Science and Technology Organization

TECH TRENDS REPORT **2017**

Empowering the Alliance's Technological Edge

NATO SCIENCE & TECHNOLOGY BOARD

STO Tech Trends Report 2017

FOREWORD BY THE CHAIRMAN

The Alliance will face increasingly complex challenges as it executes its role in helping to maintain the world's strategic balance in the future. Global trends such as demographic and economic shifts, increasingly rapid technological advances, technology proliferation, competition for scarce resources, and the changing nature of conflict portend a complex geopolitical and operational environment for future NATO actions.

Maintaining the edge in defence and security will therefore be of critical importance for the Alliance and its Partners. At the 2016 NATO Summit in Warsaw[1], the NATO Allies reiterated their intent to innovate by discovering, developing, and utilising advanced knowledge and cutting-edge science and technology. Such efforts are fundamental to maintaining the technological edge that has enabled the Alliance to succeed across the full spectrum of operations over the past decades.

Recognizing this pressing need to maintain the Alliance's technological edge, the NATO Science & Technology Board requested the NATO Science and Technology Organization (STO) Panels and Group to actively keep track of potentially disruptive emerging technologies for the Alliance. For several years, experts in the Panels and Group have been generating Technology Watch Cards which highlight potentially disruptive developments in science and technology and are used to ensure the NATO STO collaborative studies focus on the most important areas of research for the Alliance.

The Technology Watch Cards are dynamic and constantly updated with new information, but it is also useful to take a snapshot of the cards from time to time. This NATO STO Tech Trends Report for 2017 is one of those snapshots and provides a synthesis of the emerging technology trends identified in the NATO STO's Technology Watch Cards.

Please note that this is the publically releasable version of the report specifically designed to make the information widely accessible to the public - including through the internet.

I hope you will find this report both useful and informative, and should you have a further interest in the current activities of the NATO STO I strongly encourage you to read our Annual Report for 2016[2].

We also encourage you to direct any feedback you may have to techtrends@sto.nato.int so that the NATO STO can continue to enhance the relevance and further improve the utility of this product for the Alliance.

Dr Thomas KILLION
NATO Chief Scientist

[1] NATO, 2016, *Warsaw Summit Communiqué*, viewed 20 June 2017, http://www.nato.int/cps/en/natohq/official_texts_133169.htm

[2] NATO STO, 2017, *Annual Report 2016*, viewed 1 August 2017, https://www.sto.nato.int/publications/Management Reports/STO Annual Report 2016.pdf

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NATO SCIENCE & TECHNOLOGY BOARD

STO Tech Trends Report 2017

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DISCLAIMER

This report is intended to provide the highlights of Technology Trends observed by the NATO STO. It does not provide an exhaustive list of all emerging technologies but focusses on the technologies which fall under the purview of the NATO STO Panels and Group and those that are favourable to international collaborative research within a NATO context.

The predicted timeframes for when the Technology Trends are expected to disrupt military operations and capabilities should be used with due care. The predicted timeframes are an estimate for how long it may take the technologies referenced in the Technology Trends to reach maturity and how long it will take before the disruptive influence of the technologies will be strongly felt in a military context. When predicting time to maturity, it is always possible that a new discovery might spur the technology development ahead turning 20 years into 2 years, or vice versa, that today's challenges prove more difficult or even impossible to overcome, turning a prediction of 2 years into a prediction of 20 years. When predicting time to deployment in a military context it also depends on the intended applications of the technology. While some applications of the technology may already be in common use by the military, other applications may still be several years away. For example, Unmanned Air Vehicles are regularly used in theatre today so it could be argued they don't belong in this report, but further disruption from this technology is expected to come from the proliferation of Unmanned Combat Air Vehicles, and the introduction of passenger carrying Unmanned Air Vehicles, and Micro Unmanned Air Vehicles, all of which are still a few years away.

Examples of technologies are provided at the bottom of the Technology Trends descriptors to give the reader a taste for the maturity of the technology today. References to non-NATO entities in this report, including in the examples, do not constitute an endorsement of their product by NATO, the NATO STO or any of the Allies. Examples were chosen based on their quality, and appropriateness for the Technology Trend and were limited to those found in open sources published in English. Wherever possible, NATO examples were chosen over industry examples.

INTRODUCTION

This is the first biennial report on emerging trends in science and technology published by the NATO Science & Technology Organization (STO). The report has three primary objectives. First, it is intended to inform NATO and Partner Nations about science and technology trends that are likely to influence the future operating environment and shape warfighting capabilities in the short, medium and long term, up to and beyond 20 years. Second, it is intended to spark strategic dialogue around the kind of science and technology investments Allies should make to ensure that their forces maintain the technological edge in future operations. Thirdly, it is intended to make the information in the STO Technology Watch Cards more accessible to a general audience.

Anatomy of the Technology Trend one-page format used in this report.

The NATO STO Tech Trends Report 2017 is a compact synthesis of observed Technology Trends that builds on the Technology Watch Cards of the STO Panels and Group (see box at the bottom of this page) and open source literature as appropriate. This report presents 12 Technology Trends in a one-page format that includes a summary description of the technology, the trends that are being observed, opportunities and challenges arising from the trending technology, defence and security applications of the trending technology and an example of the state of the art for that technology today. The references used to build the Technology Trends are listed at the end of the report.

This report was created using a four step methodology. First, the NATO STO Panels and Group were asked to review and update the Technology Watch Cards. Second, cards relating to similar science and technology trends were grouped together to derive 12 Technology Trends. Third, text from the cards and open source literature was used to build the Technology Trends one-pagers. Finally, the 12 Technology Trends were allocated to short, medium or long term disruption categories. All steps were supported with critical review and input from experts in the NATO STO Panels and Group.

The Technology Trends in this report are presented in the order of when they seem most likely to deliver their most disruptive effect in military operations. The timeframes for disruption correspond to those used by NATO defence planners: short term <6 years; medium term 6-20 years; and long term >20 years. The tables that follow this introduction provide a visual overview of which Technology Trends have been allocated to each timeframe.

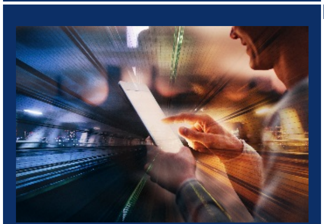
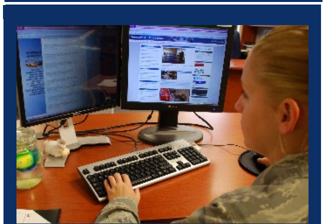
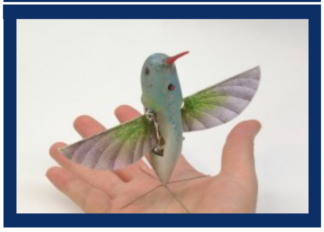
STO TECHNOLOGY WATCH CARDS

The STO Technology Watch is a systematic approach to identifying militarily important technologies that hold the potential to contribute to, or enable, the development of military capabilities that may have a "game-changing" or disruptive effect for friendly and potential adversary forces alike. The STO keeps and updates various Technology Watch Cards which are intended to communicate to NATO and National leadership the potential impacts of these technologies for both friendly and adversarial capabilities.

DISRUPTION IN THE SHORT TERM

Table 1 shows a list of the five technology trends expected to achieve peak disruption in defence and security within the next six years.

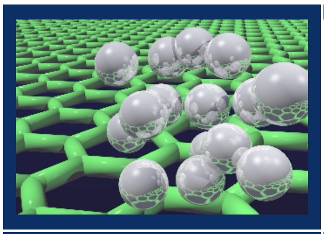
Table 1: Technology Trends for Disruption in Short Term <6 years

	**Additive Manufacturing** is the process of making a 3D solid object of virtually any shape from a digital model in ways that are impractical to achieve using conventional manufacturing. Additive Manufacturing can be used for, among other things, rapid prototyping, in-site production and repair of deployed military equipment, precision, custom and unique parts production.
	**Everywhere Computing** is computing that is available anytime and anywhere. It can occur in any device, in any location and in any format and its content is interoperable regardless of the operating system. Supported by military mobile networks and mission cloud computing, Everywhere Computing has the potential to provide real time decision support to the individual soldier and their families at all times and all places.
	**Predictive Analytics** is the process of generating understanding and providing insight for inference or forecasts of future states from data with volume, velocity, variety or dubious veracity, i.e. Big Data. Huge amounts of data in the future battlespace means potential for analytics to deliver insight across all warfighting and defence domains, real time decision support, early indicators and warnings of crises and real-time monitoring.
	**Social Media** refers to the wide range of internet-based and mobile interactions where users participate in online shared exchanges and contribute user-related content or participate in online communities of mutual interest. Its applications in defence and security include population surveillance, sentiment analysis, knowledge and information sharing, low cost means to stay in touch with families and strategic communications.
	**Unmanned Air Vehicles** are vehicles that may be remotely controlled by a person or may act autonomously depending on the mission. Applications include allowing for access to unreachable areas, persistent surveillance, endurance, robots in support of soldiers, cheaper, automated logistics deliveries.

DISRUPTION IN THE MEDIUM TERM

Table 2 shows a list of the three technology trends expected to achieve peak disruption in defence and security within the next six to twenty years.

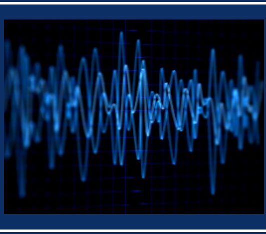
Table 2: Technology Trends for Disruption in Medium Term 6-20 years

	**Advanced Materials** are artificial materials with unique and outstanding properties. Advanced materials are manufactured using techniques such as nanotechnology or synthetic biology. Uses may include coatings with extreme heat resistance, high strength body or platform armour, stealth technologies, advanced sensors and decontamination, bulk production of food, fuel and building materials.
	**Mixed Reality** is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. Applications include heads up or head mounted displays for pilots and soldiers for real-time situational awareness, digital cockpits/windows, realistic training environments or providing hands-free job performance aids.
	**Sensors are Everywhere** refers to the ability to detect and track any object or phenomenon from a distance by processing data acquired from high tech, low tech, active and passive sensors as well as background sensors, essentially everything could be a sensor. Applications include universal air picture, underwater sensor nets, social media exploitation, automated logistics planning, autonomous systems, soldier systems.

DISRUPTION IN THE LONG TERM

Table 3 shows a list of the four technology trends expected to achieve peak disruption in defence and security after twenty years or more.

Table 3: Technology Trends for Disruption in Long Term >20 years

	**Artificial Intelligence** refers to the ability of machines to match humans in terms of learning, reasoning, planning and acting in complex cyber-physical environments. Potential impact includes replacement for human decision makers, autonomous robot or vehicle control, automated information fusion and anomaly detection, psychological operations and intelligent tutoring for a variety of military and support (medical) missions.
	**Electromagnetic Dominance** is the ability to use more of the spectrum, to share the spectrum more efficiently, to protect own forces' use of the spectrum and to deny enemy use. The future will bring, among other things, faster, more reliable wireless/radio communications, electronic warfare resilience, secure streaming video and smaller deployed footprint.
	**Hypersonic Vehicles** can be aeroplanes, missiles or spacecraft. Hypersonic vehicles can move at a speed beyond Mach 5, the same speed regime as a re-entry vehicle or space shuttle experiences as it reaches the lower atmosphere. Potential applications include fast long range strike of high value or high threat targets, ballistic missile defence and reusable space transport vehicles.
	**Soldier Systems** refers to the augmentation of individual human abilities using artificial means such as robotic exoskeletons, smart textiles, drugs, and seamless man-machine interfaces. Uses include capacity to endure extreme environments, better health monitoring and care provision, decision making at individual level.

Technology Trends

The following pages present the 12 Technology Trends in a one-page format which includes a summary description of the technology, the trends that are being observed, opportunities and challenges arising from the trending technology, defence and security applications of the trending technology and an example of the state of the art for that technology today:

1. ADDITIVE MANUFACTURING

Additive Manufacturing is the process of making a 3D solid object of virtually any shape from a digital model in ways that are impractical to achieve using conventional manufacturing. Additive Manufacturing can be used for, among other things, rapid prototyping, in situ production and repair of deployed military equipment, precision, custom and unique parts production.

TRENDS – Disruption in Short Term (<6 years)

Though Additive Manufacturing techniques, equipment and technology have been rapidly advancing in recent years, their maturity is not yet sufficient for widespread, full rate manufacturing with the requisite reliability. (Ref 3)

Roughly two-thirds of US manufacturers have already adopted 3D printing with around 50% already using it for prototyping and final products. (Ref 5)

Aerospace and defence professionals and US manufacturers predict the following trends:

- 3D printing will be used for high-volume production in the next 3-5 years. (Ref 5)
- The use of additive manufacturing – or 3D printing – will be ubiquitous in the aerospace and defence industry within the next 10 years. (Ref 2)
- 3D printing's most disruptive effects will include (Ref 5):
  - Restructuring supply chains; and
  - Threats to intellectual property.

3D bioprinting is being applied to regenerative medicine to create tissues and organs suitable for transplantation. (Ref 9)

OPPORTUNITIES

- Ability to create bespoke, customised parts (Ref 2) and for more complex parts to be produced (Ref 7).
- Cost-effective manufacturing (Ref 2), cutting down on material and production costs (Ref 7), parts costs down 50% (Ref 4), scrap down to 10% (Ref 4).
- Production of lighter materials and finished parts (Ref 2), part weight down 64% (Ref 4).
- Breaking current engineering/manufacturing limits.
- Faster prototyping cycles (Ref 7), time-to-market down 64% (Ref 4).

CHALLENGES (Ref 2)

- Availability of suitable and cost competitive materials for additive manufacturing of some types of parts.
- Production process too slow.
- Patent/intellectual property issues.
- Too much already invested in current equipment.
- It will change the profit/market structure.

DEFENCE & SECURITY APPLICATIONS

Current applications include (Ref 4):

- Concept modelling and prototyping;
- Printing low-volume complex parts;
- Printing replacement (obsolescent) parts; and
- Printing structures using lightweight, high strength materials.

Potential applications include (Ref 4):

- Embedding additively manufactured electronics directly in/on parts;
- Printing repair parts on the battlefield or in space; and
- Printing large structures directly in location thus circumventing transport vehicle size limitations.

The European Defence Agency is launching a new Additive Manufacturing project geared towards exploring and establishing how additive manufacturing can benefit and be used for defence applications. (Ref 6)

US Army Uses 3D Printing on the Frontline

As part of its mission to equip, insert and assess emerging technologies and rapidly address capability shortfalls, the US Army's Rapid Equipping Force (REF) deploys small teams of soldiers and engineers to forward locations.

In 2014, the REF inserted two, 20-foot, containerized mobile expeditionary labs to deploy to units in isolated locations. A unit approached the lab for help with the Mine Resistant Ambush Protected vehicle because the tire inflation systems deflated when rocks damaged the valve stem. REF used their advanced 3D printer facility to design a simple cap solution made using the 3D printer, which, through iterative design, evolved into a lasting solution. (Ref 8)

2. EVERYWHERE COMPUTING

Everywhere Computing is computing that is available anytime and anywhere. It can occur in any device, in any location and in any format and its content is interoperable regardless of the operating system. Supported by military mobile networks and mission cloud computing, Everywhere Computing has the potential to provide real time decision support to the individual soldier and their families at all times and all places.

TRENDS – Disruption in Short Term (<6 years)

Everywhere computing is more than just giving smartphones to soldiers. It is about connecting devices to each other and the ability for forces to benefit from distributed data structures and cloud computing services. It also encompasses software-driven functionality, the ability to process incoming data at the sensor before transmission, and advances in encryption that will enable assured information transfer across a network.

In 2017, centralized-only data silos will disappear. Smart devices will collaborate. Analytics will be processed at the edge where the data was born and exists, and in real-time. Machine learning algorithms will be able to adjudicate 'peer-to-peer' decisions in real time. (Ref 1)

Decision makers will have access to sophisticated simulation models to support time-sensitive decision making. (Ref 2) Access to models will also be available during training to improve realism. (Ref 4)

Low power flexible displays for soldiers will enhance information flow between the tactical and command levels and improve situational awareness. (Ref 5)

In the further future, quantum encryption will allow encrypted communications between parties, that instantly reveal eavesdropping. (Ref 7)

OPPORTUNITIES

- Information assured communications. (Ref 7)
- Processing at the sensor (including in space) reduces bandwidth requirements. (Ref 8)
- Faster and more flexible availability of modelling and simulation related services with reduced local footprint (computing power, storage, energy, cooling, etc). (Ref 3)
- Enriched live training environments with instrumented ranges, simulated command and control etc. (Ref 4)

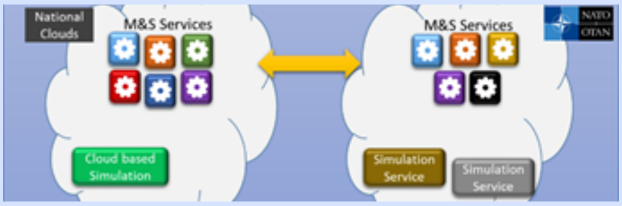
CHALLENGES

- Cyberattacks could prevent availability or assurance of the services. (Ref 3)
- Overreliance on computers in decision making.
- Proliferation of access to mobile computing solutions by adversaries. (Ref 5)
- Quantum encryption has technological challenges to overcome such as cost, range, room temperature operation and overcoming man-in-the-system intrusions. (Ref 7)
- Adversary use of quantum encryption makes it harder to eavesdrop. (Ref 7)

DEFENCE & SECURITY APPLICATIONS

- Enhanced, low power display capabilities for soldier systems. Increased information flow between the tactical and command levels and improved soldier situational awareness. (Ref 5)
- Real-time decision support at all levels of command. (Ref 2)
- Enhanced live training environments. (Ref 4)
- Advanced processing at the sensor, resulting in lower bandwidth requirements, faster sensor to shooter times and more reliable data transfer.
- Distributed data structures allow nations to maintain ownership and control of data, while sharing within a coalition.
- Presentation and visualisation of the current and future state of materiel made available by a number of different hardware tools including handheld devices. (Ref 6)
- Secure key distribution for crypto nets with fibre optic or line of sight connection (Ref 8), or between satellites. (Ref 10)

NATO Moves Towards Modelling and Simulation as a Service in the Cloud



To a great extent, future military training, analysis, and decision making capabilities will be provided by Modelling and Simulation. The combination of service-based approaches with ideas taken from cloud computing known as "Modelling & Simulation as a Service" is considered to be a very promising approach for realizing next generation simulation environments. The NATO Modelling and Simulation Group activity investigated, proposed and evaluated standards, agreements and architectures for incremental implementation of a permanently available, flexible cloud-based eco-system to provide on-demand accessible and convenient Modelling and Simulation to a large number of users. (Ref 9)

3. PREDICTIVE ANALYTICS

Predictive Analytics is the process of generating understanding and providing insight for inference or forecasts of future states from data with volume, velocity, variety or dubious veracity, i.e. Big Data. Huge amounts of data in the future battlespace means potential for analytics to deliver insight across all warfighting and defence domains, real time decision support, early indicators and warnings of crises and real-time monitoring.

TRENDS – Disruption in Short Term (<6 years)

Artificial Intelligence, specifically machine learning, can process large volumes of seemly disparate, disorganized, and ostensibly unrelated information and discern from it intangible connections between people, places and events. These predictive, correlative models are valuable measures for detecting intent and predicting likely future actions and events. The utility of these models and deep learning techniques will increase as methods for data-driven learning mature. (Ref 6)

The volume of data will continue to grow especially considering that the number of handheld devices and Internet-connected devices is expected to grow exponentially. More tools for analysis (without the analyst) will emerge. (Ref 8)

Companies will grow increasingly data-driven and willing to apply analytics-derived insights to key business operations. Intuitive decision-making will diminish somewhat as companies infuse analytics into everything that employees touch. (Ref 7)

By 2018, an expected 50% of all business ethics violations will be related to data. Organizations will struggle with data privacy, security and governance issues. (Ref 8)

OPPORTUNITIES

- Integrated Munition Health Management models enhance understanding of relative safety, reliability and performance risks and provide a number of military, logistics and monetary benefits. (Ref 3)
- Integrated System Health Management enables smarter management decisions and life cycle cost savings. (Ref 4)
- Geo-referenced social network data can be used to generate accurate models of infrastructure or energy networks, demographics, political or tribal affiliations. (Ref 2)
- Simulation is used as a tool to analyse options and bandwidth of possible outcomes in real time in the battlefield. (Ref 11)

CHALLENGES

- The commercial sector will be a provider of a substantial amount of relevant information.
- Adversaries will have access to much of the same data.
- Big data raises big concerns about security, privacy and governance. (Ref 8)
- Siloed data within different agencies is inaccessible in operationally relevant timescales. (Ref 9)

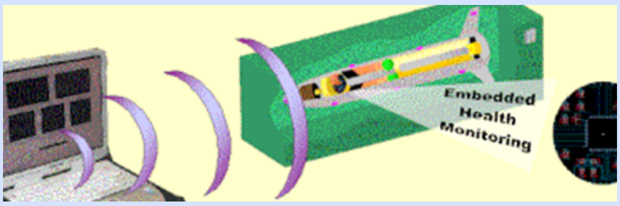
DEFENCE & SECURITY APPLICATIONS

In 2015, DARPA's budget revealed a growing focus not on new data sources but on developing entirely new and far-fetched methods for processing it. (Ref 5)

Applications in the defence and security sector include:

- Improved mapping of mission areas for planning & preparation and rehearsal environments. (Ref 2)
- Greater understanding of the current condition of munitions and their ability to complete mission objectives. (Ref 3)
- Optimization of defence capability life cycle costs. (Ref 4)
- Situational awareness, patterns of life and anomaly detection. (Ref 10)
- Real time cyber defence event detection and response. (Ref 10)
- Faster and more accurate intelligence, surveillance and reconnaissance capabilities and multiple intelligence source analysis. (Ref 10)
- Algorithmic optimization of individual personnel and team performance and readiness. (Ref 1)

NATO Integrated Munition Health Management (IMHM)



The STO Applied Vehicle Technology Panel IMHM initiative is revolutionizing the way munition health and safety is monitored, analysed, predicted and managed. In IMHM:

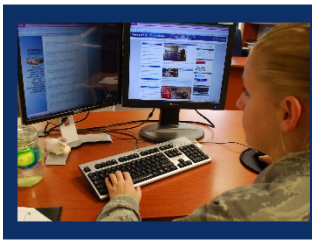
1) Data is acquired from precision sensors.

2) Data is analysed in predictive models that assess the likelihood of current defects, the extent of aging, the safe remaining service life, etc.

3) Assessments are sent to handheld devices.

4) End users such as logisticians, item and fleet managers, and safety authorities pro-actively manage the stockpile based on the analysis. (Ref 3)

4. SOCIAL MEDIA



Social Media refers to the wide range of internet-based and mobile interactions where users participate in online shared exchanges and contribute user-related content or participate in online communities of mutual interest. Its applications in defence and security include population surveillance, sentiment analysis, knowledge and information sharing, low cost means to stay in touch with families and strategic communications.

TRENDS – Disruption in Short Term (<6 years)

In 2011, DARPA set aside $40m in funds for the Social Media in Strategic Communications (SMISC) programme for study in the areas of: linguistic cues, patterns of information flow, topic trend analysis, narrative structure analysis, sentiment detection and opinion mining; meme-tracking across communities, graph analytics/probabilistic reasoning, pattern detection, cultural narratives; inducing identities, modelling emergent communities, trust analytics, network dynamics modelling; and automated content generation, bots in social media and crowd sourcing. (Ref 6)

As social media reaches more corners of society, it increasingly allows for significant and subtle influences on expression of collective political and social power. The technology has the potential to alter the nature of political and social discourse leading to new, rapid and decisive mobilization of populations at the right place and right time to achieve political and social objectives. (Ref 2)

Visualization techniques are key enablers in working with social media data. The civilian market is starting to use some visual analytics methods for marketing purposes. This technology may be partly transferable to the defence and security domains. (Ref 1)

OPPORTUNITIES

- Social media and associated mobile computing, apps, devices, programs and capabilities provide network enabled capabilities to anyone at low cost with minimal training, knowledge and skill barriers. (Ref 2)
- Social media may provide significant opportunities to forces for flexible, redundant and scalable communications at strategic, operational and tactical levels. (Ref 2)
- Capabilities inherent in devices utilized to enable social media, such as video, audio, text, GPS, proximity detection and others will transform traditional intelligence, surveillance and reconnaissance. capabilities. (Ref 2)

CHALLENGES

- Adversaries have at their disposal, low cost, capabilities with doctrinal similarities to those of conventional state-controlled forces. (Ref 2)
- Social media supports doctrines that employ deception, diplomatic 'warfare' and influence operations designed to undermine, delay or frustrate own forces or populations. (Ref 2)
- Social media streams are vulnerable to disruptive cyber actions.

DEFENCE & SECURITY APPLICATIONS

Deep learning used in the deciphering of internet content has the potential to identify security relevant information through social behaviour on the internet merged with content extraction from multiple text documents (even if specific intent is not explicitly referenced). (Ref 3)

Contextual programming will allow search engines to find more than just the searched keywords, but also discern the intent behind the search and offer more targeted information. This may be used to predict personal security risk from a deep analysis of personal contacts, personal and social network behaviour, and location. (Ref 3)

A combination of social media data with traditional sensor data can provide a richer, more accurate picture of objects of interest. (Ref 4) Geo-tagged social media data can generate accurate environmental pictures. Other contributions to intelligence, surveillance and reconnaissance are possible. (Ref 5)

Comprehension of adversarial group behaviours will enable the generation of actions that are disruptive to their goals and activities. (Ref 4)

Real-time Crisis Mapping using Social Media

Researchers at the University of Southampton have developed a social media crisis mapping platform for natural disasters. They take locations from gazetteer, street map and volunteered geographic information sources for areas at risk of disaster and match them to geo-parsed real-time tweet data streams. They use statistical analysis to generate real-time crisis maps. Geo-parsing results are benchmarked against existing published work and evaluated across multi-lingual datasets. Two case studies comparing tweet crisis maps to official post-event impact assessment compiled from verified satellite and aerial imagery sources showed 90% accuracy of this unofficial mapping. (Ref 5)

5. UNMANNED AIR VEHICLES

Unmanned Air Vehicles are vehicles that may be remotely controlled by a person or may act autonomously depending on the mission. Applications include allowing for access to unreachable areas, persistent surveillance, endurance, robots in support of soldiers, cheaper, automated logistics deliveries.

TRENDS – Disruption in Short Term (<6 years)

A variety of unmanned systems are already used within military operations in all domains. However, these systems are limited in their usage and are not able to conduct all missions. To fully cover the military needs research is still required to increase the maturity of key technologies. (Ref 1)

In the near term, full autonomy of unmanned systems for military use can be expected for simple tasks only. For example, the current state of technology may be sufficient to create remotely piloted or autonomous helicopters that are capable of delivering supplies and ammunition to troops in the field, as long as specific instructions and restrictions guide these Unmanned Air Vehicles (UAV). (Ref 1)

Micro and mini air vehicles are an emerging solution for a broad range of modern military missions, including urban and unconventional warfare, battle damage assessment, tactical intelligence, surveillance and reconnaissance. (Ref 2)

Micro unmanned air vehicle research aims to realize the stimulation of bio-mimetic materials and new flexible materials for wing surfaces. (Ref 2)

OPPORTUNITIES

- Capability to gather constant, reliable information over vast geographical areas at a much greater level of detail than ever before. (Ref 3)
- Hand-carried micro UAVs deployable by soldiers in urban environments.

CHALLENGES

- Risk of collision during operation in civil airspace.
- Risk associated with autonomous decision making for lethal actions at range emanating from challenges with reliable and precise target identification and unintended or collateral damage etc. (Ref 1)
- Technology challenges connected to micro UAVs can be summarized as: complex aerodynamics require powerful on-board computers, sensors and power sources, but weight must be minimized and size must be minimized so there is a reliance on advanced materials. (Ref 2)
- Small and mini drones can be easily acquired, transported anytime and anywhere and can be almost undetectable when they fly due to having a very low signature. (Ref 5)

DEFENCE & SECURITY APPLICATIONS

UAVs of different size and degrees of autonomy are already used for intelligence, reconnaissance and surveillance missions, taking advantage of the fact that UAVs can have long loiter times and can be positioned flexibly near potential targets. The long endurance type of UAVs is particularly important for surveillance when operations are conducted over days.

Within urban operations micro UAVs may be considered as key technologies for superiority as they are able to increase the situational awareness. (Ref 2)

An armed UAV would provide air combat capability without exposing a pilot to risk. Ordnance could be carried by the UAV or integrated in the vehicle like in a cruise missile. (Ref 1)

UAVs will transport cargo. (Ref 1)

Future combat search and rescue missions will be conducted by UAVs. (Ref 1)

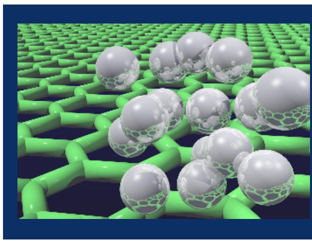
Longer-range decoys could be fielded using autonomous or semi-autonomous robotic platforms. (Ref 4)

Robot Flying Taxi can Evacuate Two Casualties

The Cormorant is a compact, unmanned, single-engine, VTOL (Vertical Take Off and Landing) aircraft. Internal lift rotors enable the Cormorant to fly inside obstructed (e.g. mountainous, wooded, urban) terrain where helicopters are unable to operate. The Cormorant is innovative due to its internal rotors and significant payload capacity that allows for the evacuation of 2 casualties as well as fast and flexible payload reconfiguration for other missions. It is also ideally suited to special robotic operation, for example via telepresence.

The Cormorant successfully completed its first autonomous flight in 2016. (Ref 6)

6. ADVANCED MATERIALS



Advanced materials are artificial materials with unique and outstanding properties. Advanced materials are manufactured using techniques such as nanotechnology or synthetic biology. Uses may include coatings with extreme heat resistance, high strength body or platform armour, stealth technologies, advanced sensors and decontamination, bulk production of food, fuel and building materials.

TRENDS – Disruption in Medium Term (6-20 years)

Recognizing the value of nanotechnology, the Ministry of Defence in the UK has predicted that technologies such as medical nanobots and nano-enhanced reconnaissance and communication devices (such as micro-radar for miniature vehicles) will begin to be used from 2030 onwards. (Ref 6)

In January 2013 graphene was identified as one of the two European Union Future and Emerging Technology Flagship projects with a budget of 1 billion euros in 10 years, forming Europe's biggest ever research initiative. Testing is being done in industry on the application of graphene to a variety of technologies relevant to sectors such as electronics, medicine, aerospace, automotive, energy storage, water desalination, composites, coatings and paints, solar technologies, oil and communications. (Ref 1)

The development of increasingly sophisticated techniques and tools to sequence, synthesize and manipulate genetic material has led to the rapidly maturing discipline of synthetic biology. To date, work in synthetic biology has focused primarily on manipulating individual species of domesticated organisms to perform specific tasks, such as producing medicines or fuels. (Ref 8)

OPPORTUNITIES

- Synthetic biological materials, fuels, drugs, sensors and weapons. (Ref 9)
- Materials with extreme physical properties such as being super-strong (Ref 1), super-elastic (Ref 1, Ref 5), extremely light-weight (Ref 1), resistant to extremely low and high temperatures. (Ref 1)
- Materials with superior electrical properties. (Ref 1)
- Materials with unique electromagnetic properties. (Ref 2)
- Smart textiles at nanoscale with functionality obtained from polymers, metals and ceramics. (Ref 4)
- Flexible display coatings on platforms, goggles. (Ref 5)

CHALLENGES

- Engineered threats and toxic by-products.
- Ethical and institutional challenges. (Ref 9)
- Proliferation of the underlying enabling technologies for synthetic biology. (Ref 9)
- Costs of maintaining required environmental controls and detecting and compensating for genetic alterations. (Ref 8)
- Affordable production and manufacturing.

DEFENCE & SECURITY APPLICATIONS

There are many defence applications of advanced materials and it can be assumed that future systems will be lighter weight, stronger and more power efficient due to the incorporation of advanced materials.

Synthetic biology specific applications include (Ref 9):

- Cost-effective production of bulk materials used as fuel, food, and building materials.
- Unique capabilities for sensing of environmental and other phenomena not currently detectable or at scales needed across the battlespace.
- Bio-data storage and processing molecules and structures that enable new forms of information collection, processing and dissemination concepts.
- New bio-threat weapons including disease agents and bio-toxins as well as potential mitigating prophylactics and therapies.
- Bio-materials and structures enabling efficient and practical interfaces between physical systems and physiological/medical systems of soldiers.

Ultracapacitors Power Unmanned Ground Vehicles

A hybrid UGV (unmanned ground vehicle) using Skeleton Technologies' advanced material ultracapacitors has been developed by Estonian industry. The use of patented nanoporous carbide-derived carbon, or 'curved graphene' material, has permitted achievement of global breakthroughs in ultracapacitor performance.

The unique, multipurpose UGV will be the first vehicle of its kind to use advanced material ultracapacitor technology. The system reduces overall energy consumption by 25–40%. Ultracapacitors can also charge and discharge millions of times, offering lifetimes up to 500 times longer than batteries and technology can operate in temperatures as low as -65 °C. (Ref 7)

7. MIXED REALITY

Mixed Reality is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. Applications include heads up or head mounted displays for pilots and soldiers for real-time situational awareness, digital cockpits/windows, realistic training environments or providing hands-free job performance aids.

TRENDS – Disruption in Medium Term (6-20 years)

Well known terms such as Augmented Reality and Virtual Reality are subsets of Mixed Reality. (Ref 6) Computer simulation models are often used to deliver these experiences.

Recent attempts at large scale commercial product releases for head-worn, see-through, virtual displays have reopened interest in the use of head or body-worn virtual displays. These displays have been primarily within the military domain due to the cost and the very specific military applications.

Significant changes advancing heads-up displays in the past 5 years or less have been (Ref 1):

- Improvements in power efficiency of micro-displays;
- Advancements in optical fabrication techniques for free-form optical surfaces; and
- Proliferation of smart phones and wireless data links.

Distributed simulation is already feasible and used in several nations. Work is in progress to make it more accessible, easier to set up, and reach the decision makers and trainees in the field. (Ref 5)

OPPORTUNITIES

- Useful when rules of engagement require a high target confidence before applying lethal force. (Ref 1)
- Outdoor and indoor micro unmanned vehicles can gather data for virtual representations. (Ref 2)
- Geo-referenced data can improve mapping of mission area; mission planning and preparation and rehearsal environments. (Ref 4)
- Cost-effective and more flexible training solutions. Seamless interoperability between live, virtual and constructive simulations. Individuals and teams have access to training anytime, anyplace. (Ref 5)
- Mixed reality is seen as one area of development for future super-soldiers. (Ref 7)

CHALLENGES

- Data timeliness, refresh rates in real time including synchronization of disparate data streams to get accurate "fused" reality.
- Indoor modelling is still in infancy. (Ref 2)
- Generation of scenario content quickly and intelligently. (Ref 3)
- Cyber-risk from increased network dependency. (Ref 5)

DEFENCE & SECURITY APPLICATIONS

There are many ways in which defence and security forces can benefit from Mixed Reality. Most obvious is in the use of heads-up displays, which are already in use for pilots. Heads up displays, currently used in aviation, could also find uses in dismounted soldier systems. (Ref 1) Heads-up, eyes-out targeting could be achieved by overlaying targeting symbols on top of real world targets. (Ref 1)

Another way Mixed Reality could be used is to assist planners and mission rehearsal. Immersive visualization of rapidly generated accurate 3D representations of physical environment (terrain + buildings + infrastructure) from open source and military data and observations could provide staff with a realistic feel for the terrain before being exposed to it in real life. (Ref 2)

Mixed Reality set ups are already used to provide realistic, cost-effective training environments. (Ref 8) Advances in computer networking, processing and analytics will see such set ups used in the battlefield as well as in expensive labs.

Mixed Reality System to Revolutionize Training

Coalescence is a wearable mixed reality training for air, land and sea domains that merges the trainee's real world view with a synthetic environment providing a seamlessly enhanced, mixed reality. This mixed reality provides trainees with immersive and engaging training scenarios for faster learning transfer and more effective training.

The system could be adapted for a variety of missions including joint tactical air control, dismounted soldier, driver training and even some rotary-wing applications. It will become available in 2017 with production anticipated in 2018. Future efforts will focus on adding depth sensing technology, increasing the positional tracking volume, and keeping up with the latest commercial developments. (Ref 8)

8. SENSORS ARE EVERYWHERE

Sensors are everywhere refers to the ability to detect and track any object or phenomenon from a distance by processing data acquired from high tech, low tech, active and passive sensors as well as background sensors, essentially everything could be a sensor. Applications include universal air picture, underwater sensor nets, social media exploitation, automated logistics planning, autonomous systems, soldier systems.

TRENDS – Disruption in Medium Term (6-20 years)

Sensor proliferation is occurring because reducing costs and sensor sizes are allowing their incorporation into a wide range of cheap every-day objects, where in the past their use was limited to only the most expensive high technology systems. Advances in materials technology also promise future sensors at the molecular, nano or quantum scale. There may come a time when everything will be a potential source of sensor data.

Advanced computational techniques to fuse sensor data will lead to an ability to sense at significantly greater ranges and with richer context than is currently possible. Air target detection range could increase from 350km to 1000km using passive over-the-horizon radar, which is predicted to be fully operational within 20 years. (Ref 3)

Some predict that social media will become the predominant sensing modality in the future (Ref 4). Smart textiles imbued with molecular/nano scale sensors will provide real-time health and environment monitoring (Ref 6, Ref 7).

In the long term, quantum sensing will make the invisible visible, such as seeing through walls or deep underground (Ref 9).

OPPORTUNITIES

- Embedding of sensors into all things from munitions, to textiles, to human beings. (Ref 1, Ref 6)
- Ability to sense through walls, detect hidden materials or deep underground activity. (Ref 9)
- Satellite-free navigation systems. (Ref 9)
- More comprehensive pictures of what's happening through the combination of social data, environmental sensor data and radar data. (Ref 4)
- Widespread environmental sensing at scale. (Ref 7)
- Ability to detect and track ballistic missile launches across nearly all of the globe. (Ref 3)
- Health monitoring and injury prevention. (Ref 6)
- Operating pictures acquired through passive means, ability to overcome adversary stealth. (Ref 3)

CHALLENGES

- Resilience to cyber-attack, electronic warfare or spoofing.
- Technical challenges relating to (Ref 3):
  - Reconstruction of signals from passive sources.
  - Throughput of data links.
  - Computational power limitations for fusion.

DEFENCE & SECURITY APPLICATIONS

Since the sensors can be included anywhere at any scale, there are a wide variety of applications. To name a few:

- Sensors in munitions could allow for integrated lifecycle management resulting in maximal use of high value resources. (Ref 1)
- The addition of social sensing data to traditional sensor data fusion would enable: Multimodal content filtering and summarization, data fusion for event detection, event tracking, analysis of social dynamics, anomaly determination. (Ref 4)
- Adaptive solid-state power amplifiers and optimized waveforms allow simultaneous search and track capability for the interdiction of multiple air, varying altitude targets in both littoral and blue-water scenarios. (Ref 8)
- Remote underwater/underground sensing. (Ref 9)
- Physiological and psychological state monitoring will maximize overall human performance and readiness through increased health and safety monitoring and potential injury protection. (Ref 2)

MEDUSA Lightweight, Low Power, HD Imagery

The MEDUSA camera is a very lightweight and low power instrument able to work at very low temperature and pressure. It can be integrated into various platforms. It uses high data rate (20 mbps) for the data transmission and allows real-time monitoring up to distances > 150 km.

Combining GPS and inertial measurements from the camera with image-based post-processing very high precision (sub-pixel) geo-referencing of the image data is achieved.

MEDUSA could also combine in one single instrument very high spatial resolution with hyperspectral information (e.g. for camouflage detection). (Ref 2)

9. ARTIFICIAL INTELLIGENCE

Artificial Intelligence refers to the ability of machines to match humans in terms of learning, reasoning, planning and acting in complex cyber-physical environments. Potential impact includes replacement for human decision makers, autonomous robot or vehicle control, automated information fusion and anomaly detection, psychological operations and intelligent tutoring for a variety of military and support (medical) missions.

TRENDS – Disruption in Long Term (>20 years)

Experts predict that Artificial Intelligence (AI) will make its way into more areas of life driven by: the acceleration of computational capability; the growing availability of large-scale data; the widespread deployment and use of digital and cyber-physical systems; the greater investment in – and wider adoption of AI; and advances in everywhere computing, database management, cloud computing, smart algorithms, and increasingly powerful software. (Ref 1)

In the 15-20 year timeframe warfighting units should have autonomous systems that are completely trusted and capable of performing both mundane and dangerous tasks. Intelligence analysts should have trusted systems capable of retrieving information across the entire spectrum of sensors and archival data that is relevant to the decision at hand. Networks and information systems should be configured, maintained, and protected by autonomous agents. (Ref 2)

Very high speed, very low power neuromorphic electronic components offer the possibility of autonomous systems and computer architectures that perform tasks that the brain excels at but which currently thwart computers, such as visual scene processing. (Ref 4)

OPPORTUNITIES

- Substantially advanced large data analysis and computer vision. (Ref 4)
- Neuromorphic computing will deliver deep learning with energy-efficiency, volume-efficiency, speed-efficiency, and scalability. (Ref 7)
- Performance of neuromorphic systems may rival human perception at very low power, enabling embedded sensor processing for scene recognition, target discrimination, etc. (Ref 6)
- Intelligent autonomy will enable capabilities such as long duration unmanned underwater vehicles. (Ref 2)

CHALLENGES

- Conveying results to the human and the impact of human-machine interface on team dynamics. (Ref 1)
- Adaptive techniques will outmode current intelligence cycles in areas like electronic warfare. (Ref 6)
- Increasingly intelligent, learning systems will enable new generations of improvised explosive devices, less susceptible to traditional countermeasures. (Ref 6)
- Increased cyber vulnerabilities. (Ref 6)
- Access to AI by adversaries enables highly competitive operational tempo.

DEFENCE & SECURITY APPLICATIONS

The integration of deep learning systems to mobile platforms will enhance the robotic capabilities for navigation within dull, dangerous, dirty or heavy, hot, and hazardous situations. AI could enable fully autonomous explosive ordnance disposal in urban areas. (Ref 1)

Intelligent autonomy extends beyond mobile platforms. For resilient autonomous networks and cyberwarfare, the system must detect, evaluate and respond well before humans would understand the situation. Desktop applications will assess and interpret vast amounts of sensor and intelligence data and will have the capacity to make independent decisions and act upon these decisions rapidly, while at the same time having the ability to work as part of a team which includes people. (Ref 2)

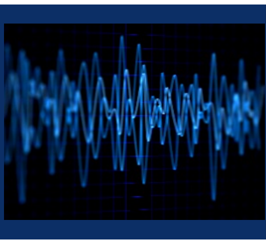
Advances in speech processing and synthesis technology are likely to allow the realistic simulation of friendly and enemy personnel over communications links and broadcast media. (Ref 3)

IBM's Brain-Inspired Cognitive Computer

The TrueNorth chip is part of an effort that began at IBM in 2008, with the goal of producing a new form of computing architecture based on the brain's neuron and synapse network. Rather than simply running calculations across 4 cores as quickly as possible, the TrueNorth chip uses 4096 cores to recognize patterns and leverage them for more efficient data handling and processing.

The 4,096 cores working in harmony represent one million neurons and 256 million synapses. Still nowhere near a human brain's ten billion neurons and 100 trillion synapses, which is the ultimate goal, but TrueNorth computers take up less than two litres of space and consume only one kilowatt of power. (Ref 5)

10. ELECTROMAGNETIC DOMINANCE



Electromagnetic Dominance is the ability to use more of the spectrum, to share the spectrum more efficiently, to protect own forces' use of the spectrum and to deny enemy use. The future will bring, among other things, faster, more reliable wireless/radio communications, electronic warfare resilience, secure streaming video and smaller deployed footprint.

TRENDS – Disruption in Long Term (>20 years)

Microwave photonics is on the verge of delivering higher performance, lower power, more robust sensing and wireless communication on the battlefield. (Ref 1)

The development of a broadband laser source would induce a revolution in countermeasures against electro-optics based threats. (Ref 6)

Passive radar systems are likely to be in mature prototype state within 5-10 years, with fully fielded systems in place in the 10-15 year timeframe. (Ref 9)

Multifunction aperture concepts are a key trend for advancing active phased array radar. (Ref 11)

In the near future, electromagnetic field based stealth systems and broadcast electronic decoys hold promise for the defensive capabilities of future electrically powered systems. (Ref 12)

By 2020, decoys will have the capability to obscure visual and thermal and radar wavebands and be an integrated part of defensive aids suites. (Ref 12) It should be technically possible to have fleets of robotic decoys for deception operations, but simple decoys aimed at mimicking the electromagnetic signature of manoeuvre unit headquarters are more likely. (Ref 12)

OPPORTUNITIES

- Digital beam forming and adaptive solid-state power amplifiers are resistant to jamming and electromagnetic interference. (Ref 2) Quantum radar is more resilient against the use of jamming countermeasures. (Ref 8)
- Twisted radar improves communication channel capacity by as much as eleven times. (Ref 4)
- Quantum radar offers the possibility of detecting, identifying and resolving stealth targets. (Ref 8)
- Passive radar reduces the vulnerability systems against electronic countermeasures and increases detection capabilities of stealth targets. (Ref 10)

CHALLENGES

- Constant evolution on both sides requires constant investment to maintain the edge.
- Directed Energy Weapons currently only operate at intermediate distances experimentally. (Ref 6)
- Passive systems are useless in scenarios where transmitters are jammed. (Ref 9)
- Spectrum is becoming more congested, contested and competitive on a global front from commercial investment in advanced radiofrequency technology.

DEFENCE & SECURITY APPLICATIONS

The race is on for Electromagnetic Dominance and cyber and electronic warfare are converging. Continuous investment in several technologies is necessary to maintain the technological advantage in the electromagnetic spectrum. Defence and security applications of these technologies include:

- Advanced infrared countermeasure systems reduce vulnerability of air and sea platforms to heat-seeking missiles. (Ref 3)
- Directed Energy Weapons have potential to dazzle opponents' optical systems such as night vision goggles or cameras, to guide microwaves or high voltage discharges and to disrupt electrical systems at a distance. (Ref 6)
- Smart Coating of Materials increases survivability of the vehicle through the reduction of reflection and radiation of electromagnetic waves. (Ref 7)

New Frontiers in Passive Radar and Smart Coating

The Lockheed Martin F-22 Raptor is a 5th Generation fighter incorporating stealth shaping and radar-absorbent materials, as well as a passive radar detector with more than 30 antennas blended into the wings and fuselage for all-round coverage.

Passive techniques rely on the environment to light up objects. Radio waves bouncing off each other from a host of other sources can give a picture without sending out a pulse. Ongoing advances in passive radar will deny traditional means to defeat enemy air defences, make air superiority difficult to achieve against a passive radar opponent, and require changes in thinking to maintain U.S. power projection capability. (Ref 5)

11. HYPERSONIC VEHICLES

Hypersonic vehicles can be aeroplanes, missiles or spacecraft. Hypersonic vehicles can move at a speed beyond Mach 5, the same speed regime as a re-entry vehicle or space shuttle experiences as it reaches the lower atmosphere. Potential applications include fast long range strike of high value or high threat targets, ballistic missile defence and reusable space transport vehicles.

TRENDS – Disruption in Long Term (>20 years)

The systems being developed and tested today are mature enough to lead us to believe they will be fielded in the foreseeable future. (Ref 6)

By 2020, the US Air Force Research Laboratory says the Air Force is likely to have operational prototypes of hypersonic missiles ready for a program of record and testing to develop an operational unit. (Ref 5)

By the 2030s, hypersonic missile technology could have expanded beyond delivering warheads at speeds faster than sound to also include hypersonic intelligence and reconnaissance flights. (Ref 5)

In 2013, the US military launched an experimental hypersonic aircraft on its swan song test flight, accelerating the craft to more than five times the speed of sound for 210 seconds in the longest-ever mission for a vehicle of its kind. (Ref 4)

Engagement in hypersonic flight is possible for nations with highly developed R&D capabilities and very high financial resources. The USA, Russia and China are the current leaders in research and development for military hypersonic vehicle applications. (Ref 1)

OPPORTUNITIES

- Shrinking world, with passengers able to fly across the Pacific Ocean in 2 hours. (Ref 7)
- Rapid delivery of weapon effect. (Ref 5) 'Time to target' worldwide less than 1 hour. (Ref 3)
- Greater survivability against enemy air defence detection as well as intercept. (Ref 5)
- NATO nations have successfully flown both boost-glide and SCRAMJET systems in the last four years. (Ref 5)

CHALLENGES

- Many scientific and technological aspects are unique to hypersonic flight, and there is limited data on heating, force loading, etc. (Ref 5)
- Launch detection and prediction of missile flight paths/trajectories in operationally relevant timescales.
- Thermal and guidance problems associated with such high speeds. (Ref 1)
- Intense, expensive R&D programme is necessary. (Ref 1)
- Conventional materials and designs are not applicable for hypersonic flight, the currently available materials limit high altitude (but not exo-atmospheric) flight to Mach 5-6. (Ref 5)

DEFENCE & SECURITY APPLICATIONS

High speeds allow for rapid strike against time critical targets from standoff distances, while keeping the launch platform out of highly contested areas. As adversaries push out the boundaries of contested areas with advanced anti-access/area denial, hypersonic flight counters the trend and allows greater standoff operations for first strike. In addition, the extreme speed of hypersonic penetrating systems makes kinetic intercept very difficult.

Long range intelligence, surveillance and reconnaissance is another potential application. This would most likely be a re-usable unmanned air vehicle. Long range intelligence, surveillance and reconnaissance by a hypersonic unmanned air vehicle would be more flexible than reconnaissance satellites with a potential option for weapon delivery. Hypersonic missiles could also be used for defence purposes as for intercept of high value/high threat time critical targets and potentially hypersonic cruise missiles.

Hypersonic flight is also possible for re-usable space transport vehicles, e.g. the state-of-the-art US Air Force X-37 space plane.

US Military Launch Rocket Plane

A team that included NASA and the U.S. Air Force Research Laboratory celebrated the successful launch of an experimental hypersonic scramjet research flight from the Pacific Missile Range Facility on the island of Kauai, Hawaii in 2012.

The HIFiRE (Hypersonic International Flight Research Experimentation Program) programme was a multiyear (2009-2016), coordinated development project that resulted in seven launches. It aimed to explore the fundamental technologies needed to achieve practical hypersonic flight. Being able to fly at hypersonic speeds could revolutionize high speed, long distance flight and provide more cost-effective access to space. (Ref 2)

12. SOLDIER SYSTEMS

Soldiers Systems refers to the augmentation of individual human abilities using artificial means such as robotic exoskeletons, smart textiles, drugs, and seamless man-machine interfaces. Uses include capacity to endure extreme environments, better health monitoring and care provision, decision making at individual level.

TRENDS – Disruption in Long Term (>20 years)

Rapid advances in material, computer and human sciences, as well as convergence between these fields, is setting the stage to significantly enhance human capabilities to push the human performance frontiers. (Ref 1)

Human physiological monitoring technologies are commercially available and more advanced sensor packages will mature in the midterm timeframe. (Ref 1)

Biotechnology, nanotechnology and genomics are advancing rapidly in the midterm timeframe. These advances are mostly driven by the private sector but can easily be transferred to the military sector. (Ref 1)

Recent army exoskeleton field tests and trials will be followed by widespread commercial production of powered exoskeletons. The deployment of exoskeletons in commercial sectors will probably remain quite limited for another decade or so, due to their high cost (more than $25,000 per suit). It is predicted there will be about 11,000 exoskeletons by 2020. (Ref 4)

OPPORTUNITIES

- Optimized cognitive or physical performance of individuals and teams. (Ref 1)
- Improved team cohesiveness and effectiveness. (Ref 1)
- Faster more context aware decision making. (Ref 1)
- Better leadership assessment of force status. (Ref 1)
- Increased health and safety monitoring as well as injury protection. (Ref 1)
- Interfacing neuroelectronic devices with biological systems will offer improved interface mechanisms between brain and electronic devices. (Ref 3)

CHALLENGES

- There are ethical issues to human enhancements, including: (Ref 1)
  - Trust in machines that could be hacked.
  - Bioethics relating to modification of physical and cognitive capabilities through new drugs or genetic manipulation.
  - Societal and cultural acceptance of potentially creating “super humans”.
  - Outbursts of new diseases.

DEFENCE & SECURITY APPLICATIONS

Human state monitoring in real-time to near real-time will allow individual and team performance to be optimized. Optimized forces should be able to operate in smaller groups, which has implications on affordability (i.e. a smaller number of soldiers can achieve as good or better effect). (Ref 1)

Smart textiles provide one potential solution for harvesting energy from the environment to supplement the soldier’s energy needs. Novel designs for hybrid battery-supercapacitors suggest potential for energy harvesting and storage to reduce the energy-related burden on soldiers. (Ref 2)

Wearable biomedical systems that provide the ability to monitor soldier health continuously could provide knowledge of the inception and progress of injury over time under normal conditions. Knowledge of the health status of soldiers on the battlefield could be of great benefit for our forces in providing essential information needed for force condition status assessment. (Ref 2)

Super Soldier 2020 HULC Exoskeleton

The HULC exoskeleton can help a soldier to lift 200 pounds without strain, and uses about 1000 watts of power. The HULC can assist speed marching at up to 7 mph with a battery-draining “burst” at 10 mph as the maximum speed. A soldier with a pack would normally go at 3 mph maximum and cover 10-12 miles in a day. A better power supply would allow the burst mode to be used more and speed to be 10 mph and coverage to be 200 miles in day. Soldiers could also carry lightweight foldable electric scooters on their exoskeleton that would enable 60-100 mph on roads. If the bike had motocross like capabilities it could still go about 30-60 mph on rougher terrain. (Ref 4)

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