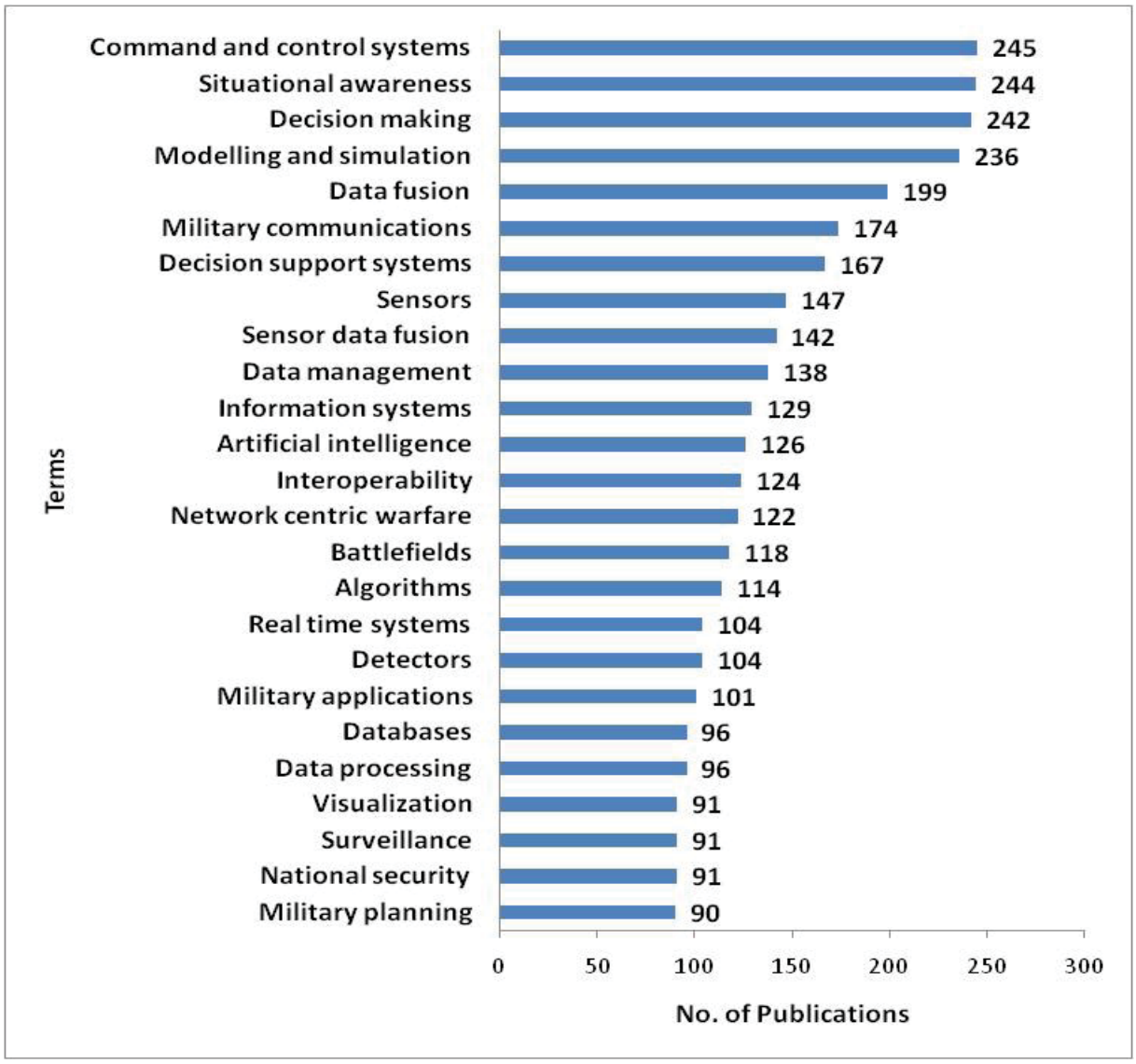


Figure 14: Military Operations: Sub-Topics

7.2 Data Fusion and Integration

There are 441 articles in this group for the period 2000-2010. Items in this group discuss topics such as the fusion of data from heterogenous sources, systems integration, and federated interfaces that manage this (sometimes dispersed) data or allow for its exploitation.

Most articles in the group discuss aspects of sensor data fusion, although other data types are present. Other examples include a (DRDC) presentation on service oriented architecture in support of Arctic C4ISR, manipulation and querying of data fusion cubes, and the use of intelligent agents to define data fusing requirements.[63]

The strongest publication performance for the group is mid-period, after which it wanes somewhat. The 2004 spike in activity appears to be due to an increase in publication for that year on the part of several organizations, notably the Swedish Defence Research Agency and NATO. The post-2004 decline may indicate that research has explored (if not perfected) the most basic issues related to fusion and integration. These issues must be tackled early in the intelligence cycle, before second generation technologies dealing with analytical methods can be addressed.

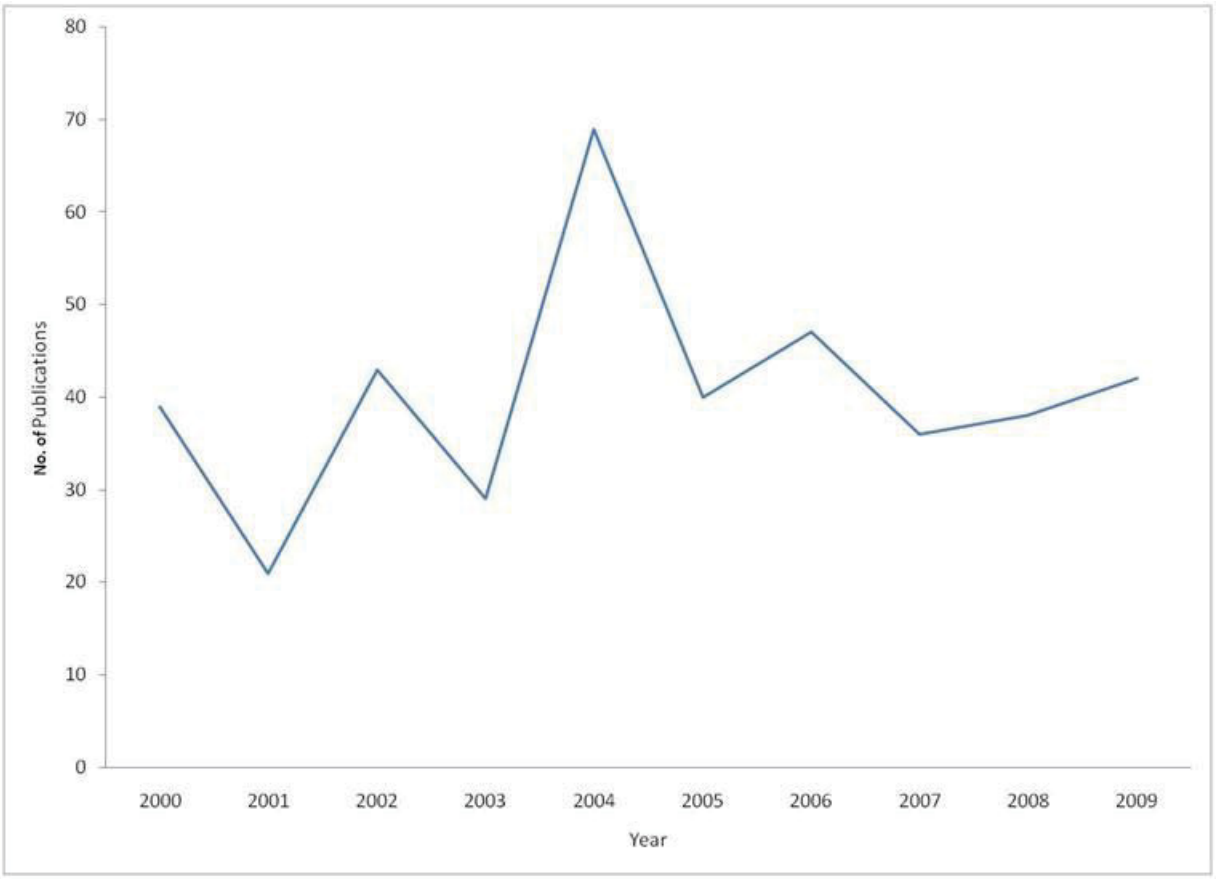


Figure 15: Publication Velocity: Data Fusion and Integration

Terms that occur 30 times or more within the *Data Fusion and Integration* group for 2000-2010 are shown below. Once again, it is clear that sensor data are the data type most often encountered, and that the

intelligence derived from these data are applied to tactical situations such as situation awareness and target tracking.

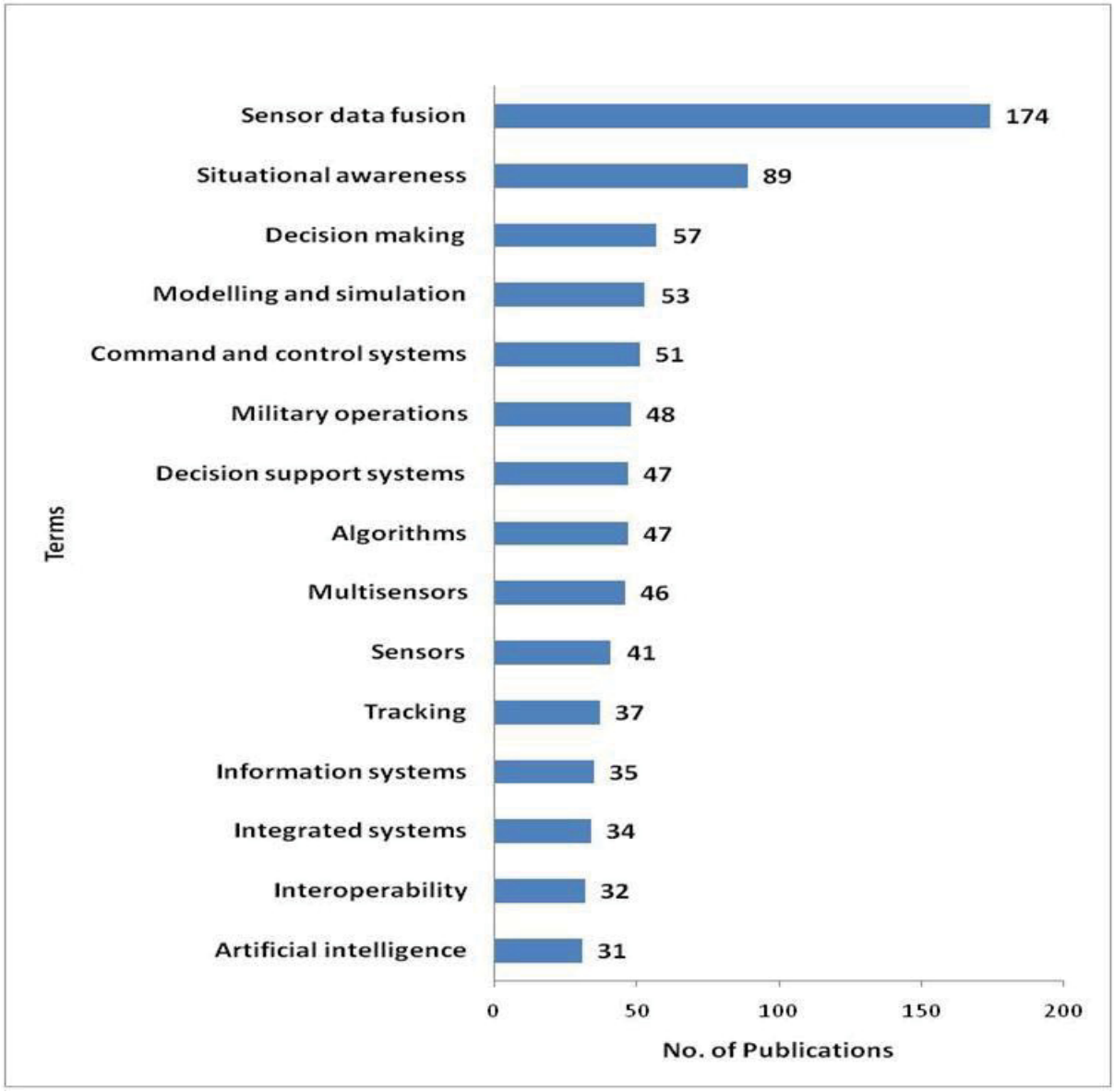


Figure 16: Data Fusion and Integration: Top 20 Keywords

7.3 Situational Awareness

There are 313 articles in this group for 2000-2010. Situational awareness in this instance usually refers to tactical (battlespace) awareness, but some emergency situations are also included. Data fusion – mostly sensor again – is an important sub-topic, but other aspects such as decision making, interoperability, and visualization are also featured.[64]

The publication velocity curve for situational awareness portrays a mixed picture, with significant increases and decreases. It is important to remember, however, that the group includes a relatively small (313) number of articles, and that "situational awareness" was not an explicitly stated term in the search strategy. The shape of the curve suggests that situational awareness as an application area has assumed a diminished role as other, new applications are explored.

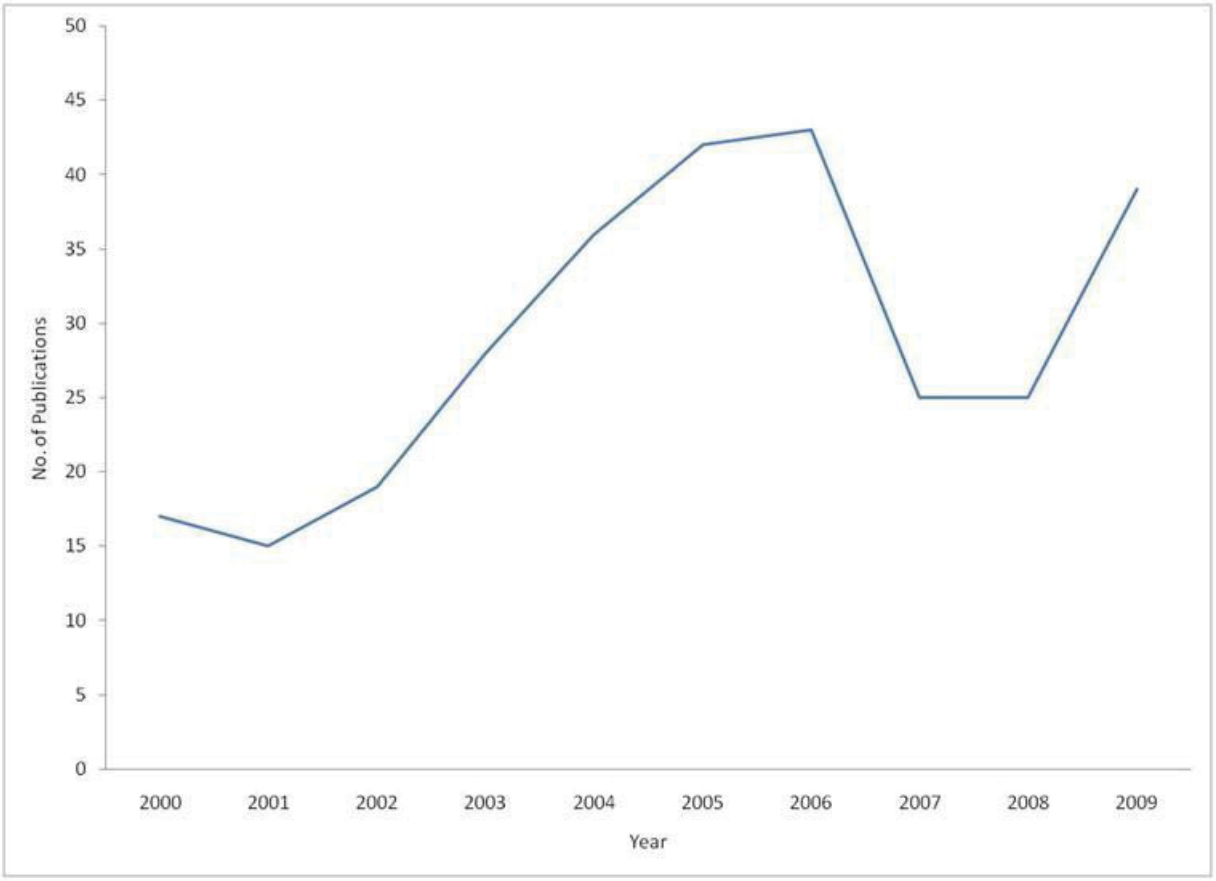


Figure 17: Publication Velocity: Situational Awareness

Terms that occur twenty times or more within the *Situational Awareness* group are shown below. Taken as a group, even these top terms demonstrate a wide range of activities, although most are tactical in nature. Interoperability and joint operations figure prominently here – no surprise, given the number of coalition campaigns that are ongoing in Afghanistan, Iraq, and elsewhere, as well as NATO operations.

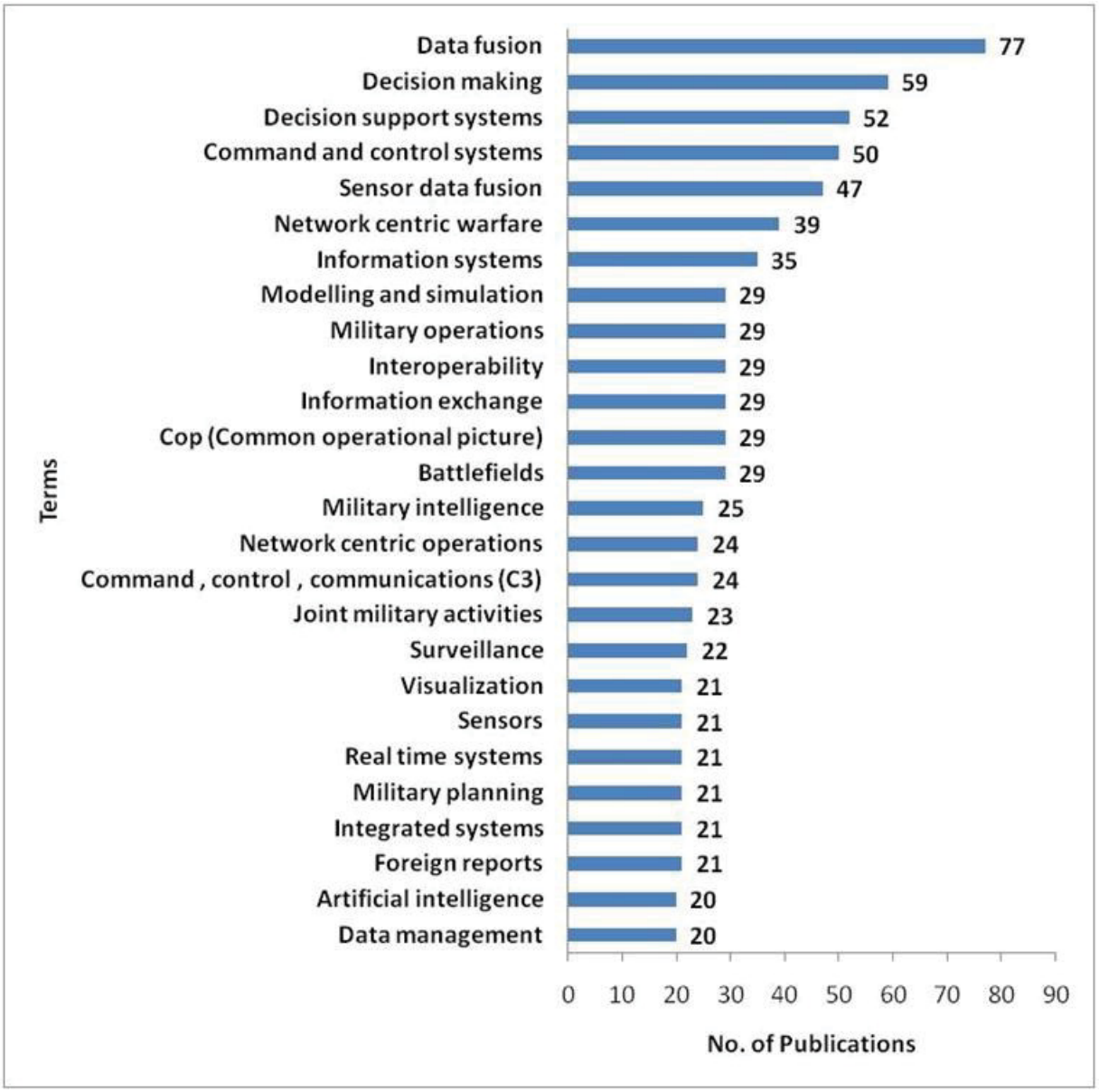


Figure 18: Situational Awareness: Top 20 Keywords

7.4 Visualization and Displays

There are 454 articles in this grouping for the period 2000-2010. Articles in this group address how visual displays contribute to intelligence in the form information such as briefing charts, and fused geographic and temporal data. The literature also discusses human factors and cognition and how they relate to visualization. Important sub-topics are battlespace simulations, virtual environments, and the use of geospatial and temporal data to generate imagery in support of threat forecasts.[65]

Although visualization as a concept and a tool can be applied in a variety of situations, most of the visualization articles appear to discuss the support of command and control (i.e., tactical situations), which understandably has a high priority for military personnel. Such is the importance of this topic to security that in 2004, the U.S. Department of Homeland Security chose to fund a National Visualization and Analytics Center in Washington state's Pacific Northwest National Laboratory, and elements of visualization appear in virtually all of the roadmaps and strategic plans for military/information technology agencies, as noted above in the section on trends.

The publication velocity for visualization shows a marked upswing post 2003. This velocity appears to continue unabated.

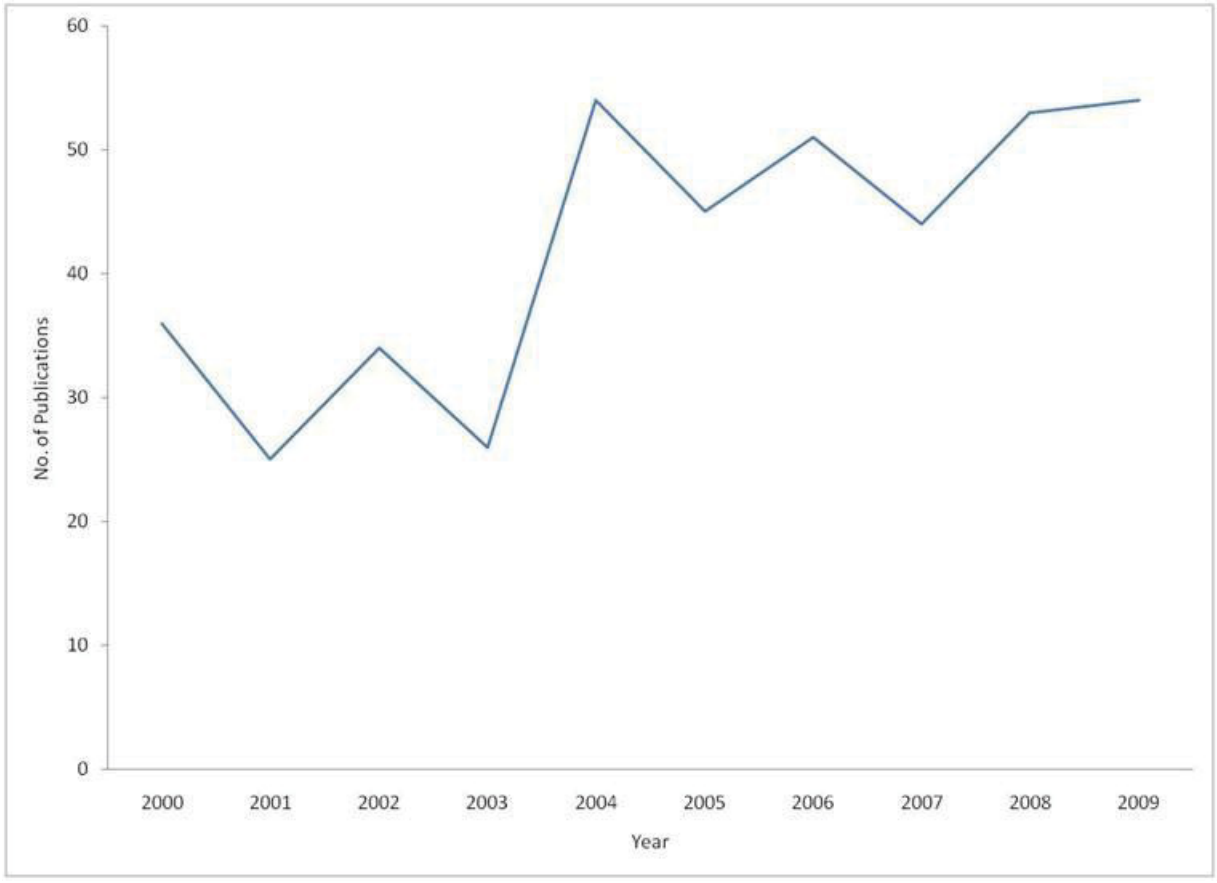


Figure 19: Publication Velocity: Visualization and Displays

Terms that occur 30 times or more within the *Visualization and Displays* group are shown below. Once again, the application to tactical situations is confirmed. Virtual reality and 3D images figure prominently, as does geospatial and sensor-derived data.

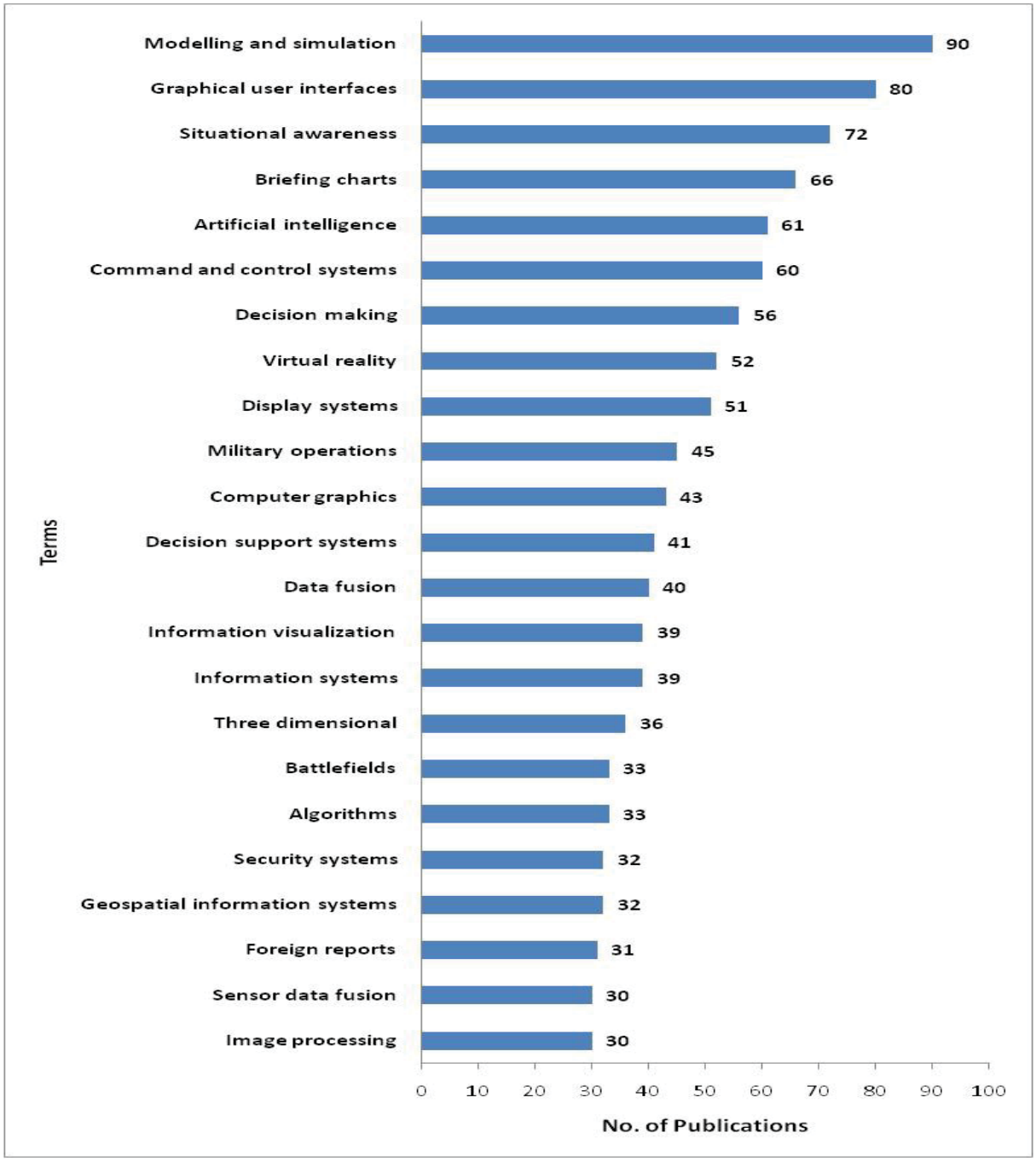


Figure 20: Visualization and Displays: Top 20 Keywords

7.5 Query/Search

The Query/Search group includes 377 articles for the period 2000-2010. Articles in this group address methods of information retrieval (often through a single interface and accessing distributed data) used in multi-type and multi-dimensional databases. Typical problems discussed in the literature include cross-layer design, federated search, ontology-based search, recommendation or other smart algorithms for knowledge discovery, and automated, knowledge/AI-based feature extraction.[66] The querying of multimedia (e.g., video, sometimes streamed and in real-time) also receives considerable attention in these data.[67]

The trajectory for publication velocity shows an upward direction for the decade covered by the search:

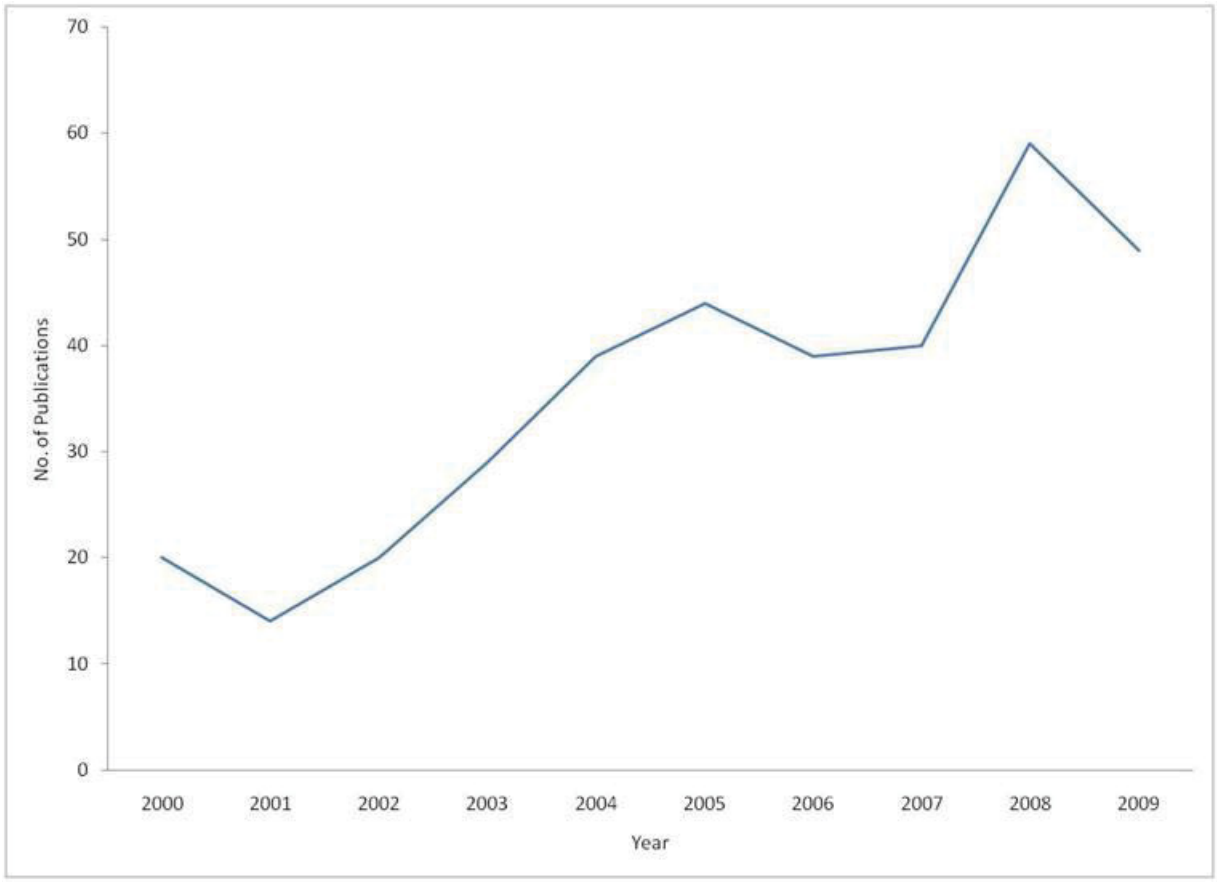


Figure 21: Publication Velocity: Query/Search

The top terms included in the *Query/Search* group (20 or more publications) indicate that key subtopics include methods of querying of fused or real-time data through agent or AI-based query aids, and visual modes of data exploration.

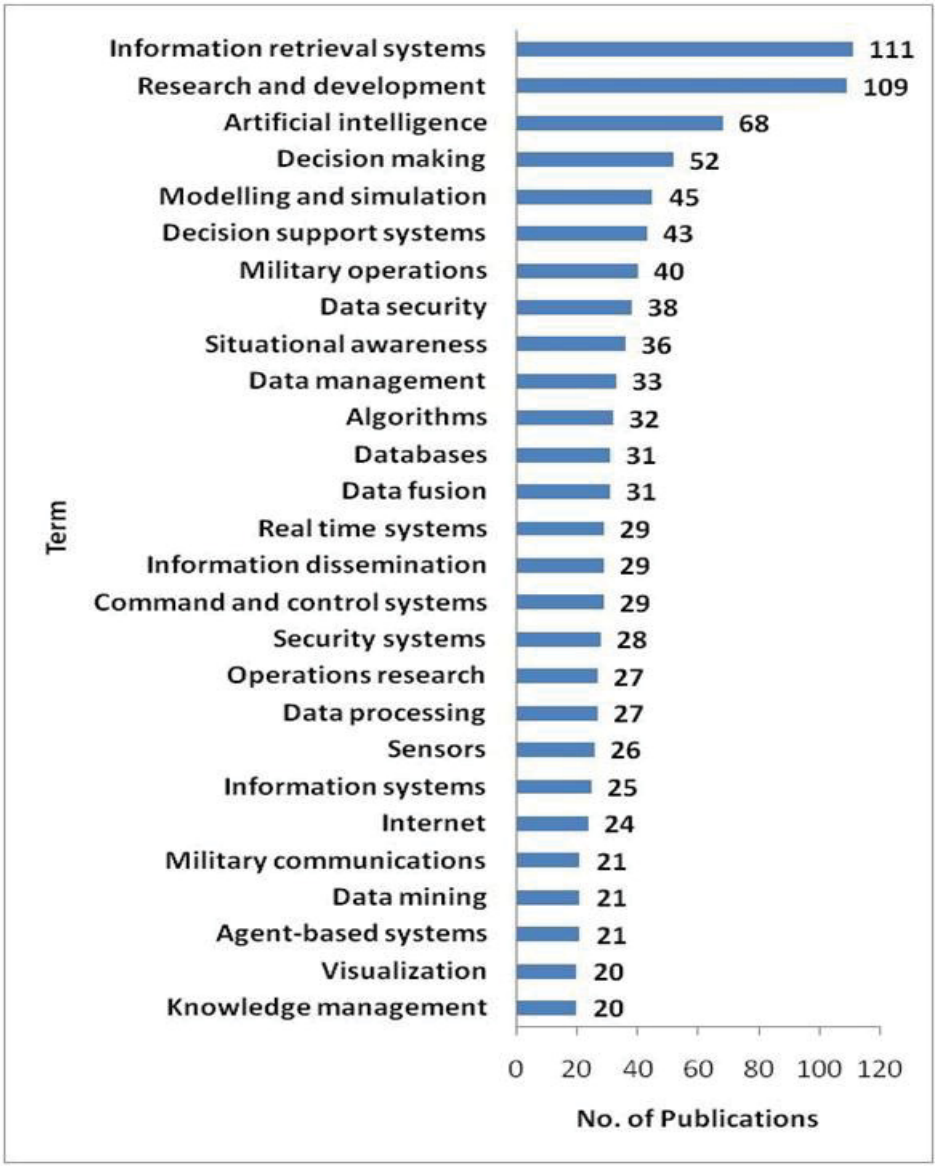


Figure 22: Query/Search: Top 20 Keywords

7.6 Information Technology

There are 536 items in the *Information Technology* group for the period 2000-2010. This is something of a catch-all label, covering protocols and standards, networked architectures, and applications. Sub-themes include fusion/integration, interoperability, collaboration, security, and standardization.[68]

Publication velocity for this group shows marked decline post-2008:

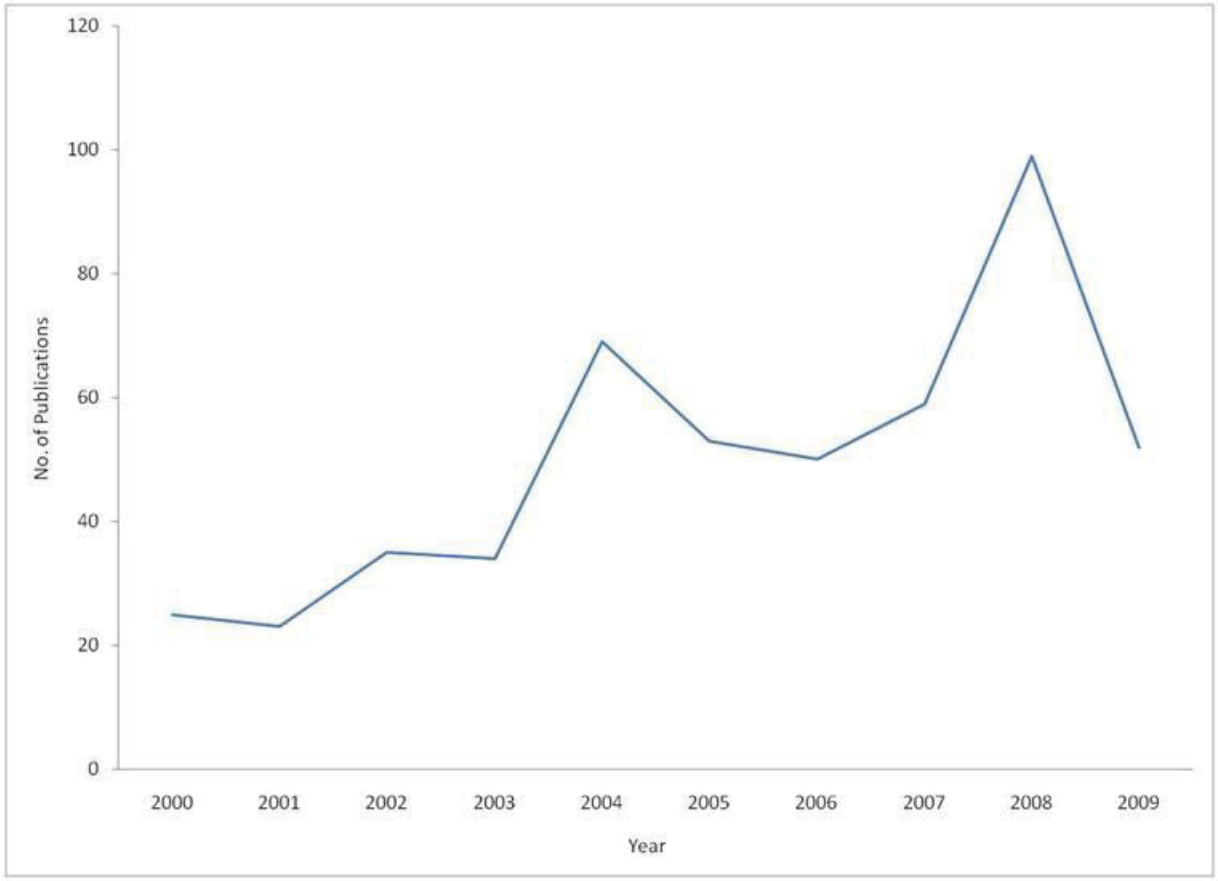


Figure 23: Publication Velocity: Information Technology

Because of the sharp dip in the most recent period, we decided to take a closer look at top terms for the whole period, as well as for early and late chronological slices, in order to see if the nature of information technology publications had evolved over time, and which factors might account for those changes.

When comparing the early (2000-2004) to the later (2005-2010) period – as seen in the graphic below -- it is important to remember that the rate of publication for all articles grew over time, and so an increase in a topic in the latter period may or may not point to a change of direction or emphasis.

That said, sub-topics areas of especially strong late growth include technology related to artificial intelligence, data processing, and data security. This suggests the more pronounced emergence of these “second generation” technologies in the later period.

In the graphic below, “blue” (early period) topics that disappear from the top twenty for 2005-2010 include foreign (i.e., non-U.S.) technology, command and control (C2), sensor data fusion, situational awareness, integrated systems, strategic planning, and data acquisition.

Topics that occur only in later period (red only) are: security systems, management information systems, image processing, technology, information theory, decision support systems, algorithms, and data management.

Topics that persist in top 20 for all years in the group are shown in both red and blue. All of these topics show an increase for the later period.

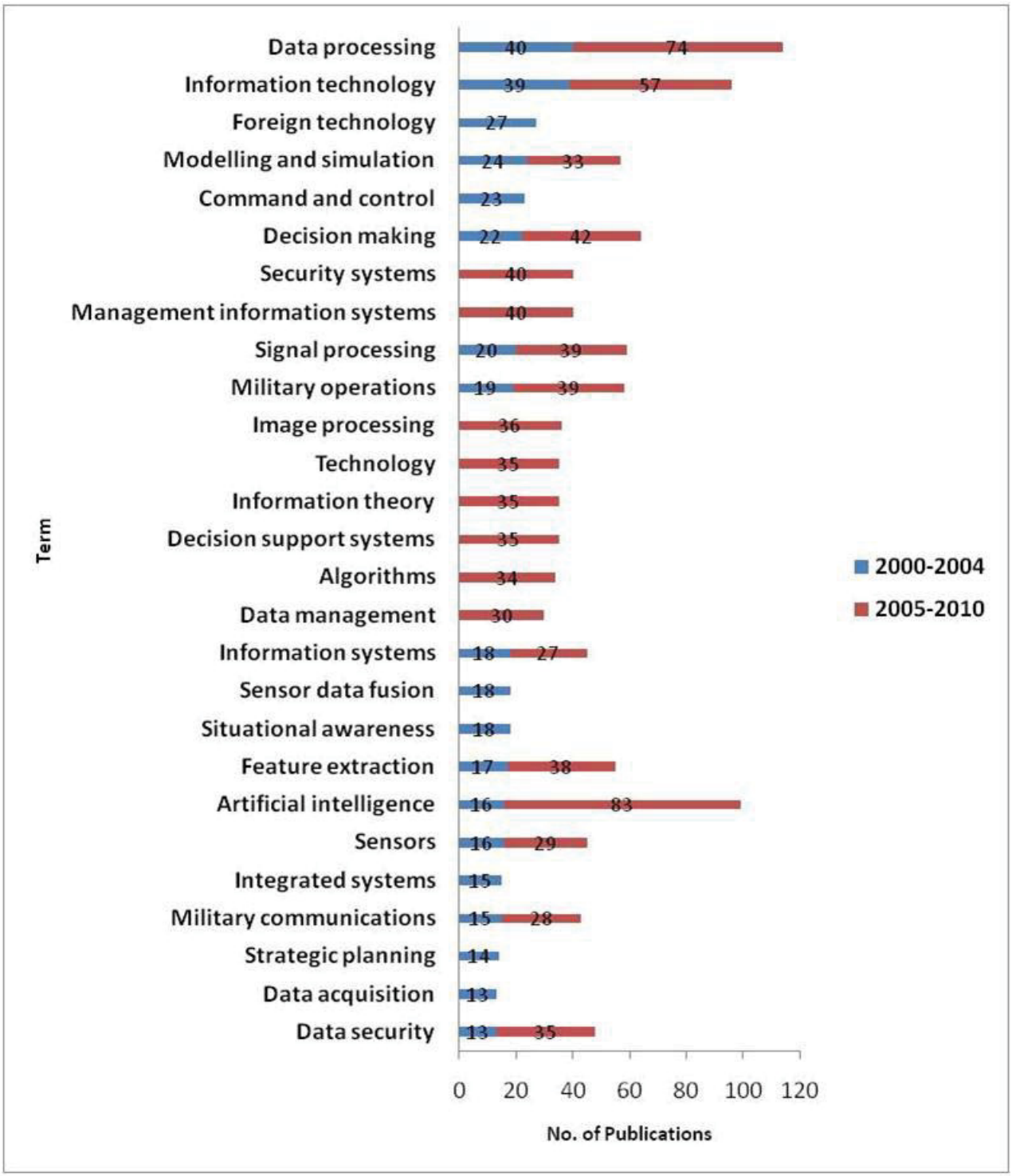


Figure 24: Information Technology: Comparison of Top Terms, Early vs. Late Period

7.7 Other Subject Areas in the Literature

Several trends mentioned prominently in the review literature also appear in the data retrieved by the scientific and technical literature search – although in some cases not with the same weight of data suggested in the market review. This is likely related to the currency of the market literature and its more journalistic nature, as compared to the scientific and technical database, which is marked by a somewhat slower and more conservative publication schedule and outlook. In some cases, the lesser profile is also undoubtedly related to the fact that some of these terms were not specified in the search strategy.

Appearing as groups (i.e., substantial content) in the literature search data are:

- **Info sharing and dissemination**. This group is related to 276 articles, and its velocity curve is shown above in Figure 2. Important subtopics are decision- making, data security, interoperability, and situational awareness.[69]

- **Mobility**: Mobility topics appear in 242 articles, and its velocity curve is shown above in Figure 3. Many of the articles on mobility actually discuss mobile robotics, communication networks, and issues such as quality of service management. Several articles report on mobile devices and applications.[70]

- **Collaboration**: This group features 233 articles and its velocity curve is shown above in Figure 4. The content of the group includes topics as varied as methods of secure collaboration, collaboration for homeland security, and agent-based team decision-making for intelligence matters.[71]

Appearing as single or multiple terms (i.e., less substantial content) in the literature are:

- **Cloud computing**: only 2 articles, and neither of these features a military context. [72]

- **Service oriented architecture (SOA)**: this term appears as part of the larger Architectures group. SOA alone is referenced in forty-four articles.[73]

- **Open Source (OSINT)**: the use of open source literature is discussed in some 15 articles, usually in relation to public security.[74]

- **Predictive analytics** includes approximately 49 articles in the larger (464 articles) group entitled *Forecasts, trends, threat, alerts*. Articles referencing prediction usually discuss mathematical methods and modelling and their application to terrorist activity or dynamic situational (battlefield) awareness.[75]

The absence of strong trends for some topics in the literature search compared to the market review does not necessarily mean that these subjects are unimportant. It may be that technologies in these areas are somewhat novel in a military context, and that development and commercialization has not yet caught up to perceived demand. In any case, we would recommend additional, more focused searches on any of these topics which may be of special interest.

7.8 All source (Multisource) vs. Multi-INT in the Literature

In the literature retrieved by our search, 156 titles that describe the fusion, integration, and analysis multiple heterogenous data sources (for example, multisensory, geospatial, open source, unstructured) were collected in a group labelled *Multisource*. This group demonstrates velocity peaks in 2004 (20 items) and 2008 (23 items), followed by a decline in 2009 (17 items).

The terms *multi-INT* or *multi-intelligence*, referring to the different specialized streams or domains of intelligence analysis (SIGINT, MASINT, OSINT, HUMINT, etc.) were not specified in the search strategy, and only very few references were retrieved which use this term, either as a subject heading or as a phrase found in titles or abstracts. The only appearance of *multi-INT*, for instance, is at 3436th place in the subject rankings. Multi-INT and related terms (e.g., multi-INT surveillance) do appear several times in other fields, however, but the ensemble of articles where the concept is found is very slight, amounting to twelve articles in all. In one case, a single article makes reference, however, to both multi-source and multi-INT.[76]

Since *multi-INT* was not specified in the search, it is difficult to draw conclusions as to its relative importance in the literature, even though references appear to be few in number. The general and pronounced trend to integration, fusion, and virtual environments overall would suggest that multiple intelligence domains are also subject to integration initiatives. One possible cautionary note regarding the challenges of integration was sounded in a recent presentation that remarked on the difficulties of developing predictive models and ontologies that apply across multiple domains.[77]

8 PATENT ANALYSES

To determine parallel trends in the patent literature, we examined velocity of activity and subject patterns.

8.1 Velocity

In the analysis below, patenting activity for 2009 and 2010 is excluded because of the 18 month "silent period" that normally ensues between application and publication of the pertinent data (i.e., data are incomplete and/or inaccessible for the 2009-2010 period). The data examined include both grants and applications, however, the units measured are patent "families" or groups of substantive equivalents.

While the dataset for patents is smaller than that retrieved for publications --it represents a "normal" ratio of publications to patents, i.e., approximately 3:1 -- the consistently upward direction of velocity indicates that this is an area of sustained high interest and commercial growth that has not yet reached maturity.

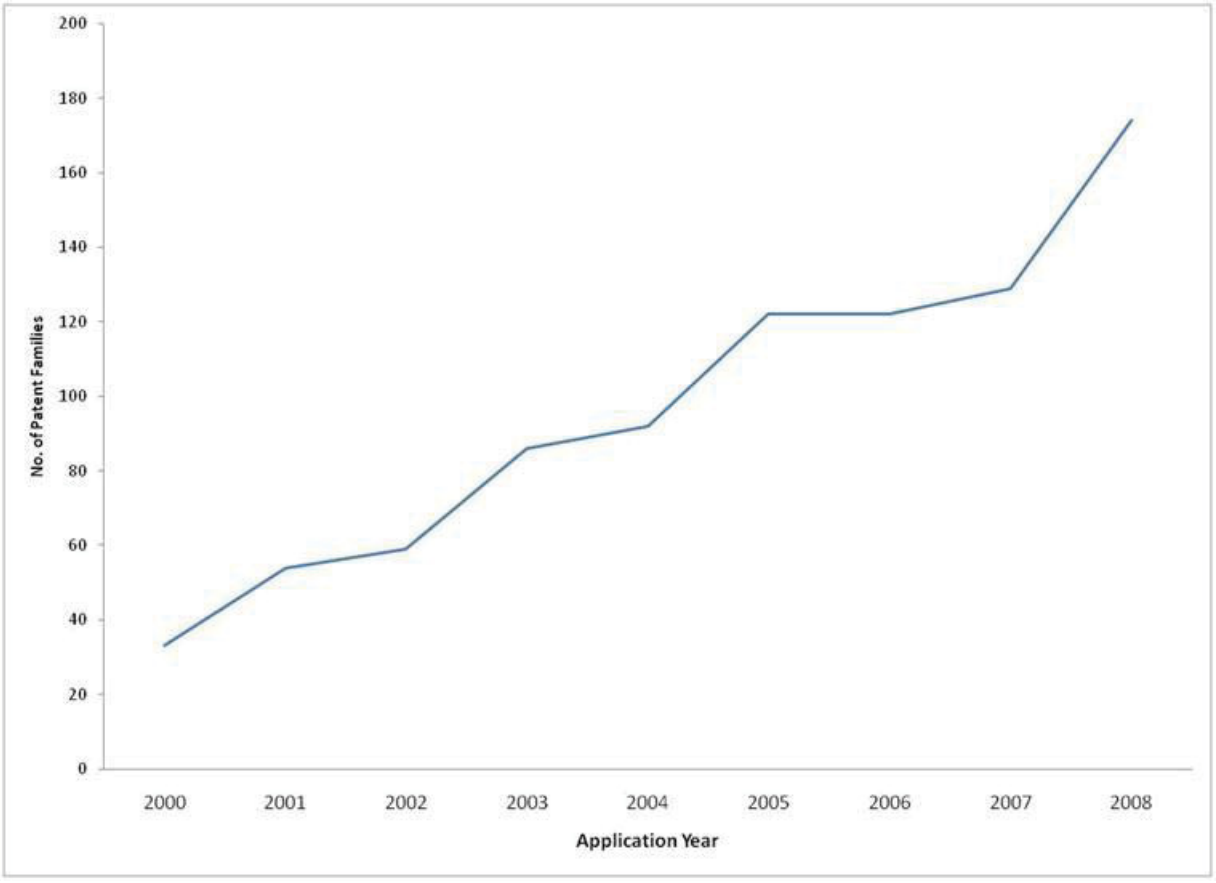


Figure 25: Velocity of Patenting Activity, 2000-2008

8.2 Patents: Subject Analyses

Subject content is not easily determined by an examination of patent language, which can be highly technical, vague, or obfuscatory in nature, depending on the intellectual property strategy pursued by the applicant and the nature of the patent in question. Furthermore, available patent databases, including the one used for this search, do not typically assign controlled vocabulary to patent records.

One method to examine subject content uses International Patent Classification (IPC) codes. IPCs are drawn from a hierarchical alphanumeric classification scheme used to describe patent content, and they are assigned by patent examiners at the time of review. The IPC codes are not mutually exclusive: a single patent application may receive three or more classifications.

For the six hundred sixty-four patent families retrieved by our search, five hundred thirty-nine IPCs were applied. The top twenty IPCs used, however, account for 81% of entire dataset.

In Figure 26 we have translated IPC codes into natural language for increased comprehension.

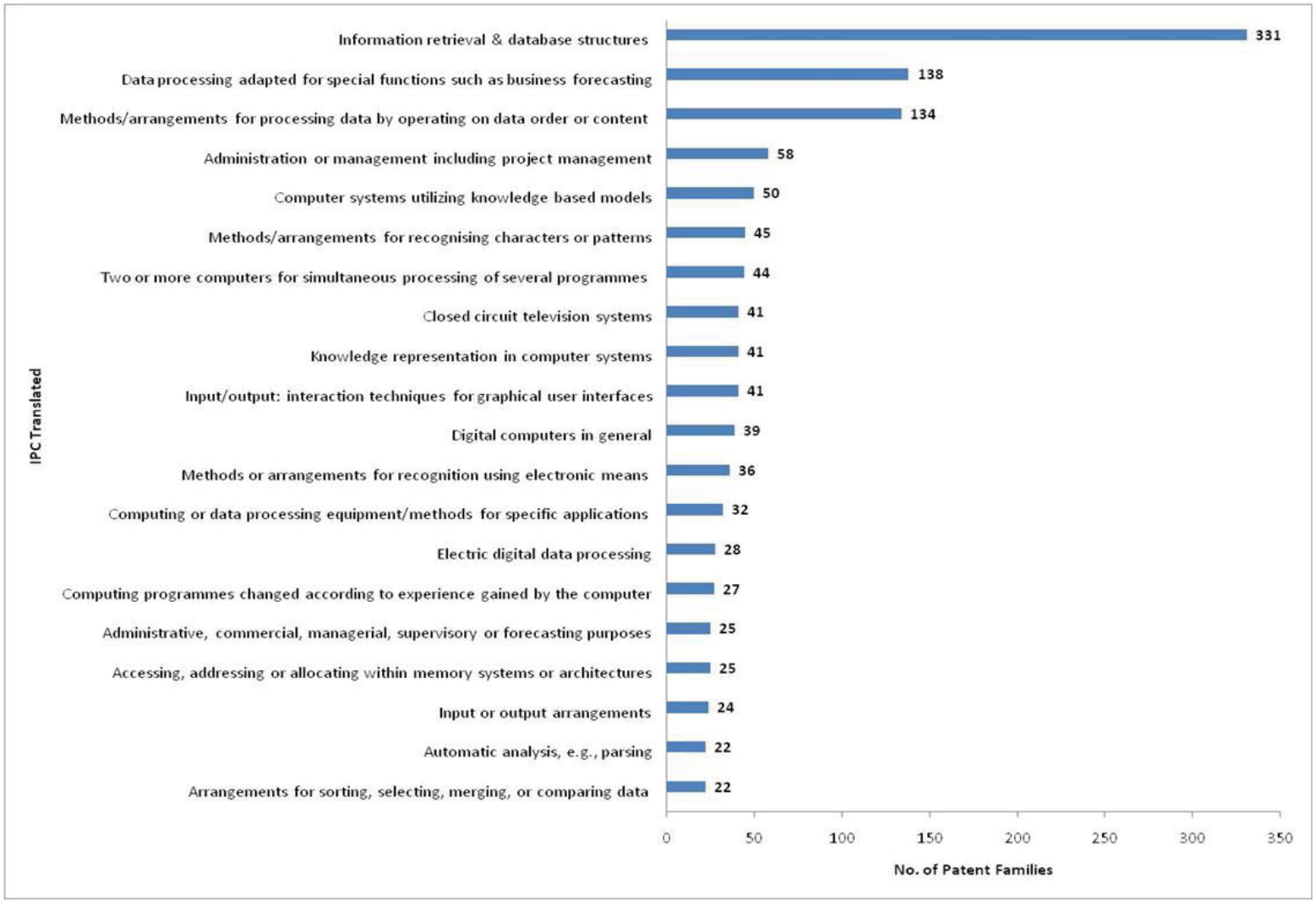


Figure 26: Patent Literature: Top 20 IPCs (Translated)

In an alternate approach, we created 54 groupings, based on keywords in the patent title and abstract fields, and plotted these by year of application. As with IPCS, the topical groups are not mutually exclusive, and their size varies greatly from 1 patent family per group (for the *Languages* and *Open source intelligence*) to 154 (*Visualization*). The patent families in the groups cover 94% of the content in the patent dataset.

(Note: in Appendix 12.5 we have included an Excel file for the entire patent dataset, with individual tabs for patents classified in each subject group. The file includes a brief record for each patent family as well as hyperlinks to the full text for each patent family).

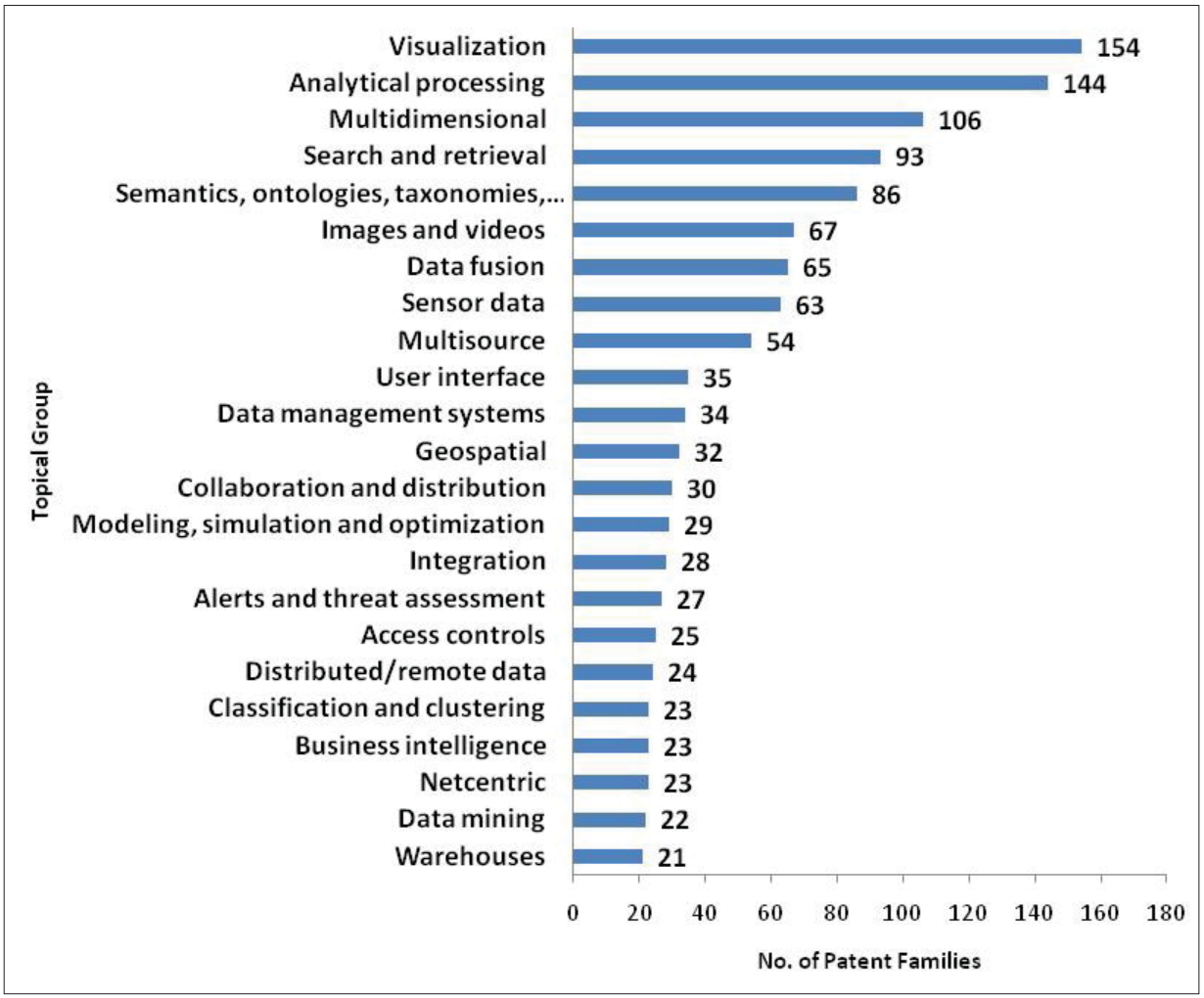


Figure 27: Patent Families: Top Subject Groupings (>20)

8.2.1 Patenting Velocity by Subject Groups

The number of records in our patent file is small, and so plotting velocity may not provide an accurate indicator of emerging technology, especially when we consider the even smaller number of families in some subject groups. For the following analysis, we opted to plot velocity only for forty-two subject groups with more than 10 patent families.

Diminishing velocity was found for ten subject groups in the patent dataset: user interface, integration, business intelligence, alerts and threat assessments, military or security context, event processing or detection, targets and surveillance, unstructured data, speech & voice processing, and agent based systems.

Rising velocity was seen for thirty-two subject groups in the patent dataset. While the trajectory for these thirty-two was upward, in some cases the pattern was intermittent (no patent families published in a given year) or erratic.

Patenting velocity for the top five groups is shown below in Figure 29. In all cases, the number of patent families rises dramatically in the period covered.

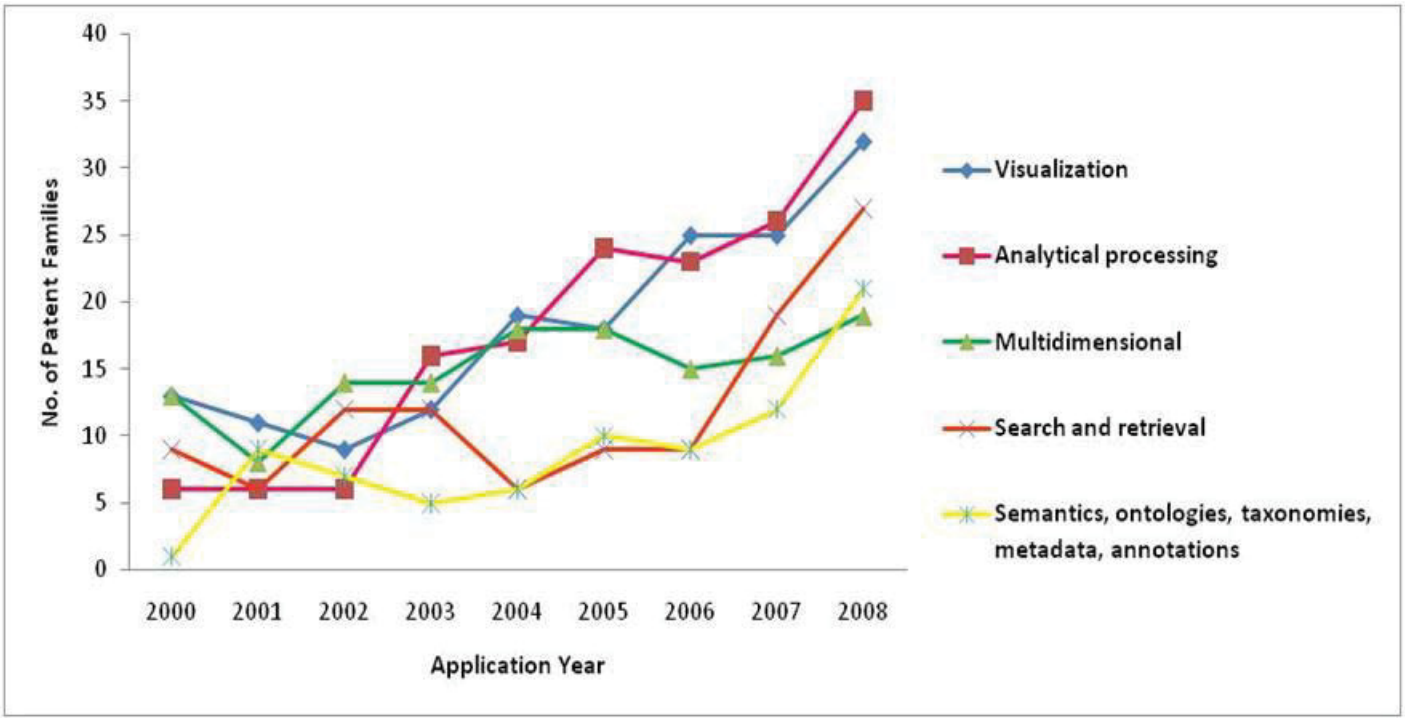


Figure 28: Patenting Velocity for Top 5 Subject Groups

9 PLAYERS AND EXPERTISE

9.1 Top Organizations in the Literature

In this section, we begin with a review of the organizations that have sponsored publication of research or other articles, i.e., organizational affiliations in the literature dataset.

Unsurprisingly, given the military and/or intelligence context specified in the search strategy, military agencies dominate the list. Of these, U.S. military groups appear most frequently, but DRDC Valcartier also appears at position number fourteen in the list of top 20 organizations. Also of note in this list is the inclusion of the Swedish Defence Research Agency and the National University of Defense Technology in Changsha, China (numbers three and four, respectively). Other important national organizations, such as the U.K.'s DSTL, appear well down in the ranked list (43rd place, 8 publications) for this dataset, but overall country data push British organizations ahead of Canadian.[78] A supplementary search of Scopus, Inspec and EI Compendex also retrieved relatively few citations for DSTL on intelligence topics (there was far greater representation in the life sciences): some references are included in Appendix 12.4. Since DSTL is known to be active in the area, it is likely that their technical and other reports are restricted, and accessible only through systems such as their Athena and Defence Research databases, which are restricted to military users.

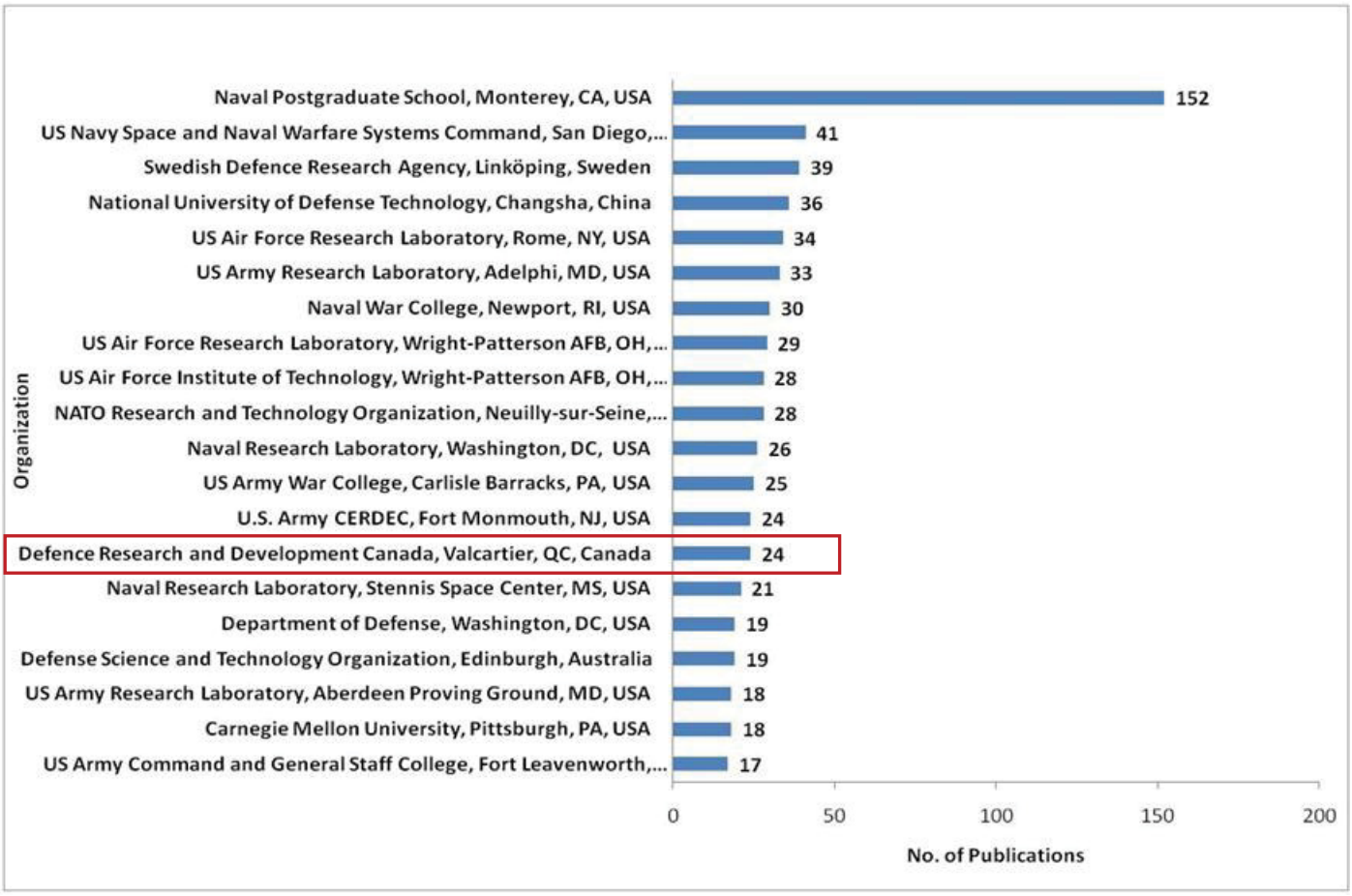


Figure 29: Literature: Top 20 Organizations

49 entities are listed for Canada: 13 or these have 2 or more publications in the dataset (all others have 1 only).

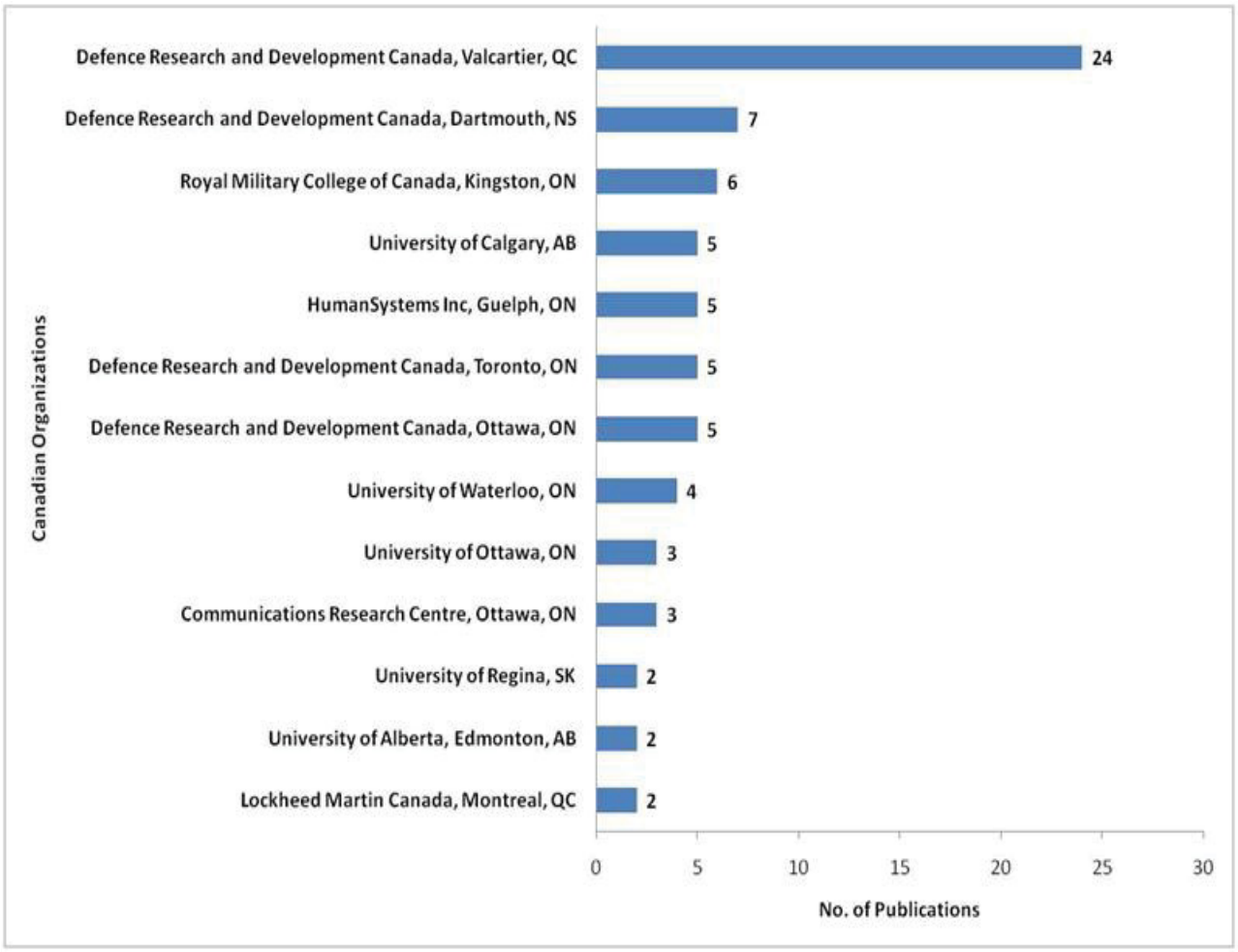


Figure 30: Literature: Top Canadian Organizations

In Appendix 12.4, we present a table of top organizations (overall and Canadian) cross-referenced with their top areas of expertise.

9.2 Top Patent Assignees

The top patent assignees disclosed by our search are chiefly corporate --- partly a function of the search strategy, which relied on known participants to retrieve data, and partly due to the nature of patenting activity. As with the review of market conditions and the literature, American or global organizations were found to dominate.

In several cases, we have removed the names of financial institutions from the top 20 list, since they appear as co-assignees (e.g., RBC Bank with Nexidia), and are not the primary creative or commercial body behind the invention.

The inclusion of the U.S. Department of Energy and Battelle Memorial Institute also require some explanation. Patents included for these assignees are associated with the Starlight visualization and analysis platform, which was developed by Battelle and the Pacific Northwest National Laboratory (part of the U.S. Department of Energy).

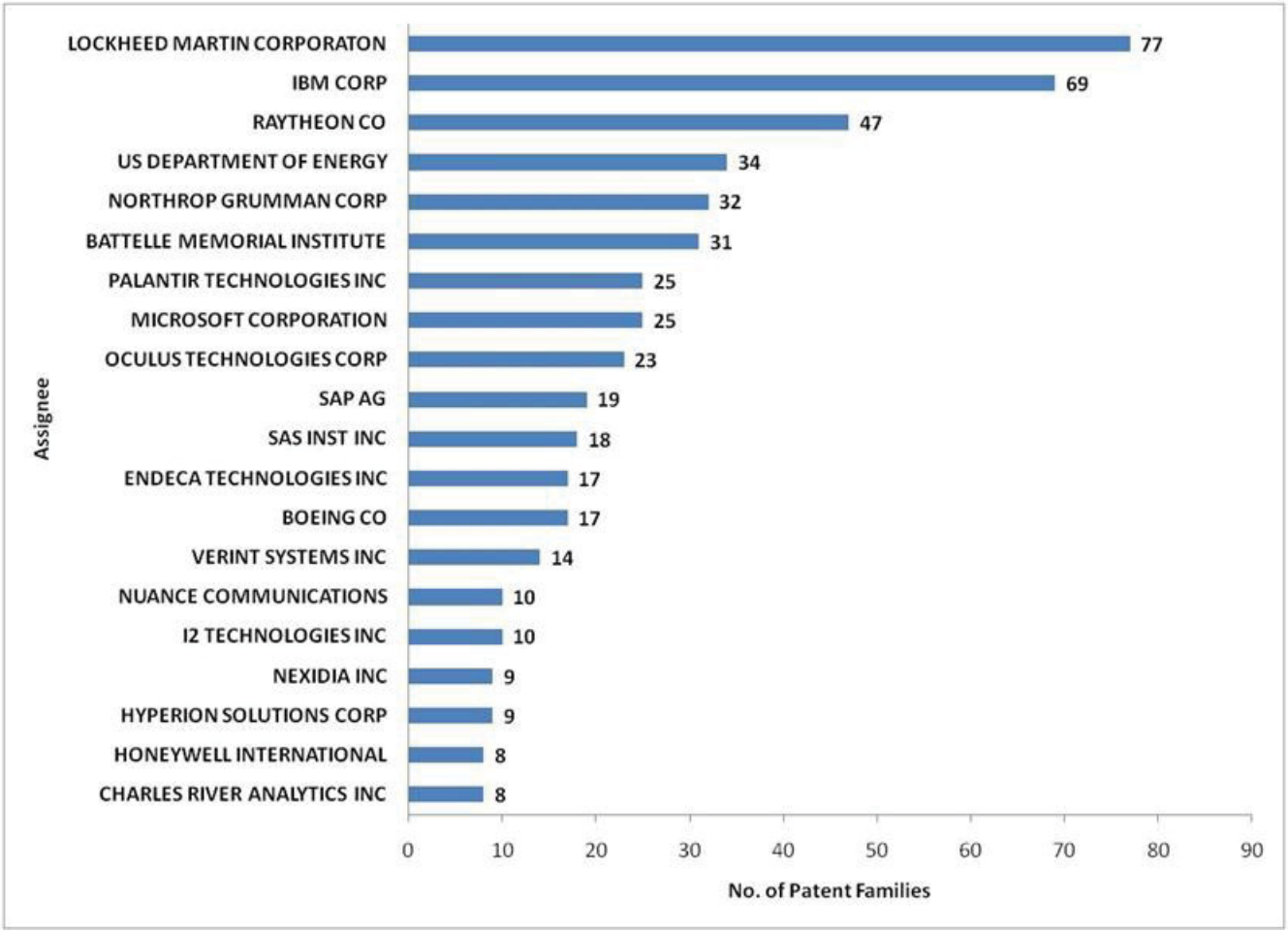


Figure 31: Patents, Top 20 Assignees

The Canadian presence in the dataset is slight, and is found only in priority applications made by Cognos (now IBM), renowned in the area of business intelligence and analytics, and Oculus Technologies, a specialist in data visualization.

A table comparing the IPC labels and subject group assignments for patent assignees in the Top 20 list appears in Appendix 12.4.

10 TRIANGULATION OF FINDINGS

To obtain the most complete analytical picture of findings, it is instructive to triangulate the data found from our market review, literature, and patent search. Each of these three data streams has its own strengths and weaknesses, and each adds its own particular perspective to the analysis.

The market review, for example, is a good source of expert opinion and is the most current of the three streams. The market literature often provides a good sense of industrial drivers and barriers, and highlights innovative developments. It is forward-looking (i.e., predicting trends and “hot topics”), but is derived from a relatively slight amount of data. Its bias is towards commercialization, and it often presents a North American point of view. Also, because it often presents synopses, it can tend to the reductive.

The scientific and technical literature retrieved by the literature search, by way of contrast, typically has a more academic focus and research orientation. It is international in nature, and provides a large and detailed amount of data for analysis. While based on authoritative sources, it can tend to be conservative in its outlook, and its content can sometimes report on projects that are already several years old, which can be a disadvantage when one is seeking a futuristic perspective. Also, as noted earlier in this report, in this case we were limited to unclassified publications only, and this probably impacts on the comprehensiveness of our survey.

Our third source, patent literature, has a definite commercial focus, and provides a good sense of the competitive environment, but is not always as useful in the identification of developing research trends or non-commercial intellectual property. This, coupled with the time lag associated with patent publication, the difficulties associated with subject analyses of patents, and the absence of software data (protected under copyright) must be considered limiting factors for this analysis.

Combining all three data streams results in an interesting composite picture, however. A summary of all three sources and how they address the key questions of the project mandate is presented below.

Table 2: Intelligence Analytical Capacity: Triangulation of Findings for Key Questions

Question	Market Literature Review	Sci/Tech Literature Review	Patent Review
Key Enabling Technologies	• Enterprise integration • Multisource & multidimensional integration & analysis • Sensor & geospatial data • Webcentricity • Semantics/ontologies • Analytics & reporting • Interoperability • Mobility	• Systems integration • Data fusion • Sensor & geospatial data • Semantics/ontologies • Architectures (web – including SOA -- communications, grid) • Interoperability • Security for data, multiple users, multiple access levels	• Integration & fusion • Data management • Analytical processing • Visualization • Search & retrieval • Semantics/ontologies
Commercial/ Deployed Technologies	• Business intelligence • Basics of key tech • DCGS & D2IE • Fusion centres	• All basics of key tech • DCGS & D2IE • Global info grid • Fusion and integration	• Business intelligence • Enterprise & data integration tech
Emergent technologies	• Smarter analytics (AI, visual, audio, agents, predictive) • Visualization • Social media • Open source INT • Mobility • Automation of processes • Collaboration • Dissemination • Information assurance, trust • SOA/cloud • Multilevel security	• Smarter analytics (AI, visual, audio, agents, predictive) • Collaboration • Dissemination • Decision making/problem solving • Collaboration • Situational awareness • HUMINT(languages, HUMINT integration) • Visualization • Virtualization • Live/streamed data & analysis • Multilevel security, cryptography • Mobility • Data quality • SOA	• Modelling & simulation • Collaboration & dissemination • Visualization • Visual analytics

Future Intelligence Analysis Capability

Project 2013
STIA Assessment
January 2011

Question	Market Literature Review	Sci/Tech Literature Review	Patent Review
Drivers	• Volume of data • Continuing campaigns • Proliferation of threats • Counter-terrorism • Interoperability	• Volume of data • Continuing campaigns • Proliferation of threats • Counter-terrorism	n/a
Barriers	• Proliferation of threats & data • Stovepiped assets • Legacy systems • Lack of policy/guidance • Entrenched competition • Regulatory environment • Bandwidth • HR & HUMINT issues - lack of language specialists, difficulties of integration • Diverse domains	• Proliferation of threats & data • Stovepiped assets • Legacy systems • Lack of policy/guidance • HR & HUMINT issues – lack of language specialists, difficulties of integration • Diverse domains	n/a
Players	• Large corporations & contractors • US Department of Defense • IARPA • DARPA • Defense Information Services Agency • National Security Agency • US Department of Justice • In-Q-Tel • Smaller, niche market companies in areas of high innovation	• (US) military agencies & research labs • Swedish Defence Research Agency • National University of Defense and Technology (China) • DRDC • NATO	• Large corporations & contractors (Lockheed, Raytheon, General Dynamics, Northop Grumann, etc.) • Niche players

Taken together, the data from all three sources trace an evolution from core enabling technologies (network and communications architectures, data fusion, systems integration, solutions for smart searching and interoperabillity) to sophisticated sensemaking tools and methods (for modelling, prediction, processing, collaboration and dissemination). Multipurpose, broadly applicable technologies with high commercial value such as visualization and service oriented architecture also receive sustained interest in all three sources.

Common themes across all streams are the importance of systems integration and data fusion, the need for common standards, and volume and richness of available multisource data available for exploitation. The collective literature also speaks to the close relationship between commercial off the shelf technologies and their government equivalents.

With regard to players and expertise, U.S. military and intelligence agencies have played a leading role, as have global firms such as General Dynamics, Raytheon, Northrop Grumann, and others. Internationally, Chinese institutions have been active, as well as the Swedish Defence Research Agency, NATO, and DRDC. Small companies, supported by government contracts and venture capital funding, are making innovative contributions in areas such as visualization and predictive analytics.

11 Conclusions

This is an active space, with both commercial and military participants. Private enterprise has made significant contributions in the form of the key technologies underpinning business intelligence architectures and analytical methods. The intelligence community has adapted that functionality to its own purposes and advanced capability in areas such as data governance and grids, security, visualization, interoperability, and the exploitation of specific types of intelligence data (sensor/signals, geospatial, visual, HUMINT).

Analysis of the data reveals what appears to be a natural progression from supporting technologies to analytical applications. In the earliest stages, there has been an effort eliminate or integrate data systems and silos, accompanied by initiatives to build networked structures for shared applications and intelligence. Most of the work accomplished for large, early stage integration, fusion and networking projected has been undertaken by global firms such as Raytheon and Northrop Grumann. In some cases, these may create truly integrated enterprise systems; in others, middleware or other services are at work to provide a layer that links disparate sources and systems, granting functional integration even when the data and systems are still dispersed and independent. Efficiencies have also been achieved in leaner methods of data warehousing, data reduction, and automate processes, such as tagging of legacy or unstructured information.

Data fusion has also been a matter of early concern, and techniques have been developed – if not necessarily perfected – to reduce errors and uncertainty related to data propagation. The need to merge sensor-derived data has driven much of the development in this area, but as time has gone on, other data types have entered the fusion equation.

Key technologies based on semantics, ontologies, and taxonomies, all of which support data fusion, retrieval, classification and analysis, have been the object of considerable research and commercialization. Standards and schema developed by the U.S. Departments of Defense and Justice have made significant contributions in this regard.

With such basic enablers in place, research has moved on to second generation technologies, such as those for feature extraction, search, interpretation, pattern recognition, link analysis, and prediction. Certain challenging areas, such as those related to interpretation of non-textual and multi-domain data, continue to attract research

attention and funding. Multifunctional technologies, such as visualization methodologies, are of strategic interest, as are ways to automate basic processes.

The need for speed, mobility, and interoperability are also emergent. With diverse users in multiple locations, and with differing security clearances and job profiles, complex methods of data sharing, collaboration, access and data security are also of high interest. The network of data fusion centers in the United States and ongoing coalition campaigns in Afghanistan and Iraq have done much to advance critical data collection and sharing initiatives, but this is still a hot area for development. Military officials and the strategic plans of key agencies also stress the need for smarter means of dissemination. The Internet and service oriented architecture are key elements in the information sharing and dissemination process.

The analysis supports an evolutionary hypothesis, with research efforts moving from core and enabling technologies through analytical methods and dissemination techniques. Our results demonstrate that technology for collection, storage, and integration is slightly more mature, while solutions related to interpretation, security and dissemination are less fully developed but well established in the testbed/demonstration phase.

Many technologies are already available commercially, since many defence contractors are also active in the business intelligence space and thanks to programmes to encourage technology development and transfer, as sponsored by government agencies. Defence requirements are different, but cross-fertilization between the two domains (military/commercial) has benefited both.

The approach for this project was broad, and the intent was to gain a birds' eye view of intelligence analysis capabilities. Our results describe general trends and support general hypotheses, such as the importance of data fusion, systems integration, multisource intelligence, semantic interoperability, agent-based analytics and in all things, netcentricity.

Our findings describe the recent history of intelligence analysis, and demonstrate changing patterns of research focus. While the results cannot predict the future of analytics, and while they are in no way linked to official policies and priorities of the Defence Research and Development Canada, our assessment suggests future directions, especially those categorized as "Emergent Technologies". Important topic areas for consideration in the near and far term include semantic and agent based analytics and predictive tools, visualizations of all types, technologies that can automate basic processes, exploitation of service oriented architecture and cloud computing, multimedia analytics, support for mobile applications, the use of open source literature, better multilingual capabilities, and a variety of techniques to support improved and secure collaboration and dissemination.

For more focused views in areas DRDC deems critical in the near term, we recommend additional future research in regard to available technologies and expertise.

12 APPENDICES

12.1 Search Methodology and Sources

12.1.1 Search Strategy: Literature

For the literature search, articles and conference proceedings were sourced from:

- SCOPUS: a multidisciplinary database; searches were limited to the physical sciences (including computer science)
- INSPEC and EI COMPENDEX: engineering databases, including electrical engineering
- NTIS (National Technical Information Service;): a database of publicly funded research
- NATO Research and Technology Organisation Publications database

The search was conducted using clusters of Keywords (uncontrolled vocabulary) and Descriptors (controlled vocabulary). These appear below as concept clusters which were combined using proximity operators as well as the Boolean AND. Term searching was also delimited to the title, abstract, and keyword/descriptor fields.
In SCOPUS, the search delimited to the physical sciences subset. Articles which discuss both eh social or cultural aspects of intelligence analysis AND technologies for storage and extraction would nonetheless have been retrieved. All items were delimited to a publication date later than 1999. Duplicates were removed, with a final result of 2749 unique titles

Concept Cluster 1	Concept Cluster 2	Concept Cluster 3
Data or file* or format? or information	Multisource or multimedia or heterogenous or text* or database or video or numeric or audio or geospatial or picture* or graphic* or ELINT or GEOINT or HUMINT or IMINT or MASINT or OSINT or RADINT or SIGINT or TECHINT or “all source”	Synthes* or mine or mining or extract* or interpret* or visuali* or analy* or fusion or “knowledge discovery” or “knowledge management” or “link analysis” or “information management” or integrat* or shar* or tagging or exploit* or interpret* or collect* or collat* or disseminat* or (sense or meaning) NEAR making or grid or distributed or SOA or “service oriented” or P2P or “point to point”

Concept Cluster 4	Concept Cluster 5
military or defen* or homeland or security or "law enforcement" or police or policing or army or naval or navy or "air force" or fbi or "Federal Bureau of Investigation" or cia or "Central Intelligence Agency" or interpol or surveillance or reconnaissance	intelligence or tactic* or strategic or C3I* or C4I* or ISR or operational or I2 or INT

12.1.2 Search Strategy: Patents

The search was conducted in the Questel Orbit database (patent grants and applications, all major jurisdictions and authorities). The search was delimited to title, abstract, and key content (description and independent claims fields). Results were limited to an application date greater than 1999.

The search strategy outlined above (concept clusters) was originally used, but resulted in too many hits of peripheral relevance due to the nature of patent language and broad interpretation of words like "intelligence" in the content. Limiting to military applications was also judged not to be useful in this context, since the patent literature rarely references the context. Instead, we searched on assignees (companies, agencies) known to be active in the field, and then extracted content using selected keywords from clusters 1-3, above in proximity to each other. Companies searched were as follows:

- **Defence C4ISR contractors**: General Dynamics, Lockheed Martin, Boeing, Raytheon, Northrop Grumann, BAE, BAH, SAP, SAS Institute , SAIC, SRA, EMC Corp., Battelle Memorial Institute (Pacific Northwest National Laboratory), EADS, Textron Defense Systems, L-3 Communications, Man Tech International Corp.
- **In-Q-Tel funded companies**: Psydex, Recorded Future, CallMiner, GeoSemble, Endeca, FortiusOne (George Mason University), Palantir Technologies, Thetus, Visible Technologies, CleverSafe, Agent Logic, FMS Advanced Systems Group (Sentinel TMS)
- **Business Intelligence companies**: IBM Cognos, SAP, Oracle, Information Builders, Microsoft, Microstrategy, Actuate, Tibco Spotfire , ESRI, i2, Clarabridge, Qlikview, Intergraph, Nexidia, Oculus
- **Other companies identified in the literature search**: Vision Systems and Technology (VSTI), Charles River Analytics, Modus Operandi, Prosync, Memex, Cernium

- Results: 664 patent families (substantive equivalents, grouped) representing 1989 grants or applications

12.1.3 Additional Sources Consulted

- AFCEA (Armed Forces Communications and Electronics Association) International http://www.afcea.org/mission/intel/ [presentations at http://www.afcea.org/events/pastevents/]
- Australia Defence Intelligence Organisation http://www.defence.gov.au/dio/index.html
- C4ISR Journal http://www.c4isrjournal.com
- Canadian Security Intelligence Service http://www.csis-scrs.gc.ca/
- Center for Advanced Defense Studies http://www.c4ads.org
- Center for Multisource Information Fusion, University of Buffalo, NY http://www.infofusion.buffalo.edu/
- Canadian Security Intelligence Service http://www.csis-scrs.gc.ca/
- CUBRC http://www.cubrc.org/WebModules/ServiceCategories/information.aspx
- Data Warehousing Institute http://tdwi.org/
- Geospatial Intelligence Forum http://www.geospatial-intelligence-forum.com
- ISR Technology Consortium http://isrtc.ndia.org/ (Member companies at http://isrtc.ndia.org/members.html)
- National Defense Industrial Association http://www.ndia.org
- National Military Intelligence Association http://www.nmia.org/
- National Visualization and Analytics Center http://nvac.pnl.gov/
- Open Source Center https://www.opensource.gov/
- Pacific Northwest National Laboratory: Technosocial Predictive Analytics Initiative http://predictiveanalytics.pnl.gov/
- Swedish Defence Research Agency http://www.foi.se/FOI/templates/startpage____96.aspx (some content in English)
- U.K. Defence Science and technology Laboratory (DSTL) http://www.dstl.gov.uk/
- U.S. Army Net-Centric Data Strategy http://data.army.mil/
- U.S. Army Intelligence Knowledge Network https://ikn.army.mil/
- U.S. Defense Intelligence Agency. Solutions for the Information Technology Enterprise (SITE) http://www.dia.mil/contracting/site/
- U.S. Department of Defense. Defense Information Systems Agency http://www.disa.mil/
- U.S. Department of Defense. Horizontal Fusion Project http://horizontalfusion.dtic.mil/
- U.S. Department of Homeland Security State and Local Fusion Centers http://www.dhs.gov/files/programs/gc_1156877184684.shtm
- U.S. Department of Justice Fusion Centers and Intelligence Sharing http://www.it.ojp.gov/default.aspx?area=nationalInitiatives&page=1181
- Global Justice XML http://www.it.ojp.gov/default.aspx?area=nationalInitiatives&page=1013
- US Intelligence Advanced Research Projects Activity http://www.iarpa.gov/
- U.S. National Geo-Spatial Intelligence Agency https://www1.nga.mil/Pages/Default.aspx
- U.S. National Reconnaissance Office http://www.nro.gov/

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Entries are presented in alphabetical order, and hyperlinks are provided whenever publications are freely available online.

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This Appendix presents notes on companies active in the area of technologies and information services for military intelligence. In the table, companies with a Canadian presence and/or products or services are shaded in blue.

Company	Notes and Sources
Accenture (US based with a Canadian office)	A consulting, technology services and outsourcing company which offers a business intelligence platform and services such as cloud computing. The company's US Defense group offers "…design, development and support of multi-level secure command and control systems; modeling and simulation; and satellite communications." Systems integration, data fusion, and analytical tools/services for the intelligence community are described in the company brochure.
Analytical Graphics Inc. (AGI)	A software developer for space, defence and intelligence applications. Their basic platform, STK, performs temporal and spatial analyses and simulations with 3D visualizations. It is interoperable with ESRI, Excel, Mathworks, Phoenix Integrations' ModelCenter, and many applications. It also offers functionality for the Android phone. Their webpage on C4ISR Software says that STK can be used for : "…real-time decision support, as well as operations research and post-mission analysis. With 40,000 global software installs and more than 1,000 deployed C4ISR systems, AGI's desktop applications and software development kits are immediately available to respond rapidly to warfighter requirements." Case studies are provided for the U.S. Marine Corps, the US Navy, and other vendors (Northop Grumann, Applied Defense Solutions).
Aptima Inc.	A Connecticut based firm specializing in human centered engineering, modelling and prediction, and the creation of collaborative online environments. Their case studies feature several examples of architectures that have been used for command and control, emergency response, and intelligence analysis. One of their prototype tools, VISTA (Visualization of Threats and Attacks in Urban Environments), was featured in a 2003 issue of the *Military Intelligence Professional Bulletin*. Customers include DISA, the US Army Research Laboratory, the Office of Naval Research, and others.
Autonomy	A global enterprise software and business intelligence firm offering functionality in areas such as enterprise (including legacy and federated) search, autonomic taxonomy generation and classification, real-time predictive queries, natural language processing, data governance, and collaboration/social networks. The company cites many intelligence and defence customers at http://www.autonomy.com/content/Customers/index.en.html. They are also mentioned in a 2004 report on information effusion and extraction initiatives on the part of Australia's Defence Science and Technology Organization.

BAE Systems	Global defence firm BAE is, among many other things, a provider of systems integration and (shared) content management. BAE provides intelligence support to UK forces in Iraq and Afghanistan.
Charles River Analytics, Inc.	A provider of sensor and image processing, situation assessment and decision aiding, human systems integration, and cyber security for government and commercial clients and based on heterogenous data sources. Their systems employ a mixture of statistical and algorithmic techniques (Bayesian and neural networks, case-based reasoning, genetic algorithms, etc.). Case studies on their website mention various defence/space applications. In December of 2010, Charles River was awarded a $4 million contract to support DARPA's GUARD DOG (Graph Understanding and Analysis for Rapid Detection - Deployed on the Ground) Project through its (to be developed) DEPEND (Detection, Explanation, and Prediction of Emerging Network Developments) System: "DEPEND will allow soldiers and intelligence analysts to rapidly discover, monitor, and predict changes in the people, organizations, and events they encounter, providing real-time assessments of threats and vulnerabilities."
CGI Group Inc. Montreal, QC	Montreal-based CGI provides a variety of enterprise solutions to governments, and in October of 2010 they were named as one of several firms to provide cloud computing services to the U.S. government.
Data Tactics Corporation	A provider of enterprise architecture and data integration/security/storage/management solutions. In December 2010, Data Tactics was awarded a contract with US Army Communications-Electronics Command for provision of cloud computing data mining services.
Decisive Analytics Corp.	A specialist in data fusion, analysis, and prediction, especially in distributed and real-time environments. Their website states: > Our complimentary functional areas include: Intelligent Decision Support Systems, Video Asset Management, Systems Analysis, Acquisition Support, Strategic and Operational User Support, International Support and System Security Engineering. Our customers include various DoD activities, other Government agencies and commercial businesses with requirements for affordable, effective systems solutions. In May of 2010, the company was named to the VAR500 list as one of North America's top technology integrators.

Future Point Systems Inc.	Future Point is the commercial vendor of Starlight, a data mining and data visualization tool developed by the Pacific Northwest National Laboratory and Battelle Memorial Institute. It can fuse numerous types of information and allows collaboration on the part of multiple users.
CallMiner	Maker of Eureka, speech analytics software suite that provides automatic categorization, search capability and trend analysis based on voice clips for various languages, dialects, and accents. The software is offered as a client-based version or as software as a service (with data housed locally, analysis and reports provided on the web). CallMiner is funded in part by In-Q-tel.
Cernium	Maker of video analytics products, primarily for security and (airport) traffic monitoring.
CUBRC	CUBRC is a not for profit research corporation, working closely with the University of Buffalo's Center for Multi-Source Information Fusion, and a recipient of US DoD funding. CUBRC has developed solutions for healthcare, defence, and homeland security, including a collaborative knowledge discovery tool called ORA which are geared specifically toward the research needs of intelligence analysts.
EADS	EADS and its sub-companies (e.g., Cassidian) provide system integration, simulation, communication, intelligence and surveillance products to military clients worldwide. ACTINT is its platform for the acquisition, processing and dissemination of ISTAR data products. EADS Exploitation et Valorisation des Images (EVI) system is a client-server image analytics program developed first for satellite imagery but also suitable for other image types. According to *Jane's C4I Systems*, it is used by the French Direction du Renseignement Militaire. EADS is also a commercial provider of satellite imagery to the US National Geo-Spatial Intelligence Agency. The company also provides portal access to military satellite imagery through PHAROS (Portail Hôte d' Accès au Renseignement de l'Observation Spatiale).
Endeca	Maker of an information access platform that can search database and unstructured information via its search engine and data integration. Endeca also provides data cleaning and enrichment (rules-based, entity extraction, statistical processing and metadata/taxonomy application) tools. Customers include the US Defense Intelligence Agency. Endeca is partly funded by In-Q-Tel. Endeca has also been awarded several contracts by the government of Canada (including DND) for faceted/semantic search.

FortiusOne	FortiusOne, a spin-off of George Mason University, is a maker of web-based location analysis software for decision making. . Its customers include US intelligence and defence agencies and the Department of Homeland Security. The company is funded in part by In-Q-Tel. The main product, GeoIQ, is a browser based tool for geospatial data management and analysis. GeoCommons and GeoIQ APIs extend functionality to support data exchange, tagging, and sharing mechanisms.
Fujitsu Consulting Canada	General provider of IT consulting services, Fujitsu has been awarded several government of Canada contracts in recent years for design/provision of service oriented architectures, enterprise platforms, and business intelligence tools. They also provided the platform and consulting services for the RCMP's new national criminal intelligence system.
General Dynamics Canada	General Dynamics offers system integration and data fusion techniques for data from sensors and other platforms. GD systems are also integrated into their other surveillance, command con control tools.
GeoSemble Technologies	GeoSemble provides automatic techniques for extracting and fusing geospatial data sets with other types of information. The main product, GeoXRay, filters content to a geographic area and keywords of interest, focusing on location and using text matching algorithms and natural language processing. The application is based on the Open GeoSpatial Consortium Application Programming Interface and can run on any OGC compatible client software. A graphical user interface is also available. GeoSemble is funded in part by In-Q-Tel, DARPA, the US Air Force, and others. The company is a spin-off of the University of Southern California.
HP Labs	Maker of tools and systems for enterprise computing, including analytics, cloud computing, interactive interfaces, and other information management systems. Taxonom DTX (Document Taxonomy Content – in public beta, and offered online as software as a service) automatically builds and refines conceptual models of information domains by mining content: this sensemaking taxonomy has been proposed for IARPA's ICARUS program.

HRL Laboratories	HRL's Information and System Sciences Lab conducts research into brain-machine interfaces, trusted computing, and automated knowledge and content extraction. HRL is a 2010 recipient of IARPA funding to develop "sensemaking" computational models for the interpretation of relationships within sparse or ambiguous data (part of IARPA's Integrated Cognitive-Neuroscience Architectures for Understanding Sensemaking, or ICArUS Program).
i2 Group	Maker of a suite of intelligence integration, analysis and visualization products. The main product, Analyst's Notebook, is available in 18 languages as an ESRI edition, and as a secure web-based (IntelliShare) application. Open source data analysis also features prominently on their website. With a worldwide customer base of over 4500 organizations, i2 supports operations for the defence, law enforcement and national security sectors.
IBM	IBM has managed numerous data fusion and system integration, software engineering and security projects for defence and intelligence agencies, per Frost and Sullivan market reports and business literature. Their ILOG technologies currently provide web-based architectures, integration, visualization, tactical decision support, and threat forecasts (as well as logistical supports) for military customers. In 2007, IBM purchased Cognos, the Canadian business intelligence software firm, and Cognos functionality is now central to IBM's BI offerings. [Cognos has also been awarded numerous government of Canada contracts for BI tools].
Interactive Visualization Systems (IVS3D) Fredericton, NB	Maker of interactive visualization and analysis products for marine/geospatial applications. Several military applications are cited on their corporate website.
Intergraph	http://www.intergraph.com/global/ca/events/canada2010/sgiseminars/defence.aspx Intergraph is a provider of engineering and geospatial analytical software. Its products are used by defence and intelligence agencies to produce operational maps, support decisions, manage weapons support, dispatch support teams, track threats and distribute information. Geospatial data can also be fused with full motion video supplied by unmanned aerial vehicles.

JackBe	Maker of Presto enterprise, on-the-fly, interactive and web-based data mashups for various government agencies including the Defense Intelligence Agency.[1]
SDL Language Weaver	Automated translation and natural language processing, available as a cloud service (SDL BeGlobal). funded in part by In-Q-Tel.
Lockheed Martin	One of the prime contractors for the Distributed Common Ground System (providing the backbone and SOA). An upgrade, announced in September 2010, will incorporate full motion video and imagery, as well as report compilation. See their page on intelligence solutions at http://www.lockheedmartin.com/isgs/intelligence.html Products include: Warfighter's decision aid (situational awareness product) Spatial Awareness Fusion Environment (ImSAFE) : Reports, visualization and tracking, accessed according to communities of interest; interactive polling, analysis and feedback. They also offer analyst training: http://www.lockheedmartin.com/products/intelligence-analysis-training/ Lockheed Martin Canada is also a key defence contractor, offering their full slate of products and services in this country.
Louis Tanguay Informatique et Génie Quebec, QC	Products for artificial intelligence, modelling/simulation, and system integration. The company has received several DND/DRDC awards in recent years for development of products/services.
MacDonald, Dettwiler and Associates Ltd. Vancouver, BC	"MDA's operational information solutions address all aspects of the complex information life cycle including data collection, data processing and management, information extraction, information distribution, and ultimately decision making."—website. Information integration is one cited specialty, as is management of geospatial data.
Modus Operandi	Service oriented architecture ("Wave Exploitation Framework")for multisource intelligence data enrichment, fusion and exploitation. Client base includes DARPA and various US defence agencies.

Northrop Grumann	Large scale network infrastructure and analytical systems for military and intelligence markets. One of the prime contractors for the US Distributed Common Ground System. The company is also a major defence contractor in Canada, selling mainly navigational and sensing equipment.
Oculus Inc. Toronto, ON	Visualization software for spatial/temporal intelligence analysis, and a partner with Endeca in the Endeca Latitude product. Oculus also provided the underlying software for DARPA's Command Post of the Future and several other C2 applications are referenced on the company website.
OSI Geospatial Ottawa, ON	Software for real time geospatial awareness, including fusion tools, decision support, and systems integration.
Palantir Technologies	Maker of a full-featured analysis platform, including versions for defence/intelligence/law enforcement. "We support many kinds of data including structured, unstructured, relational, temporal, and geospatial. Our products are built for real analysis with a focus on security, scalability, ease of use, and collaboration…Palantir enables secure information sharing across agencies and organizations in real-time while providing the strongest protection on privacy and civil liberties. " –website. Its open architecture also makes it easy to integrate with other products.
PrismTech	Standards based, secure, OpenFusion CORBA Middleware and other products for data distribution in netcentric environments. Contractor for some of the world's largest defence and aerospace companies. PrismTech's solutions comply with major current and emerging open standards including the OMG's Object Management Architecture (OMA), the Navy Open Architecture Computing Environment (OACE) and the Air Force Command and Control (AFC2) Enterprise Architecture.
ProSync Technology Group	Provider of a variety of IT services to the US DoD, including all source intelligence analytics
Psydex	Technologies for real-time searching, data mining, and predictive semantics. They cite DoD and the intelligence community as customers.

Quantum4D	Visual analysis platforms: "the technology easily converts [and overlays and integrates] multiple spreadsheets, databases and data feeds into visual moving models which enable real time identification of patterns, anomalies, correlations and trends." Also permits collaborative model-building. Quantum4D is funded in part by In-Q-Tel.
Raytheon	Maker of intelligence and analysis systems for DoD, DIA, NSA, FBI and others. Raytheon is one of the principal contractors for the DCGS system. Other offerings in their product line include security solutions in multi-user, multi-level environments, service oriented architectures, modeling, simulation and visualization. A recent presentation to the Geospatial Intelligence Forum gives some idea of Raytheon's current capabilities and R&D plans.[2] Raytheon Canada is also a major supplier of goods and services to DND.
Recorded Future	A web-based, semantically-driven predictive analytics engine, available by subscription at $149/month per seat.
Saffron Technology	Data and predictive analytics and decision support solutions for business and governments. Saffron's customers include U.S. national security and military agencies: it has been used to track criminal and terrorist activities and to analyze IED patterns in Iraq. Also one of the products cited in a report from Australia's Defence Science and Technology Organisation (re information fusion and extraction).
SAIC [Science Applications International Corporation]	A major ISR and defence contractor (e.g., a $6.6 billion contract from DIA for provision of information technology services[3]), with expertise in the area of data collection and analysis, network operations, web and content management and information assurance. Their search and visualization suite enables data mining and knowledge discovery for both structured and unstructured data.
Salience Analytics Vancouver, BC	"Surveillance and domain awareness techniques and technology", including visualization tools and ontology modelling. The company has been awarded several government of Canada contracts in recent years for products/services in the area.
SAP	SAP's Business Objects is one of the market leaders in business intelligence, but they also produce a data analytic tool based on Business Objects which is targeted for defence and security applications. Launched in 2010, Readiness Assessment, launched in 2010, is designed to help forces integrate data in order to gauge force readiness and plan missions. Collaboration and visualization tools are part of the package.[4]

SAS Institute	SAS is a global full service business intelligence and analytics company. They also provide functionality for Defense and Aerospace, including national security. In 2010, they acquired Vision Systems and Technology, thus bolstering capacity in the area of multi-INT data integration and analysis for the intelligence community. SAS also recently purchased Memex, which specializes in mission critical enterprise search solutions, with particular expertise in data integration, enterprise search and analysis technologies, for law enforcement. SAS is also known for its products for Social Network Analysis.
Semandex	Maker of Tango, a semantically enabled wiki for collaboration and dissemination, and based on data from SQL databases, RSS feeds, and numerous other sources. Past recipient of DARPA and CIA funding; DoD is also a client. Their case studies page offers several examples of military/security applications (including a web portal for inter-agency sharing of intelligence).
Soar Technology	Decision making support based on multisource data fusion (some from autonomous platforms), with an emphasis on human cognition and socio-cultural behaviour models. Customers include defence and government.
Streambase Systems	Complex event and streamed event processing. Developed principally for financial markets, but also has a military and intelligence version. Streambase Systems is funded in part by In-Q-Tel.
Temis	Multilingual text mining and productivity tools (the Luxid suite of products). Their web pages cite successful "homeland security" implementations for Europol and the French Ministry of Defence, among others.
Textron Systems	Collection, aggregation and analysis of data for situational awareness/intelligence. Overwatch, fusing multisource INT, is used by over 25,000 DoD and intelligence analysts; a September 2010 update provides enhanced feature extraction for image and LIDAR data. Full motion video is also supported. Textron is also a DCGS contractor
Thales Group Several offices in Canada	Numerous products for intelligence collection, fusion, and dissemination, such as Comm@nder Intel, Commander Joint (part of DND COP 21), MINDS (Multisensor Image Interpretation and Dissemination System), NIES (Networked Images Exploitation System), digital mapping tools and image analysis.

Thetus Corporation	Semantically based knowledge modelling and discovery products for a variety of markets, including law enforcement, defence and intelligence. Products include: • Thetus Publisher: modelling platform. Server-based. Policy management for user permissions across distributed systems. Inference search capabilities based on RDF/OWL. Information (event and entity) extraction can be integrated with geo-location. • Savannah: a geo-cultural and human terrain analytical workspace and inference engine. • Knowledge Services: the user interface. Thetus is supported in part by In-Q-Tel.
Tibco Spotfire	Tibco Spotfire for Government adapts the product's (web-based) business intelligence and analytics/visualization functionality for the public sector (including intelligence and law enforcement). The company states that it is used by over U.S. 65 government agencies.
Verint	Offers a suite of products for multisource (web, audio, video, and more) data integration and analysis for law and national security, including the ability to intercept communications and track mobile devices (within national and international laws and regulations).
Zel Technologies	ZelTech offers system engineering and process solutions to the intelligence and law enforcement communities, including platform integration, C4ISR systems based on multisource (structured and unstructured) data. Their website emphasizes visualization and integration of HUMINT and MASINT data as well as information assurance.
Zementis	Maker of predictive analytics platforms for finance, healthcare, energy, and defence industries. Awarded a contract by the U.S. Army's National Ground Intelligence Center in December 2010 for their Adaptive Decision and Predictive Analytics (ADAPA) Server-Production base. ADAPA is also available as a cloud-based application.

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Contents

Tables 1-3 present a matrix of the top players for literature and patents crossed with top subject areas.

Tables 1 and 2 (Literature) are colour coded: they use variable shades of red (bright red through pale pink) to indicate the top three values for each organization.

Because the distribution of "top values" expertise for patent assignees (Table 3), we have opted not to use a heat map for this table. Rather, to give a sense of the expertise and technological interests of each of the top 20 patent assignees as regards intelligence analytics, we present a comparison of the top three IPC values and subject groupings.

Table 1: Literature: Top 20 Organizations and Their Expertise

Organization	Military operations	Intelligence	Networks (Computer/Communications)	Modeling and simulation	Sensors and sensor nets	Analysis and analysts	Communications	Control	Learning systems and AI	Statistical methods	Information technology	Geospatial data & mapping	Algorithms	Information (knowledge) management	Data security, trust and access	Decision making	Surveillance and reconnaissance	Software	Forecasts, threat, alerts, patterns	Visualization and displays
Naval Postgraduate School, Monterey, CA	139	49	79	75	44	58	49	47	23	33	20	25	27	34	10	30	28	37	40	37
US Navy Space and Naval Warfare Systems Command, San Diego, CA	41	20	18	6	15	9	14	24	3	1	4	5	5	8	6	10	8	11	2	8
Swedish Defence Research Agency, Linköping, Sweden	31	8	10	13	17	12	13	13	5	7	30	4	4	4	6	7	5	3	6	4
National University of Defense Technology, Changsha, China	26	25	10	13	3	6	11	16	4	3	6			2	4		8	11	2	
US Air Force Research Laboratory, Rome, NY	31	12	18	16	14	8	12	9	8	6	8	6	8	10	3	10	2	6	7	10
US Army Research Laboratory, Adelphi, MD	28	16	13	9	19	4	15	6	3	3	6	3	8	5	4	1	16	4	4	4
Naval War College, Newport, RI	30	12	13	6	3	4	8	8	2		2	3	4	6	5	5	3		2	1
US Air Force Research Laboratory, Wright-Patterson AFB, OH	25	10	10	11	15	4	2	10	4	9	4	7	8	3	4	10	9	8	7	8
NATO Research and Technology Organization, Neuilly-sur-Seine, France	27	17	19	20	14	9	10	13	5	4	7	15	7	13	1	13	9	8	10	6
US Air Force Institute of Technology, Wright-Patterson AFB, OH	25	7	13	10	8	13	5	5	3	10	6	9	10	7	2	1	4	7	5	6
Naval Research Laboratory, Washington, DC	22	9	8	12	9	7	10	3	4	8	4	8	8	3	3	1	6	4	11	10
US Army War College, Carlisle Barracks, PA	24	12	5	5	5	7	7	6	4	1	2	1	2	5	4	5	5	1	3	1

Organization	Military operations	Intelligence	Networks (Computer/Communications)	Modeling and simulation	Sensors and sensor nets	Analysis and analysts	Communications	Control	Learning systems and AI	Statistical methods	Information technology	Geospatial data & mapping	Algorithms	Information (knowledge) management	Data security, trust and access	Decision making	Surveillance and reconnaissance	Software	Forecasts, threat, alerts, patterns	Visualization and displays
Defence Research and Development Canada, Valcartier, QC	23	8	12	10	8	6	3	12	5	4	3	10	3	7	2	11	3	3	8	8
U.S. Army CERDEC, Fort Monmouth, NJ	24	12	18	6	14	2	15	7	4	2	2	3	1	5	2	3	4	5	2	3
Naval Research Laboratory, Stennis Space Center, MS	18	3	3	1	10	7	1	1		3	3	9	5	7	2	6	2	9	2	1
Defense Science and Technology Organization, Edinburgh, Australia	18	8	7	5	11	6	2	6	3	7	6	6	9	4	2	2	7	5	7	3
Department of Defense, Washington, DC	17	6	12	3	8	4	9	6	1	1	4	3	3	3	2	4	3	2	1	6
Carnegie Mellon University, Pittsburgh, PA	9	8	6	5	7	13	5	2	5	9	3	4	7	4	6	5	2	3	1	3
US Army Research Laboratory, Aberdeen Proving Ground, MD	17	3	5	13	8	6	5	3	4	6	1	2	8	5	1	7	3	3	10	7
US Army Command and General Staff College, Fort Leavenworth, KS	17	6	6	5	2	1	4	6	2	1	1	5	2	3	1	4	4		3	

Table 2: Literature: Top Canadian Organization and Their Expertise

Organization	Military operations	Intelligence	Networks (Computer/Communications)	Modeling and simulation	Sensors and sensor nets	Analysis and analysts	Communications	Control	Learning systems and AI	Statistical methods	Information technology	Geospatial data & mapping	Algorithms	Information (knowledge) management	Data security, trust and access	Decision making	Surveillance and reconnaissance	Software	Forecasts, threat, alerts, patterns	Visualization and displays	Interoperability & joint operations
Defence Research and Development Canada, Valcartier, QC	23	8	12	10	8	6	3	12	5	4	3	10	3	7	2	11	3	3	8	8	10
Defence Research and Development Canada, Dartmouth, NS	6	6	1	4	4	1	1	2	1	1	3	1		5	1	1	4	1		1	1
Royal Military College of Canada, Kingston, ON	1	2	2	2	4	2		1	3	5		3	1			1	1		1		
Defence Research and Development Canada, Ottawa, ON	5	2		2	2	2	1	2	2		2	1	1	2		1	1		2		2
Defence Research and Development Canada, Toronto, ON	5			2	3	1		1	1	1	2		1			1		1	1	2	
HumanSystems Inc, Guelph, ON	5	1		3	2	2	1	1	1		1					1	1		1	3	4
University of Calgary, AB	3	1		2	3	2	1	1	3	1		2				1	2	1			2
University of Waterloo, ON	1	3	2	3	1	3		1	3		4	1	3	1	2	3		1	2	1	1
Communications Research Centre, Ottawa, ON	3		3	2	2	1	3			1		1	1						1		
University of Ottawa, ON		2	2			2	1		3	1	1		2	1	1				1		
Lockheed Martin Canada, Montreal, QC	1	1	1	1	1	1	1		1	2		2	1	1		1			1		1
University of Alberta, Edmonton, AB						2								1		1					

Organization	Military operations	Intelligence	Networks (Computer/Communications)	Modeling and simulation	Sensors and sensor nets	Analysis and analysts	Communications	Control	Learning systems and AI	Statistical methods	Information technology	Geospatial data & mapping	Algorithms	Information (knowledge) management	Data security, trust and access	Decision making	Surveillance and reconnaissance	Software	Forecasts, threat, alerts, patterns	Visualization and displays	Interoperability & joint operations
University of Regina, SK	1	1	1	2	1	2		1	1		2	1	2		1	2		1	2	1	

Table 3: Patents: Top 20 Assignees and Their Expertise (IPCs and Subject Groups)

Patent Assignee	Top Three IPCS (Value)	Top Three Subject Groups (Value)
Lockheed Martin	• Information retrieval & database structures therefor (20) • Methods or arrangements for processing data by operating upon the order or content of the data handled (15) • Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes (14)	• Collaboration and distribution (16) • Data fusion (15) • Sensor data (13)
IBM Corporation	• Information retrieval & database structures therefor (40) • Methods or arrangements for processing data by operating upon the order or content of the data handled (21) • Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes (18)	• Multidimensional data (22) • Analytical processing (13) • Search and retrieval (12)
Raytheon Co.	• Information retrieval & database structures therefor (14) • Combinations of two or more digital computers... for simultaneous processing (8) • Methods or arrangements for reading or recognising printed or written characters or for recognising patterns; Administration or management; Methods or arrangements for reading or recognising printed or written characters or for recognising patterns; Digital computers in general (6)	• Sensor data (9) • Data fusion; Visualization (7) • Semantics, ontologies, taxonomies, etc.; Data security and encryption (6)
U.S. Department of Energy	• Information retrieval & database structures therefor (18) • Methods or arrangements for processing data by operating upon the order or content of the data handled (5) • Digital computers in general (4)	• Visualization (11) • Analytical processing (8) • Semantics, ontologies, taxonomies, etc.; Data fusion (4)
Northrop Grumann Corporation	• Computer systems utilizing knowledge based models (12) • Knowledge representation in knowledge based computer systems (10) • Computer systems based on specific mathematical models (8)	• Algorithms; Decision support and problem solving (9) • Event processing and detection (6) • Data fusion; Sensor data (5)

Patent Assignee	Top Three IPCS (Value)	Top Three Subject Groups (Value)
Battelle Memorial Institute	• Information retrieval & database structures therefor (19) • Methods or arrangements for processing data by operating upon the order or content of the data handled; Digital computers in general (4) • Interaction techniques for graphical user interfaces; Digital computers in which a programme is changed according to experience gained by the computer itself (2)	• Visualization (11) • Analytical processing (9) • Data mining (6)
Microsoft Corporation	• Information retrieval & database structures therefor (14) • Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes (8) • Methods or arrangements for processing data by operating upon the order or content of the data handled (7)	• Multidimensional data (11) • Analytical processing (9) • Visualization (9)
Palantir Technologies	• Information retrieval & database structures therefor (10) • Methods or arrangements for recognition using electronic means; Finance, e.g. banking, investment or tax processing (risk analysis) (5) • Methods or arrangements for processing data by operating upon the order or content of the data handled; Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; Segmentation of touching or overlapping patterns in the image field; Context analysis based on the provisionally recognised identity of a number of successive patterns (3)	• Pattern classification and recognition (6) • Data integrity, governance, quality (4) • Access controls; Data mining; Large or massive datasets (2)
Oculus Technologies Corporation	• Digital output to display device (14) • Information retrieval & database structures therefor (11) • Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes (10)	• Visualization (22) • User interface (6) • Link analysis (5)
SAP AG	• Information retrieval & database structures therefor (9) • Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes (4)	• Analytical processing (10) • Visualization (7) • Multidimensional data (6)

Patent Assignee	Top Three IPCS (Value)	Top Three Subject Groups (Value)
	• Methods or arrangements for processing data by operating upon the order or content of the data handled; Methods or arrangements for effecting co-operative working between equipments covered by two or more of main groups (3)	
SAS Institute Inc.	• Information retrieval & database structures therefor (8) • Methods or arrangements for processing data by operating upon the order or content of the data handled; Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes (7) • Arrangements for sorting, selecting, merging, or comparing data on individual record carriers; Digital computers in general; Digital computers in which a programme is changed according to experience gained by the computer itself during a complete run; Computer systems utilizing knowledge based models; Computer systems using neural network models (for adaptive control); Administration or management; Finance, e.g. banking, investment or tax processing (risk analysis) (2)	• Analytical processing (6) • Visualization (5) • Multidimensional data; Prediction and forecasts (4)
Boeing Co.	• Methods or arrangements for processing data by operating upon the order or content of the data handled; Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes (4) • Accessing, addressing or allocating within memory systemsor architectures; Digital computers in general; Digital computers in which a programme is changed according to experience gained by the computer itself during a complete run; Information retrieval & database structures therefor; Commerce, marketing; Information storage based on relative movement between carrier and transducer (3) • Direction finders using electromagnetic waves other than radio waves; Control of position, course, altitude, or attitude of land, water, air, or space vehicles; Target seeking control; Computer systems utilizing knowledge based models; Knowledge representation; Data transmission control procedure (2)	• Integration (4) • Netcentric systems; Targets and surveillance; Data cleaning (3) • Alerts and threat assessment; Multidimensional data; data mining (2)

Patent Assignee	Top Three IPCS (Value)	Top Three Subject Groups (Value)
Endeca Technologies Inc.	• Information retrieval & database structures therefor (15) • Methods or arrangements for processing data by operating upon the order or content of the data handled (7) • Arrangements for sorting, selecting, merging, or comparing data on individual record carriers (2)	• Search and retrieval (16) • Semantics, ontologies, taxonomies, etc. (6) • Classification and clustering; Data integrity, governance, quality (2)
Verint Systems Inc.	• Information retrieval & database structures therefor (4) • Arrangements for sorting, selecting, merging, or comparing data on individual record carriers; Administration or management; Determination or detection of speech or audio characteristics; Monitoring arrangements; Communication control or processing; Systems providing special services or facilities to subscribers (2)	• Search and retrieval (3) • Images and video; Sensor data; Link analysis; Speech and voice processing; Large or massive datasets; Multisource data (2) • Analytical processing; Semantics, ontologies, taxonomies, etc.; Data management systems; Real time or streamed data; Prediction and forecasts (1)
I2 Technologies Inc.	• Methods or arrangements for processing data by operating upon the order or content of the data handled (5) • Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes (4) • Information retrieval & database structures therefor; Administration or management (3)	• Semantics, ontologies, taxonomies, etc. (3) • Visualization; Analytical processing; Business intelligence (1)
Nuance Communications	• Methods or arrangements for recognition using electronic means (4) • Segmentation of touching or overlapping patterns in the image field (3) • Methods or arrangements for reading or recognising printed or written characters or for recognising patterns using sequential comparisons of the image signals; Methods or arrangements for reading or recognising printed or written characters or for recognising patterns using context analysis based on the provisionally recognised identity of a number of successive patterns; Image analysis (2)	• Pattern classification and recognition (6) • Data integrity, governance, quality; Data mining (2)
Hyperion Solutions Corp.	• Information retrieval & database structures therefor (9) • Methods or arrangements for processing data by operating upon the order or content of the data handled (8)	• Multidimensional data (6) • Data management systems (3) • Visualization; Search and retrieval; Integration (2)

Patent Assignee	Top Three IPCS (Value)	Top Three Subject Groups (Value)
	• Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes (3)	
Nexidia Inc.	• Information retrieval & database structures therefor (6) • Speech recognition; Speech segmentation or word limit detection (4) • Digital computing or data processing equipment or methods specially adapted for specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; Speech or audio signal analysis-synthesis techniques for redundancy reduction (3)	• Speech and voice processing (5) • Search and retrieval (3) • Visualization; Semantics, ontologies, taxonomies, etc. ; Multisource data (2)
Charles River Analytics Inc.	• Computer systems using knowledge based models (5) • Knowledge representation in knowledge based computer systems (4) • Digital computers in general; Handling natural language data; Inference methods or devices; Computer systems based on specific mathematical models; Computer systems using fuzzy logic (2)	Pattern classification and recognition; Scenarios and game theory (3) Sensor data; Collaboration and distribution (2) Analytical processing; User interface; Modelling, simulation and optimization; Alerts and threat assessment (1)
Honeywell International	• Methods or arrangements for reading or recognising printed or written characters or for recognising patterns; Closed circuit television systems (3) • Information retrieval & database structures therefor; Methods or arrangements for recognition using electronic means (2) • 23 other IPCS with a value of 1 only	Images and video (5) Data fusion; Sensor data (3) Analytical processing; Search and retrieval; Collaboration and distribution; Distributed/remote data (1)

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12.5 Patents (in a separate file - available on request)

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[78] The top five country rankings were: United States, 1717 publications; China, 237; United Kingdom, 104; Canada, 83; and Australia, 52.

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To address the questions posed in the project mandate, we collected data from three complementary information streams: market research, scientific and technical literature, and patent grants and applications.

Results indicate this is an active and competitive space, with both commercial and military participants. Private enterprise has made significant contributions in the form of the key technologies underpinning business intelligence architectures and analytical methods. The intelligence community has adapted that functionality to its own purposes, and advanced capability in areas such as data governance and grids, security, visualization, interoperability, and the exploitation of specific types of intelligence data (sensor/signals, geospatial, visual, HUMINT).

Pour répondre aux questions posées dans le mandat du projet, nous avons recueilli des données à partir de trois sources d'information complémentaires : études de marché, documentation scientifique et technique, et brevets approuvés ou demandés.

Les résultats indiquent qu'il s'agit d'un milieu actif et compétitif, avec des participants commerciaux et militaires. L'entreprise privée a apporté des contributions significatives sous la forme de technologies clés qui sous-tendent des méthodes d'analyse et des architectures de renseignements d'affaires. La communauté du renseignement a adapté cette fonctionnalité à ses propres fins, et a perfectionné des capacités dans des domaines tels que la gouvernance et les grilles de données, la sécurité, la visualisation et l'interopérabilité, et l'exploitation de types précis de données de renseignement (capteurs/signaux, géospatial, visuel, HUMINT).

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