Evolving technologies

Challenges and opportunities from an operational health perspective

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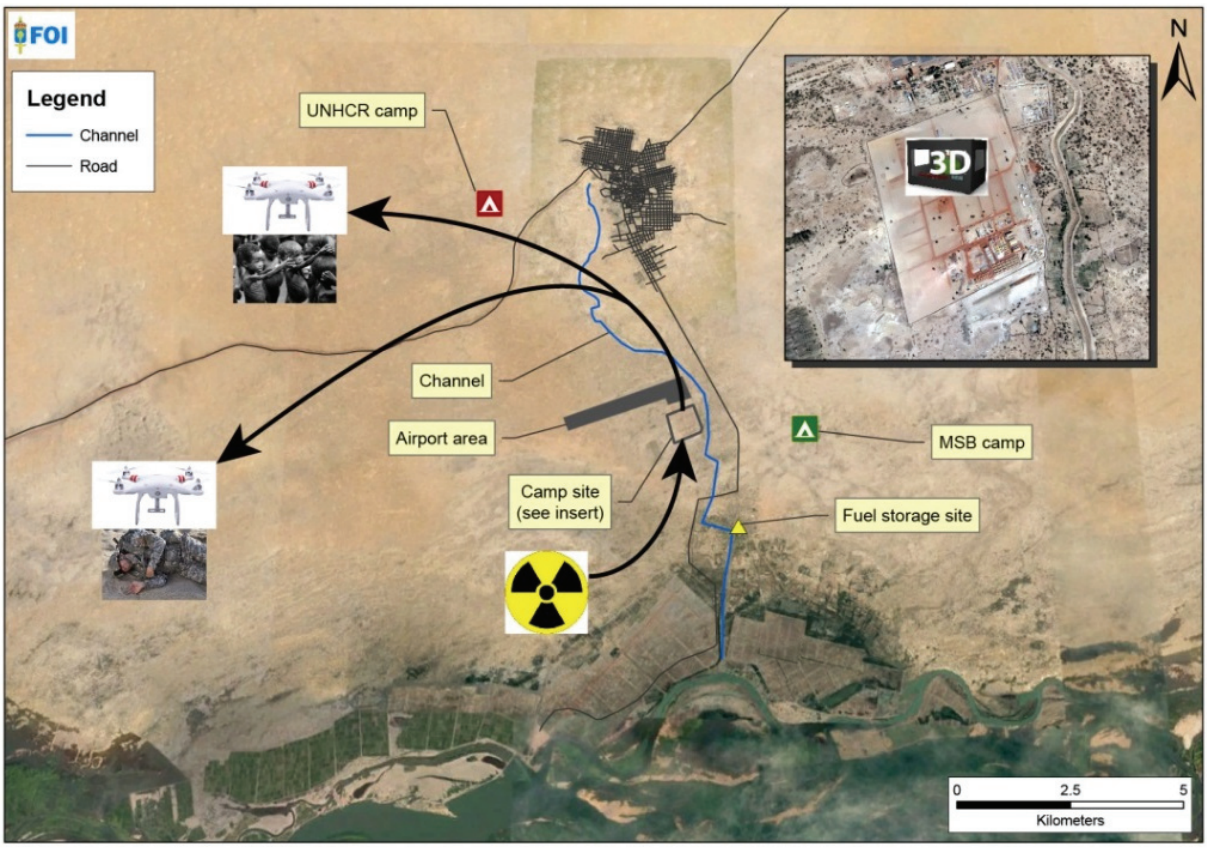

FOI-R--4256--SE
ISSN 1650-1942 April 2016

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Titel	Teknikutveckling – utmaningar och möjligheter från ett insats- och hälsoperspektiv
Title	Evolving technologies - Challenges and opportunities from an operational health perspective
Rapportnr/Report no	FOI-R—4256--SE
Månad/Month	April
Utgivningsår/Year	2016
Antal sidor/Pages	29 p
ISSN	1650-1942
Kund/Customer	Swedish Armed Forces/Swedish Ministry of Defence
Forskningsområde	CBRN and Non-proliferation
FoT-område	
Projektnr/Project no	E4173/A403715
Godkänd av/Approved by	Mats Strömqvist
Ansvarig avdelning	CBRN Defence and Security

Cover: Per Wikström, FOI

Sammanfattning

Den snabba teknologiutvecklingen kan medföra nya möjligheter att hantera hälsorisker vid insatser, såväl för militära som civila insatser. Flera tekniska verktyg som autonoma obemannade farkoster (s.k. drönare) och additiv tillverkning (AM eller 3D-skrivare) är redan operativa för olika ändamål. Samtidigt kan nya risker med potentiella hälsoeffekter öka som en följd av den snabbt växande teknologiutvecklingen.

En snabb skanning av några teknikområden har genomförts och ett fiktivt scenario där teknologierna skulle kunna appliceras har tagits fram. Det förefaller som om de nya teknikerna, som en oönskad bieffekt skulle kunna medföra nya hälsorelaterade hot och risker, och nya rutiner för att hantera dessa kan komma att behövas. Därför kan det vara värdefullt att göra en uppföljande djupare utvärdering med fokus på potentiella hälsorisker och möjligheter från den tekniska utvecklingen.

Några områden som kan vara lämpliga att studera vidare är exempelvis

- Möjligheten att skriva ut reservdelar i avlägsna områden, med hänsyn av ritningar tillgängliga via internet – vilket kan minska föroreningar från verksamheten
- Individualiserad 3D-scanning av människor, för att minska utrustningsrelaterade skador och belastningsskador.
- Möjlig användning av mikrodrönare för spanings- och övervakningsändamål eller för medicinskt stöd i avlägsna områden
- System för tidig varning och identifiering av CBRNE vid potentiella intrång med hjälp av drönare

Ett gemensamt seminarium med deltagare från exempelvis FOI, Försvarsmaktens medicinska expertis, CBRN-intressenter och Försvarets Materielverk (FMV), med det framtagna fiktiva scenario som utgångspunkt, skulle kunna vara en möjlig väg framåt att skapa ökad kunskap kring dessa frågor.

Nyckelord: teknologiutveckling, additiv tillverkning, 3D-printer, autonoma obemannade farkoster, drönare, CBRN, internationella insatser, hälsorisker, hälsohot

Summary

Evolving technologies may provide new opportunities to manage health risks during field operations. This holds true for both military and civilian operations, and several tools such as unmanned aerial vehicles (drones) and additive manufacturing (AM, or 3D-printers) are already operationalized for various purposes. At the same time, new hazards with potential health implications may rise from the rapidly developing "new normal" of technologies.

An initial quick scanning of some evolving technologies was performed and a fictive mission scenario created, to subsequently, in a follow up phase apply these technologies to. The findings so far suggests that new health hazards indeed may arise, and new health management procedures therefore may be required. Hence, it might be valuable to make a deeper evaluation with focus on of potential health hazards and opportunities from evolving technologies.

Some areas that may warrant further study, include

- Access to blue print drawings of spare parts via internet to be 3D-printed in remote areas – to reduce hazardous pollution during missions
- Individualized 3D-scanning of human physical properties – to reduce equipment related injuries and musculoskeletal disorders.
- Potential use of mini-drones for reconnaissance and surveillance purposes or for medical support in remote areas
- CBRN detection systems for early warning and identification of potential intrusion via drones

It is suggested, that a joint seminar, with FOI, the Swedish Armed Forces medical expertise, CBRN stakeholders and the Swedish Defence Material Administration (FMV), is conducted to highlight potential way ahead regarding this matter. The fictive scenario described in this report might provide input for discussions.

Keywords: technologies, additive manufacturing, 3D-printing, unmanned aerial vehicles, UAV, drones, CBRN, international operations, health hazards, and health threats

Contents

1 Introduction

1.1 Background

There are several key driving forces of change in the international security landscape. The driving forces are highly interconnected, each interacting with and affect the others. One of those forces are technological innovation. Technological innovation is not only a driver in its own right, but also significant amplify other drivers.[1]

In addition, military and civilian operations in conflict and crises areas face continuous challenges regarding mandate, complexity, geographical focus and security context. As an update regarding the 'new normal' baseline for health threat assessments in operations, it was identified to be of interest to make a swift scanning of evolving technologies, that may be of relevance from a health perspective.

The scan is followed by a brief discussion focusing on how this 'new normal' may apply to health threats and/or opportunities in military or civilian operations in where functional infrastructure may not be present.

Finally, some reflections and suggestions for further studies are made. This includes the introduction of a 'fictive mission scenario', built on collective, international experiences regarding health aspects from deployments to e.g. Afghanistan, Mali, Somalia and the Democratic Republic of Congo.

The report has been produced within the framework of FOI support to the Swedish Armed Forces Medical Intelligence, supported by the FOI research project 'Health impact in operations' (financed by the Swedish Ministry of Defence). Some sections from this report have previously been touched upon in the annual 'Horizon scanning' from the latter project.[2]

1.2 Aim

The aim of this report is to give a swift scanning over some evolving technologies, and reflect on what challenges and opportunities they may provide from an operational health perspective.

[1] WEF (2016) Global Risk Report 2016, http://www3.weforum.org/docs/Media/TheGlobalRisksReport2016.pdf
[2] A. Waleij. 'Horizon scanning - Health threats in international operations' FOI-R--4030--SE (2014)

2 Evolving technologies – a brief scanning

This chapter focuses mainly on additive manufacturing (AM), where the authors see several immediately possible applications. The chapter then touch upon some new technologies, with potential applications in a near, or more distant, future. For an elaborated discussion of the use of AM in operational settings, see Waleij et al 2016.[3]

2.1 Additive manufacturing (AM)

So what?

With 3D-printers rapidly becoming more robust and reliable, and the 3D-printed products are increasingly of higher quality combined with the continuous fall (increased competition in the business, lapsing patents) in cost of investing in a 3D-printer means that the long anticipated ´3D-revolution' is at our doorstep. Perhaps 'revolution' is a misnomer as it did not happen as quickly as the early buzz suggested, but the effect is still the same. Today hobby quality 3D-printers are found in every enthusiast's home, and higher grade 3D-printers are used for rapid prototyping in the industry. Tomorrow 3D-printers will be commonplace, even on missions to the most remote places. Indeed they will change the way missions are planned and realised.

Additive manufacturing (AM), also known as 3D-printing, is an umbrella term that covers different manufacturing technologies in which a product is produced layer by layer. This method enables production of complex blueprints in single pieces without the need of joining of parts, thus decreasing weight as well as allowing designs currently not possible with conventional manufacturing techniques. The blueprints for 3D-printers are CAD (computer-aided-design) drawings which can be made available through the internet.[4]

Plastics, resin and metal are among the most common materials for 3D-printers. There are also more advanced printers which can use other materials, e.g. bio printers designed to print human organs.[5] Recently, scientists at the Computer Science and Artificial Intelligence Laboratory (CSAIL) at Michigan Institute for Technology (MIT) for instance claim to have constructed a 3D-printer that can print ten different materials.[6]

NASA (National Aeronautics and Space Administration) has also invested in 3D-printing, having installed a 3D-printer on the International space station in 2014.[7] The main advantage is the time saving aspect that is, not having to wait weeks or potentially months for a spare part. 3D-printing also have the advantage of being more resource efficient, i.e. using less raw material while producing close to zero waste. This is of special interest in regions where there are limited waste management capabilities. NASA has also been testing whether 3D-printed rocket engine parts can withstand the epic pressure and heat

[3] Waleij, A. Tjäder, Z. Liljedahl, L. Brännström, N. (2016) Additive manufacturing revamps supply chains for humanitarian aid or peace support interventions. FOI Memo 5569

[4] 3Dprinting.com. What is 3D printing?. http://3dprinting.com/what-is-3d-printing/

[5] Anthony Atala. TED. Printing a human kidney. www.Ted.com. (2011) www.ted.com/talks/anthony_atala_printing_a_human_kidney

[6] Davies, J. L (2015) Newly Developed 3D Printer Can Print With Ten Different Materials IFL Science, 26 August, 2015 http://www.iflscience.com/technology/newly-developed-3d-printer-can-print-ten-different-materials

[7] NASA (2014) Open for Business: 3-D Printer Creates First Object in Space on International Space Station. November 23, 2014, http://www.nasa.gov/content/open-for-business-3-d-printer-creates-first-object-in-space-on-international-space-station

associated with a launch into space. So far, the researchers have not seen any difference between their 3D-printed parts and parts manufactured using more traditional means.[8]

Military applications

The US military are investing in 3D-printing for the production of spare parts in deployed locations. The logistical advantages of producing spare parts in theatre or aboard a naval vessel are considered useful and 3D-printers are therefore deployed in both instances. The US military have also invested in bio printing, with the purpose of recreating skin, and eventually also organs, for wounded soldiers. Increased survivability of US soldiers thanks to improved body armour and improved field medicine capabilities, have led to less mortality but also an increase of disabled veterans with increasing demand for skin transplants.[9]

According to the defence research laboratory Qinetic, the British Royal Navy might have small 3D-printed ships within 15 years.[10] Private enterprises are also expressing interest and the shipping company Maersk has installed 3D-printers on their transport vessels.[11, 12, 13]

Other areas of increased interest for the technique is individually adopted artificial limbs[14,15] and, in a more commercial field, individual fitness of e.g. clothing[16], shoes[17] and high quality music ear plugs[18] and hearing protection.[19] This has set the limelight on personalized 3D-scanning to ensure better fit of various kinds of fabrics.[20, 21, 22]

Applications for disaster management

3D-printing is also seen as an option, to support early recovery efforts in disaster areas. Architects in Amsterdam are building a 3D-printed house - an effort some say could soon transform disaster reconstruction, and help the homeless around the world as the technology becomes increasingly more affordable. The idea behind the project, according to the architects, was to develop ways to build homes in a faster and more efficient way,

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[8] Reid, C. (2015) NASA Successfully Tests 3D-Printed Rocket Parts, IFL Science, August, 27 2015 http://www.iflscience.com/technology/3d-printed-rocket-parts-no-different-traditionally-made-parts

[9] Lafontaine, Dan. Army invests in 3-D bioprinting to treat injured Soldiers. United States Army. 2014 http://www.army.mil/article/129584/Army_invests_in_3_D_bioprinting_to_treat___

[10] Katz, B. (2015) Royal Navy Could Have Unmanned, 3D-Printed Surface Ships by 2030, Bloomberg Buisness, 7 September 2015, http://www.bloomberg.com/news/articles/2015-09-07/royal-navy-could-have-unmanned-3d-printed-surface-ships-by-2030

[11] Kyle. Maxey. 3D Printing Moving to the Front Lines. (2012) http://www.engineering.com/3DPrinting/3DPrintingArticles/ArticleID/4964/3D-Printing-Moving-to-the-Front-Lines

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[18] Findling, D. (2014) Earphones: The holy grail for 3D printing? CNBC News, August 8 2014, http://www.cnbc.com/id/101903754

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[20] Lantos technologies, Aura 3D Ear Scanenr http://lantos.wpengine.com/#earscanner

[21] Minerva hearing protections http://www.minerva-hearingprotection.co.uk/custom-in-ear-monitors.html

[22] Saxena, A. (2014) OwnPhones – Custom 3D Printed Bluetooth Headset. August 10, 2014 http://ayushsaxena.com/custom-3d-printed-bluetooth-headset/

while making use of newly developed substances derived from bio-based raw materials. Trials with bio plastics, which are 80% made from vegetable oil, are for instance taking place and the architects are also researching the possibilities of printing with recycled materials, including plastics, wood pallets and natural stone waste. Haiti is one location where 3D-printers have been used operationally, in earthquake disaster relief efforts.[23, 24]

Industrial applications

Meanwhile, the Chinese WinSun company has printed private villas as well as six-story tall buildings. As 'ink' for the massive 3D-printer, construction waste such as concrete, fiberglass, sand and a special hardening agent was used.[25]

Some observers say the 3D-printing technology is likely to revolutionize the construction industry, as there are almost no transport costs, since designs can simply be transferred digitally and printed locally.[26, 27, 28]

Limitations and future outlook

Concerns regarding 3D-printing have largely involved the printing of firearms or other products which could prove useful for criminal and terrorist organizations. Currently 3D-printed firearms are however highly inferior to conventionally produced weapons, often breaking down after a few shots. Yet, the quality and availability is developing at a rapid pace.[29]

3D-printing has limitations, in particular the speed of printing and the quality of the 3D-printed products[30]. These limitations have so far hampered the since some years expected '3D-revolution'.[31]

A new breakthrough in 3D-printing has increased the speed of resin based printing, by a factor of 25 to 100. The new method which "grows" objects, is not only faster than traditional 3D-printing but also lack much of the structural weaknesses as the layers won't bond as well in the Z axis as they do in the X and Y plane.[32, 33]

[23] Halterman, T.E, (2015) Power to the People — 3D Printing Being Used in Disaster Relief, 6 April 2015, 3D.priont.com, http://3dprint.com/56149/3d-printing-disaster-relief/

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[26] Al Jazeera http://www.aljazeera.com/indepth/features/2014/10/3d-printing-future-disaster-relief-20141016825642208.html

[27] NPR (2015) A New 3-D Printing Method Is Rising Out Of The Ooze, March 25, 2015 http://www.npr.org/blogs/alltechconsidered/2015/03/21/394308967/a-new-3-d-printing-method-is-rising-out-of-the-ooze

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[31] Gilpin, L. (2014) 3D printing: 10 factors still holding it back, Tech Republic, February 19, 2014, http://www.techrepublic.com/article/3d-printing-10-factors-still-holding-it-back/

[32] Wakefield, J. (2015) TED 2015: Terminator-inspired 3D printer 'grows' objects, BBC News, March 17, 2015 http://www.bbc.com/news/technology-31918215

[33] DeSimone, J (2015)

2.2 Unmanned aerial vehicles (UAV) and autonomous vehicles

Unmanned Aerial Vehicles (UAV), often known as "drones", is a rapidly growing field.[34] This chapter discusses some current applications of drones as well as reflects on opportunities and challenges of the increased accessibility and use of drones.

So what?

Applications for Unmanned Aerial Vehicles (drones) in both civilian and military context are virtually exploding. Fundamental improvements regarding battery technology and stabilization and navigation systems have allowed for this dramatic development. New practical applications are presented in many different fields and drones for personal use are also increasing as prises go down.

United Nations peacekeeping operations, humanitarian actors and the Swedish Armed forces makes everyday use of drones in operations. The concerns regarding drones are however several. Spraying capable UAV's are already commercially developed and probably one of their biggest application will be within the agricultural area. However, the application could potentially also be used in other more harmful applications, where highly toxic or otherwise dangerous agents could be dispersed. Indications are that military drone operators suffer from mental health problems at the same rate as manned aircraft pilots. This situation warrants further interest and studies with respect to challenges and opportunities with drone technologies and uses.

Several concepts and nomenclature are used in this field and the most common are listed below. In addition to those, corresponding ground or naval systems also exist.

UAV - Unmanned Aerial Vehicle	Unmanned Aircraft	"Drones"
UAS - Unmanned Aerial System	Automated System	
RPAV – Remotely Piloted Arial Vehicle	Autonomous System	

2.2.1 Various applications

Military applications

The Secretary of the US Navy has indicated that the F35 Fighter yet probably will be that last fighter jet procured by the US Navy. Instead, the usage of drones will increase accordingly.[35] At the same time, the US DARPA (Defense Advanced Research Projects Agency) is considering to equip all American destroyers with drones. In addition to increased flexibility, the risks associated with resource consuming aircraft carriers, is expected to decrease.[36]

The US military is also investigating the use of unmanned vehicles roll onto battlefields to rescue injured Soldiers, rather than having MEDICS do it.[37]

[34] Shalal, A. (2014) Lockheed sees huge potential for military-, commercial-use drones, Reuters, Febryary 21, 2014, http://www.reuters.com/article/2014/02/21/us-lockheed-martin-unmanned-idUSBREA1K0EK20140221

[35] LaGrone, S. (2015) Mabus: F-35 Will Be 'Last Manned Strike Fighter' the Navy, Marines 'Will Ever Buy or Fly', USNI News, April 15, 2015 http://news.usni.org/2015/04/15/mabus-f-35c-will-be-last-manned-strike-fighter-the-navy-marines-will-ever-buy-or-fly

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In parallel, the military also explores the use of smaller drones that can fit in a pocket and provide real-time information.[38, 39, 40]

Since a few years ago, United Nations peacekeeping operations also regularly use drones. For instance, MONUSCO in the Democratic Republic of Congo (DRC), the mission in Central African Republic (C.A.R.), and Mali (MINUSMA).[41] The governments in South Sudan and Rwanda, however, have expressed concerns about potential espionage.[42, 43]

TUAV 03 (tactical unmanned aerial vehicle), Örnen (the Eagle), used by the Swedish Armed Forces, offers a view of the extensive area of operation. It can stay in the air up to seven hours, providing snap shots from a distance up to 125 km and 5 km height. The pictures are transmitted to a ground station for interpreting and processing. From 2011, Örnen was deployed to the Swedish support to the NATO ISAF mission in Afghanistan.[44]

Sweden has also deployed Örnen as a contribution to the UN peace-keeping mission in Mali (MINUSMA) where it is used in reconnaissance operations.[45]

For health purposes drones are also increasingly used. A university in the Netherlands has for instance developed a drone that can deliver a defibrillator to a patient with a speed of 100 km per hour. Once arrived, the physicians can use tele medicine to instruct the user on site.[46]

Humanitarian applications

Humanitarian drones are being tested for various purposes, such as to deliver medical supplies and vaccines to remote areas[47], food supply and first aid support.[48] Also, the use of drones for surveillance of wildlife crime and terrorism is increasing.[49]

UAVs have been used during the Sunderban oil spill in Bangladesh as a supplement to satellite surveys. It is less costly than manned aircraft and can provide visualization on shorelines covered by weather or vegetation, blocking satellite coverage. The data

[38] Sisto, Jeffrey. Army researchers develop pocket-sized aerial surveillance device. United States Army. 2014.http://www.army.mil/article/138418/Army_researchers_develop_pocket_sized_aerial_surveillance_device/

[39] Delft University of Technology. TU Delft's ambulance drone drastically increases chances of survival of cardiac arrest patients. Delft University of Technology. 2014. http://www.tudelft.nl/en/current/latest-news/article/detail/ambulance-drone-tu-delft-vergroot-overlevingskans-bij-hartstilstand-drastisch

[40] CBS. Amazon unveils futuristic plan: Delivery by drone. CBS News. 2013. http://www.cbsnews.com/news/amazon-unveils-futuristic-plan-delivery-by-drone/)

[41] GPF (2013) UN uses drones in Eastern Congo. Global Policy Forum, December 5 2013, https://www.globalpolicy.org/component/content/article/181-congo/52554-un-uses-drones-for-surveillance-in-eastern-congo-.html

[42] Sengupta, S. (2014) Unarmed Drones Aid U.N. Peacekeeping Missions in Africa, New York Times, July 2, 2014 http://www.nytimes.com/2014/07/03/world/africa/unarmed-drones-aid-un-peacekeepers-in-africa.html?_r=0

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[48] Shadow Wiev Foundation (2014) Humanitarian Aid Demo, October 16, 2014 http://www.shadowview.org/news/humanitarian-aid-demo/

[49] The Other Side of Drones: Saving Wildlife in Africa and Managing Global Crime by Johan Bergenas, Rachel Stohl and Alexander Georgieff, page 3 http://www.accord.org.za/images/downloads/ct/ACCORD-Conflict-Trends-2013-3.pdf

collected could aid in assessing the conditions of the environment in this case shorelines, vegetation and waterways.[50]

In the aftermath of the Nepal earthquake NASA deployed its FINDER technology in a disaster for the first time finding four survivors trapped in rubble. The device which is carried by rescue workers sends out low-power microwaves which can detect small movements such as heartbeats. FINDER has a detection range of 9 meters trough rubble of 6 meters of solid concrete.[51] Drones saw extensive use by journalists and relief works to assess damage to villages and towns which would have been hard to reach by road.[52]

Industrial applications

Recent years also have seen an increased use of drones for civilian applications. In China, drones are used to monitor polluting industries and the company Amazon is using drones to deliver packages to costumers. Drones for personal use are also increasing.

In addition to unmanned aerial vehicles there are also land based ones in development. Autonomous, or 'Self driving' cars are already being tested in civil society, and are expected to have a major breakthrough around 2025.[53]

Limitations and future outlook

The concerns regarding drones are however several, and can be exemplified with the non-nuclear-activist-protest landing of a low-level radio-active drone on the Japanese Prime minister's office[54, 55] and the crash landing of a drone used for drug smuggling on a parking lot in United States[56]. Also, small drones could launch 'chemical and biological attacks' during football games and rallies, warns the former head of GCHQ (the digital intelligence agency in the UK).[57] In addition, he warned that the use of military drones could be breaking international law.

The downside of operational drone operations in the military has however led to the US Air Force facing a shortage of UAV pilots as they are opting to leave when their contract is up rather than remain. According to interviews the pilots feel overworked and undermanned with few prospects for promotion or academic breaks. They also report problems combining their work with their personal lives as they shift between civilian and military life on a daily basis. The pilots are also suffering from stress, according to a 2013 study they suffer from mental health problems at the same rate as manned aircraft pilots deployed ton Iraq and Afghanistan.[58]

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[50] Joint UNEP/OCHA Environment Unit. "Sunderban oil spill Assessment, Joint United Nations Government of Bangladesh Mission". Switzerland: Joint UNEP/OCHA Environment Unit, Emergency Preparedness and Environment Section, Emergency Services Branch, OCHA, 2015

[51] See http://news.nationalgeographic.com/2015/05/150507-nasa-finder-nepal-earthquake-survivors-rescue-technology/

[52] Howard, B. C. (2015) NASA Technology Finds Nepal Survivors by Their Heartbeats, National Geographic, May 7, 2015, http://www.huffingtonpost.com/2015/05/07/nepal-earthquake-drones_n_7232764.html

[53] Leban, M. (2014) 2025 kommer självkörande bilar på allvar, 16 januari 2014, http://www.nyteknik.se/nyheter/fordon_motor/bilar/article3798150.ece

[54] Dagens Nyheter (2015) Radioaktiv drönare landade hos premiärminister, 22 april, 2015 http://www.dn.se/nyheter/varlden/radioaktiv-dronare-landade-hos-premiarminister/

[55] Kravets, D. (2015 Man lands drone carrying radioactive sand on Japanese prime minister's office, Arstechnica, April 25, 2015 http://arstechnica.com/tech-policy/2015/04/25/man-arrested-for-flying-drone-carrying-radioactive-sand-in-tokyo/

[56] Dagens Nyheter (2015) Drönare med knark kraschade på parkering, 22 januari, 2015 http://www.dn.se/nyheter/varlden/dronare-med-knark-kraschade-pa-parkering/

[57] Vincent, J. (2014) Small drones could launch 'chemical and biological attacks' during football games and rallies, warns former head of GCHQ, The Independent, October 22, 2014 http://www.independent.co.uk/life-style/gadgets-and-tech/small-drones-could-launch-chemical-and-biological-attacks-during-football-games-and-rallies-warns-former-head-of-gchq-9809673.html

[58] Drew, C. & Philips, D. (2015) As Stress Drives Off Drone Operators, Air Force Must Cut Flights, New York Times, June 16, 2015. http://www.nytimes.com/2015/06/17/us/as-stress-drives-off-drone-operators-air-force-must-cut-flights.html?smid=fb-nytimes&smtyp=cur

A British study recently looked into the hostile use of drones by non-state actors against British targets. While the focus was on unmanned aerial vehicles, the designs and capabilities of over 200 current and upcoming unmanned aerial, ground and marine systems was also examined in order to understand the threat these platforms pose to potential targets. According the study, a variety of potential targets, such as power stations, international summits and the PM's car are all potential targets for unmanned aerial vehicles carrying explosives[59, 60].

2.2.2 Drones as carriers of dispersal tools

Spraying capable UAV's are already commercially developed and probably one of their biggest application will be within the agricultural area.[61] Crop spraying, seeding and general agricultural surveillance[62] are functions that will be very much simplified using this technology. Other areas where spraying capable UAV is emerging are exemplified with the police authorities in India, which is about to start using drones that can carry up to 2 kg of pepper spray for mob control purposes[63]. The concept of using drones to disperse other material is coming up in many different areas so that means that there is already commercially available technology for precise positioning of and spraying material with UAVs.

This could potentially be used in other more harmful applications, where highly toxic or otherwise dangerous agents (such as CBR-agents) could be carried and delivered either to a very precise location or sprayed over a larger area.

The smallest type of UAV ("hobby-level") could carry a payload of a few hundred grams, but with the most potent CBR agents only a minute amount can have very serious effects. This means that also a very small UAV could carry enough material for creating a really big problem.

This could have an impact on the type of risk scenarios that has to be dealt with in different operations. Small, almost invisible UAVs, could fly in over a "secure" perimeter and deliver toxic or contagious material.

The risks associated with spraying capable UAVs are further exasperated by lowered thresholds to run dispersion models. If a substance is released (sprayed) in the air then will subsequently be blown downwind. A dispersion model is a mathematical model that allows the user to predict where the wind will carry the released substance and in which quantities. To run a dispersion simulation one needs a dispersion model and meteorological data, both of which are readily available[64, 65]. In addition to this, computing power is required, but to run a light (simplified) model a desktop computer or even smartphone will suffice. The entry barriers of limited availability of computer power, meteorological data (wind fields) and dispersion models no longer apply.

[59] Remote Control project (2016) Hostile drones, the hostile use of drones by non-state actors against British targets, January 2016, http://remotecontrolproject.org/wp-content/uploads/2016/01/Hostile-use-of-drones-report_open-briefing.pdf

[60] Weaver, M. (2016) UK should prepare for use of drones in terrorist attacks, says thinktank, The Guardian, 11 January, 2016, http://www.theguardian.com/uk-news/2016/jan/11/drones-terrorist-attacks-security-thinktank

[61] Byford, S. (2015) DJI announces $15,000 agricultural drone designed to spray crops. The Verge, 26 November, 2016, http://www.theverge.com/2015/11/26/9805778/dji-agriculture-drone-agras-mg-1

[62] DoneUAV (2015) UAV use in Agriculture, March 30, 2015, http://droneuav.co.uk/civilian-drones/uav-use-in-agriculture/

[63] Mogg, T. (2015) Protesting in India? Look out for pepper-spraying drones, Digital trends, April 9, 2015 http://www.digitaltrends.com/cool-tech/pepper-spraying-drones-to-take-on-unruly-protesters-in-india/

[64] Flexpart, http://flexpart.eu/

[65] The Weather Research & Forecasting Model http://www.wrf-model.org/index.php

2.2.3 UAV as carriers for detection and sampling equipment

UAVs are equally fitted to serve as carriers of CBRN-detection and sampling equipment. A drone scouting of an area is attractive as possible threats can be discovered before troop enters. Defence and police forces are already now using different type of UAVs in surveillance applications. The most powerful detection equipment's are still rather big and heavy and not easily carried, but smaller, lightweight detection equipment that still has a good performance can be integrated in a UAV system. Examples of CBRNE detection UAV are the Research Internationals "*Flying UAV Laboratory*"[66], where a fixed wing UAV carries chemical, biological and radiological sensors. The system has an Ion Mobility Spectrometer (IMS) that can detect up to 20 different chemical agents and toxic industrial chemicals. A fluorescence based simple sensor can detect presence of biological aerosol particles. Fluorescence based sensors will not be able to identify the true origin of the biological agent, but they can serve as a good warning device and trigger for taking a sample. The system also carry Geiger counters and gamma spectrometers that can detect and identify nuclear materials and monitor radiation levels. Finally, the system also has an aerosol sampler that can collect particles for further analysis. This system is currently more a demonstrator, but it is nevertheless a good example of the ongoing development.

In the EU Horizon 2020 security research program, a call has recently been open for projects that focus on remote controlled devices (air based and ground based) for performing forensic investigations in areas where a CBRN incident has occurred and where it will be very difficult or dangerous for humans to enter. It is envisaged that such systems will carry detectors, samplers but also manipulators (robot arm with multiple tools etc.).

Another interesting possibility is to use drones in detection/surveillance applications is to have them cooperating in swarms. Together, they can cover a larger area or they can have different specific sensors.[67, 68, 69]

Dispersion modelling can further increase the efficiency of the surveillance task: instead of performing a blind search, a dispersion simulation can guide the UAVs where to search for the CBRN substance and increase the likelihood of an early warning/verification. Or, alternatively, if a swarm of UAVs on routine patrol makes a detection, inverse dispersion modelling[70] can suggest where the source of the CBRN substance is/was located and even guide the UAVs in that direction.

As mentioned before, dispersion modelling requires access to meteorological data and forecasts. Incidentally this means that it will be possible to determine how good the flying conditions are for the UAV. Dispersion models also have the ability to predict the path of wind-blown dust (sand).

2.3 IT, gaming, social media and big data

In this chapter some evolving techniques are described, of which some already today are used as direct or indirect supporting tools regarding health aspects of missions. Others are highlighted for discussion on what health implications and/or opportunities that should be addressed in future and 'new normal'. In a series of videos called the "Forward to the

[66] Flying UAV laboratory (COTS) System, http://www.resrchintl.com/Flying_UAV_Lab.html
[67] K. Daniel, B. Dusza, A. Lewandowski, and C. Wietfeld, "AirShield: A system-of-systems MUAV remote sensing architecture for disaster response," in 3rd Annual IEEE International Systems Conference, Vancouver, Canada, 2009, pp. 196-200
[68] A. Bürkle, F. Segor, and M. Kollmann, "Towards Autonomous Micro UAV Swarms," Journal of Intelligent & Robotic Systems, vol. 61, pp. 339-353, 2011
[69] K. Daniel and C. Wietfeld, "Using Public Network Infrastructures for UAV Remote Sensing in Civilian Security Operations," Homeland Security Affairs (HSAJ), March 2011
[70] Niklas Brännström and Leif Å Persson 2015 *Inverse Problems* 31 025009

Future," researchers from the US DARPA has instance predicted how the world will look in 2045, involving some of the technologies described below.[71]

So what?

It's not so far-fetched that *robots and artificial technology* are going to transform the contemporary industrial landscape, in many ways for the better. But what are the down sides?

Big data can create individual profiles to e.g. detect increased risk for serf-harming behavior and suicide's, but also involves questions of personal integrity. Self-improving artificial intelligence might head towards superhuman levels of intelligence, but may also lead to setbacks for mankind, in combination with more robots making many professions expandable.

Citizen science and do it yourself movements open up many opportunity for the ordinary citizen to be informed of, and involved in, developments of society in a very democratic way. Among the downsides are that individuals and groups with ill-meaning intentions such as criminals and terrorists may have access to the same information and material, even harmful substances, and can use it for illicit use.

2.3.1 Virtual reality (VR) and the gaming industry

Exposure-based therapies for PTSD with help of virtual reality (VR) are developed at the University of Southern California's Institute for Creative Technologies in Los Angeles. The first versions of the virtual-reality program ("*Virtual Iraq*" and "*Virtual Afghanistan*") were adapted from the first-person video game "*Full Spectrum Warrior*," released for Xbox in 2004. The program featured a wide range of combat situations, and allowed the user to tweak the time of day, the weather conditions and the wound levels of characters in the game. In addition, medical experts could insert "trigger stimuli" to mimic the original traumatic experience.[72]

Another area where the gaming industry is used, is the gaming company Mojang that collaborates with UN Habitat using *Minecraft* to develop sustainable cities.[73]

2.3.2 Big data

Big data is a broad term for data sets so large or complex that traditional data processing applications are inadequate. Today, new and improved data processing, gives an opportunity to analyse such big, complex and multiple sets of data. Expected advantages with big data analyses, is that they may lead to more confident decision making, resulting in greater operational efficiency, cost reductions and reduced risk. Analysis of data sets can also find new correlations, to spot business trends, prevent diseases, combat crime and so on.

Mental health

Research funded by the US military has identified patterns for individuals with an increased risk of suicide. Using "big data" the researchers used an algorithm to find the risk cases by analysing a variety of data. The algorithm was tested on American veterans between the years of 2004-2009 which marked out a high risk group consisting of 5% of the veterans which represented 50% of all suicides. In this group 3.8% had committed

[71] US DARPA (2015) Forward to the Future- Visions of 2045 http://www.darpa.mil/news-events/2015-10-21
[72] Lewis, T. (2014) Virtual-Reality Tech Helps Treat PTSD in Soldiers, LiveScience.com, August 08, 2014, www.livescience.com/47258-virtual-reality-ptsd-treatment.html
[73] Sida (2014) Omvärlden, november 2014,s 47 http://www.omvarlden.se/

suicide while 46% was forced to seek medical attention of different reasons.[74, 75] 'Big data' is also used in Big areal data-satellite imagery, where high resolution locally printed maps can be obtained within 24 hours[76].

Citizen's individual profiles

Big data is used on a daily basis, when compiling personal information about citizens shopping habits (via credit cards specification), interests (via google accounts), physical whereabouts (GPS mobile tracking) etc., to create individual profiles to assist for example individualized, commercial advertising.

2.3.3 Social media, crowd sourcing and citizen science

The UN has created a disaster organization named *MicroMappers*. *MicroMappers* use twitter to gather data during a disaster from the affected area. The messages are then analysed and sorted by volunteers using either a mobile apps or their website. Once sorted, the tweets can be used by the UN in their planning. This occurred during the Typhoon Pable in the Philippines 2012, when *MicroMappers* analysed 20000 tweets less than 10 hours which laid out a foundation for the UN disaster map over the area.[77, 78, 79, 80]

Ushahidi is a nongovernmental organisation (NGO) that has developed an open source software that allows people on the ground to report events. A programme, *Crowdmap*, allows for mapping an event and thereafter, people can e-mail or SMS additional geo-referenced information to *Crowdmap*. Crowdmapping was initially used for gathering evidence for election fraud in Kenya in 2007 but have since then also been used during for instance the insurgencies in Egypt in 2011 during the Haiti earth quake in 2010 and to evacuate Kenyan citizens from South Sudan in December 2013. Ushahidi has also developed a cheap, mobile, rugged portable internet solution for remote places.[81, 82]

Different types of technological tools and the role of social media were also frequently discussed during the peak of the Ebola outbreak in West Africa.

According to the UN Environmental Programme (UNEP) the above described phenomena can be summed as *citizen science*, an increasing form of grass roots engagement in science and science based information gathering.

PAX, an NGO, has examined the potential for using citizen science tools in Syria to quantify the extent of environmental degradation. The idea is that citizen science tools could inform both efforts to reduce threats to public health from environmental risks, and longer term remediation plans.[83]

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[74] Kessler, Ronald C, PhD. Predicting Suicides After Psychiatric Hospitalization in US Army Soldiers The Army Study to Assess Risk and Resilience in Service members (Army STARRS). JAMA Psychiatry. 2014. http://archpsyc.jamanetwork.com/article.aspx?articleid=1935484

[75] Kime, P. (2014) Soldiers' suicide risk predictable with Big Data, study says, Military Times, November 12 2014, http://www.militarytimes.com/story/military/2014/11/12/big-data-suicide-risk/18907171/

[76] IRevolution (2014) Humanitarians in the Sky: Using UAVs for Disaster ResponseJune 25, 2014 http://irevolution.net/2014/06/25/humanitarians-in-the-sky/

[77] Gilbert-Knight, Ariel. Social media, crisis mapping and the new frontier in disaster response. The Guardian. 2014-10-08, http://www.theguardian.com/global-development-professionals-network/2013/oct/08/social-media-microtasking-disaster-response

[78] Luckerson, V. (2014) Fear, Misinformation, and Social Media Complicate Ebola Fight, Time, October 8, 2014. http://time.com/3479254/ebola-social-media/

[79] BBC Trending (2014) Can social media help prevent the spread of Ebola? July 29, 2014, http://www.bbc.com/news/blogs-trending-28552917

[80] van Niekerk, B & Maharaj, M. (2013) Social Media and Information Conflict International Journal of Communication 7 (2013), 1162–1184, http://ijoc.org/index.php/ijoc/article/viewFile/1658/919

[81] BRCK, http://www.brck.com

[82] Personal communication Daudi Were, USHAIDI

[83] Zwijnenburg, W. (2016) Using Citizen Science to Assess Environmental Damage in the Syrian Conflict, January 21, 2015 https://www.bellingcat.com/resources/how-tos/2016/01/22/using-citizen-science-to-assess-environmental-damage-in-the-syrian-conflict/

2.3.4 Self-improving artificial intelligence (AI)

A self-improving AI, is a theorized capability of an advanced program or machine that would be capable of upgrading its own software. As it keeps upgrading itself, the rate of self-improvement will increase exponentially. Once it's passed 'the knee of curve' it might head towards superhuman levels of intelligence, maybe in a matter of months or even days. The potential benefits of such an AI would be tremendous if properly executed, possible being able to solve complex problems (or even virtually any technical problem). A self-improving AI is of some people called 'the last invention man will ever need'. Research for a self-improving AI is ongoing. The time when a self-improving AI would be achievable has long been a subject of speculation, from 30 to 100 years into the future. Experimenting includes analyses of possibilities for, and consequences of, what happens if programmers do not need to tell a computer how to accomplish a task, but only provide it with the end-goal they want it to achieve.

Several leading experts within the scientific and technology fields such as Steven Hawking and Tesla's Elon Musk of have expressed concerns on the development of stronger AI. Some even argue it could lead to mankind's extinction. They urge the need of research of safeguards when developing AI, and including values such as ethics and empathy for AI development with the goal of making a super intelligent AI's values like human goals and values. Meanwhile, discussions are ongoing about the 'robotisations' potential impact on different professions.[84, 85, 86]

2.3.5 Laboratory at home – Do-It-Yourself movement

There is a growing globally movement towards performing scientific experiments outside professional laboratories. For long, wet laboratory experiments in the fields of chemistry and life science have been done only by a few well-educated individuals and only at universities and companies premises. In the recent decade, along with the internet revolution, higher education is more achievable and more people get a university degree, information is more shared and easy to access and there is an increasing global market for laboratory equipment, lab-ware, chemical substances, and biological agents and reagents. These factors have together made it easier than ever for people to explore scientific areas in their private homes or in community laboratories.

It is not only that the number of high-educated people has increased but the know-how is no longer only for persons that has attended a classical university program but virtually any curious and ambitious person with a decent internet connection can acquire tremendous information and competence by consuming demonstration videos, lecture presentations, discussion groups, and scientific literature openly available on the internet.

Chemistry boxes, including household chemicals, suitable for children, have been around for decades. Chemicals are nowadays commercially available for anyone, not only scientifically interested youngsters, and not only harmless substances but precursors (raw material) that can react and form even more harmful products such as narcotics and explosives. There are more or less skilled individuals that wish to explore the field of chemistry out of curiosity and with no ill-meaning agenda. However, the opportunity to purchase chemical substances and lab-ware over the internet from sources that do not ask whether you have a legitimate purpose is better than ever.

The Do-It-Yourself Biology (DIYBio) is a well-established global community consisting of people that have a strong interest in life sciences and wish to do explore a certain

[84] Rawlinson, K. (2015) Microsoft's Bill Gates insists AI is a threat, BBC News, January 2015 http://www.bbc.com/news/31047780

[85] Mack, E. (2015) Why Elon Musk Spent $10 Million To Keep Artificial Intelligence Friendly, Forbes Tech, January 25, 2015

[86] Bostrom, N. (2015) What happens when our computers gets smarter than we. Ted talk, March 2015, http://www.ted.com/talks/nick_bostrom_what_happens_when_our_computers_get_smarter_than_we_are

biological issue. Many individuals in the DIYBio movement are scientists by profession, have a university degree, and work in a biotech company or in the academia but wish to do things that lies outside their professional mission or assignment. The DIYBio community also includes people that do not have a formal education. These people use this web-based community to ask questions and often get guidance in the right direction from more experienced members. Tips included from where to get lab-ware, reagents, protocols, and equipment, which books they should read, to how to set up a laboratory and how to build one's own equipment.

This very democratic approach to embrace science has many advantages such as a growing scientific awareness in the population, opening up science for people that cannot attend universities due to geographic, cultural, or financial constraints, and the possibility that a hobby project could lead to a new creative idea and eventually initiate new start-up companies.

The fact that potential harmful chemicals and microorganisms may be found in places outside conventional institutions and thus can be an exposure risk to, not only the hobby scientist but to people that for some reason enters that persons premises.

2.4 Medical advancements

This chapter touches upon some recent medical advances of relevance.

So what?

Driven by globalization, climate change and the continuing pace of modern society, infectious disease is constantly evolving and spreading constituting a health threat for personal deployed in operations. To avoid future epidemics and pandemics, and to furthermore evolve in trauma treatment and battlefield related wound, the medical and preventive medicine toolbox has to constantly grow. Many promising new technologies within the areas of e.g. bionic technologies, genome sequencing, vaccine developments and innovation in wounds treatment are being development. A trend is also increased public-private partnerships.

2.4.1 Innovations in bionic suits and implants

Exoskeletons

The US military has been developing a variety of exoskeletons in order to enhance a soldier's performance. One of these programs is the "Warrior Web Program" which aims to develop technologies to prevent muscle and skeletal injuries. The results are a number of exoskeletons which allow the wearer to move at a higher pace, carry more equipment and reduce the risk of injuries in muscles and joints. The goal is for the Exoskeletons to consume less than 100 watt.[87, 88]

In July 2105 researchers were able to stimulate the nerves of patients who were completely paralyzed so that they could move their legs in a rhythmic pattern. Later the same year, the same team of scientists enabled a paralyzed man to take thousands of steps during a five-day training session, with the help of a bionic suit and for the two weeks that followed. It will likely be many years before these new approaches are available to everyone, but in the

[87] DARPA. Lightweight, Soft Exosuit Aims to Prevent Musculoskeletal Injury in Warfighters. DARPA. 2014. http://www.darpa.mil/NewsEvents/Releases/2014/09/16.aspx

[88] Upbin, Bruce. First Look At A Darpa-Funded Exoskeleton For Super Soldiers. Forbes. 2014. http://www.forbes.com/sites/bruceupbin/2014/10/29/first-look-at-a-darpa-funded-exoskeleton-for-super-soldiers

longer these technologies could potentially improve the quality of life for those with both partial and complete paralysis.[89]

Will-powered implants

Scientists at Case Western Reserve University in Ohio say they've used electronics to get around a paralyzed man's spinal injury, permitting him to use an implant in his brain to move his arm and hand. The test represents the first time that signals collected in the brain have been conveyed directly to electrodes placed inside someone's arm to restore movement.[90]

2.4.2 Innovations in wounds treatment

Statistics show that up to 90 % of preventable combat deaths occur due to uncontrollable bleeding, and that keeping a patient alive during the first 10 minutes after injury can substantially reduce mortality rates.

RAIDER therapy

The Rapid Active Injury/Distress Enhanced Recovery (RAIDER) project, at the Pacific Joint Information Technology Center Biotechnology Hui, is looking at ways to control and stop bleeding in the field faster and save war fighter lives.

ON of RAIDER's research goal is the development of wound treatments for both immediate and longer-term use to better address changing war fighter priorities.

Currently, two types of wound treatments have been developed and are currently undergoing testing. These include RAIDER therapy for immediate use on the battlefield and first aid posts to stabilize wounds; and RAIDER+ Hydrogel therapy for longer-term use at higher levels of care.

In lab tests, RAIDER therapy has been effective at clotting plasma and blood within three seconds. RAIDER+ Hydrogel therapy on the other hand, provides physical protection while maintaining a moist environment to aid long-term healing and prevent infection.[91]

Vetigel

Vetigel is a polymer gel which can stop a severe bleeding, that would take trained medical personnel minutes to treat, in a few seconds. The gel consists of a plant based polymer which coagulates blood without need for stitching or applying pressure to the wound. In an emergency situation, the gel is placed on the wound using a syringe without the need of preparations. Vetigel is marketed as a potential replacement for bandages and patches. Its creator Joe Landolina began selling Vetigel to veterinary clinics in 2015. Vetigel is currently estimated for human applications in 2016. When it is approved, usage within e.g. the military are considered the next step.[92]

Chitosan treated bandages

Plasters and bandages could soon be fitted with the shells of crabs to help cuts and scrapes heal faster. The key ingredient is a mineral called chitosan found in crustacean shells.

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[89] Maldarelli, C. (2015) Bionic Suits helps a paralyzed man takes thousands of steps, Popular Science, September 4, 2015, http://www.popsci.com/bionic-suit-helps-paralyzed-man-voluntarily-take-thousands-steps

[90] Regalado, A. (2015) Paralyzed Man's Arm Wired to Receive Brain Signals. MIT Technology Review, October 20, 2015, http://www.technologyreview.com/news/542581/paralyzed-mans-arm-wired-to-receive-brain-signals

[91] Military Health System Communications Office (2015) Research to control blood loss underway for enhanced battlefield care, 9 September 2015, http://www.health.mil/News/Articles/2015/09/16/Research-to-control-blood-loss-underway-for-enhanced-battlefield-care

[92] Landolina, Joe. This gel can make you stop bleeding instantly. TED. 2014. http://www.ted.com/talks/joe_landolina_this_gel_can_make_you_stop_bleeding_instantly

Chitosan is known for its healing properties as well as its ability to kill bacteria and has been used in China to treat battle wounds for centuries.[93]

2.4.3 Rapid genetic sequencing

Since the first successful whole sequencing of a human genome (HUGO), a dramatic development has occurred in the speed and miniaturisation of the sequencing equipment used. Today genome sequencing is performed in hours/days compared to the traditional methods that required months and years of work. This is referred to as "High throughput sequencing (HTS)" An example of the state of the art system used is the Oxford Nanoporetech's system MinION.[94]

The MinION is still under development, but several promising results have been published. It is a significant development in this field and it is expected that within a few years from now, rapid, small portable devices are capable to provide very high resolution genetic sequence data in virtually real-time.

Rapid genetic sequencing can be used for applications such as on site rapid identification of pathogenic or antibiotic resistance properties of microorganisms, which in turn will speed up treatment of infected people. Another application could be to examine persons for genetic differences that may have an importance for how soldiers can cope with different situations. A third application may be to assist in identifying victims etc.

2.4.4 CRISPR

Clustered regularly-interspaced short palindromic repeats (CRISPR) is a new genome editing tool that could transform the field of biology. However, scientists have been tinkering with genomes for decades. CRISPR is a naturally-occurring, ancient defense mechanism found in a wide range of bacteria. So why is CRISPR suddenly such a big deal? The short answer is that CRISPR allows scientists to edit genomes with unprecedented precision, efficiency, and flexibility.[95] There are however also concerns, elaborated in a forthcoming report by FOI.[96]

CRISPR modified malaria mosquitoes

A team of researchers led by Imperial College London have genetically modified the mosquito species *Anopheles gambiae* so that they carry a modified gene disrupting egg production in female mosquitoes. The *Anopheles gambiae* is a major carrier of dangerous malaria parasites in sub-Saharan Africa, where 90 % of annual malaria deaths occur.[97]

De-extinction with CRISPR

Woolly mammoths (*Mammuthus primigenius*) have been extinct for millennia, with the last of the species dying out about 3,600 years ago. But scientists say it may be possible to bring these and other species back from the grave, through a process known as de-extinction. Harvard geneticists have used the gene-editing technique CRISPR to insert mammoth genes for small ears, subcutaneous fat, and hair length and colour into the DNA of elephant skin cells. Next, they need to find a way to turn the hybrid cells into specialized tissues, to see if they produce the right traits. After that, the team plans to grow

[93] Vollaston, V. (2016) Bandages made of cab shell could help wounds heal faster. Daily mail, 25 January, 2016, http://www.dailymail.co.uk/sciencetech/article-3415566/Bandages-CRAB-SHELLS-soon-help-wounds-heal-faster-Mineral-taken-crustaceans-absorbs-liquid-kills-bacteria.html#ixzz3yWoMIPUv

[94] MinIon, www.nanoporetech.com

[95] Zhang, S. (2015) Everything You Need to Know About CRISPR, the New Tool that Edits DNA, Gismodo, 5 June 2015, http://gizmodo.com/everything-you-need-to-know-about-crispr-the-new-tool-1702114381

[96] Frithz, E. Allgardsson, A. Stenberg, P. (2016) Genomics in perspective science - science-society-security FOI-R--4217--SE

[97] EurekAlert (2015) Modified mosquitoes could help fight against malaria, Eurekalert, Decembebr 7, 2015, http://www.eurekalert.org/pub_releases/2015-12/icl-mmc120415.php

the hybrid cells in an artificial womb. If the researchers can get these hybrid mammoth-elephants to survive, they hope to engineer an elephant that can survive in cold climates, where it should face fewer threats from humans.[98]

2.4.5 Zombie infections

The British Medical Journal has released an informative, peer-reviewed study on zombies as part of their Christmas 2015 edition. Zombies that is undead troublemakers are complex creatures that can use variable methods of infection. According to the report, they have become a "dominant part of the medical landscape," and so have to be considered carefully. It's probably worth pointing out that this study is decidedly tongue-in-cheek, and references both zombie fiction and real-life pathogens.[99]

2.4.6 Preventable diseases and microbial drug resistance

The counterfeit medicines is an increasing problem that contributes to human suffering as well as growing drug resistance.[100] For instance, around a third of malaria drugs in Sub-Saharan Africa are of poor quality: either containing less of the active ingredient than advertised or being adulterated with things such as corn flour, paracetamol or aspirin. Substandard drugs can cause drug resistance without effectively treating the illness, while contaminants can even kill patients.

Test to discover counterfeit medicines malaria drugs

Scientists have designed a cheap and easy-to-use paper test card that uses colour coding to detect fake antimalarial drugs. To test a pill or tablet, it is crushed and swiped across the card that is then placed in water for a few minutes.[101]

Countering reoccurrence of preventable diseases

With the increased migration and the conflict in Ukraine, concerns are that several preventable diseases, like tuberculosis and polio is returning to Europe.
A tuberculosis drug specifically designed for children — combining sweet flavours and the correct dosage in a dissolvable tablet — is expected to hit markets early 2016, according to the NGO TB Alliance.[102]

2.4.7 New vaccines

Ebola vaccine partnership

At the World Economic Forum 2016 in Davos Gavi, the Vaccine Alliance and MSD, a subsidiary of Merck & Co., Inc. announced that they have signed an agreement to support the provision of a vaccine to protect against future Ebola outbreaks. The agreement, announced today at the World Economic Forum in Davos, will help Merck take the

[98] Lewis, T. (2015) Woolly Mammoth DNA Inserted into Elephant Cells. Life Science, March 26, 2015, http://www.livescience.com/50275-bringing-back-woolly-mammoth-dna.html
[99] Smith, T.C. (2015) Zombie infections: epidemiology, treatment, and prevention, B*MJ* 2015; 351, 14 December 2015. http://www.bmj.com/content/351/bmj.h6423
[100] PhRMA http://www.phrma.org/counterfeit-drugs
[101] Naragi, S. (2015) Paper test cards pick out fake malaria drugs. SCi Div Net, 15 jnuary, 2015 http://www.scidev.net/global/medicine/news/innovation-for-fake-malaria-drugs-test.html
[102] Loke, A. (2016) First children's TB drug hits market, SCi Dev Net, 4 January 2016. http://www.scidev.net/global/tb/news/children-tb-drug-hits-market.html

vaccine through licensure and WHO prequalification.[103] For an elaborated discussion of the use of 3D-printing, see Bucht et al 2016.[104]

Dengue vaccine

Sanofi Pasteur, the vaccines division of Sanofi, announced recently that the Mexican authorities have granted marketing authorization to Dengvaxia®, making it the first vaccine to be licensed in the world for the prevention of dengue. The approval is based on results from an extensive clinical development program involving over 40,000 people of different ages, geographic and epidemiological settings, and ethnic and socio-economic backgrounds living in 15 countries. The World Health Organization (WHO) has called for development of a dengue vaccine as an essential part of the integrated dengue prevention effort needed to significantly lower the dengue burden globally. The WHO has called on endemic countries to reduce dengue mortality by 50 % and morbidity by 25 % by 2020.[105]

2.5 Energy developments

This chapter briefly describes some of the developments in the energy sector that are of relevance for military and civilian operations. The topics are further elaborated in other recent reports, cited below.

So what?

The military is a large consumer of energy, both domestically and in international operations. Internationally, also humanitarian agencies are large consumers of non-sustainable energy sources. Not seldom are the majority of infrastructure and transport systems run by diesel and lack of thereof creates vulnerabilities and operational implications, as seen by military organisations in e.g. Afghanistan and humanitarian and development counterparts during the Ebola-outbreak in East Africa. A more self-sustained energy system increases the operational capability as well as decreases health exposure from e.g. air pollution and noise.

2.5.1 Renewable energy on the increase

Solar power

Since 2010 the capacity of solar energy in the world has increased more than the previous four decades combined. In late 2014, the global production capacity was nearly 200 GW. Solar energy is becoming increasingly common in both industrialized and developing countries. India, for instance, hostess the world's first airport operated 100 % by solar energy and in Nepal 80 % of Bhutanese refugees in two refugee camps in south eastern Nepal acquired solar panels by themselves and shared experiences on what works and what does not work.[106, 107] In Africa, the trend of PAYG (Pay as you go) solar energy is

[103] Berkely, S. (2016) An Ebola vaccine and the future of fighting infectious disease. Wef Forum Industry Agenda, 22 JANUARY, 2016,
http://www.weforum.org/agenda/2016/01/new-challenges-smart-solutions-partnership-is-antidote-to-future-epidemics

[104] Bucht, G., Frithz, E. Waleij, A.(2016) Ebola: fakta och farhågor mot bakgrund av epidemin i Västafrika. *Forthcoming*

[105] Sanofi Pasteur (2015) Dengevaxia ® World's first dengue vaccine approved in Mexico, Press release, December 9, 2015,
http://www.sanofipasteur.com/en/articles/dengvaxia-world-s-first-dengue-vaccine-approved-in-mexico.aspx

[106] Upadhyay, A. (2015) 1st Airport In World To Go 100% Solar Is In India. CleanTechnica, August 21st, 2015, http://cleantechnica.com/2015/08/21/1st-airport-world-go-100-solar-india/

[107] UNHCR (2015) 'From Street Lights to Micro-grid, Mission Report', *UNHCR Innovation, Engineers Without Borders*, unpublished, 2015

furthermore increasing. It is estimated that solar power will account for at least 16 % of the global energy production by 2050.[108]

Technical progress continuously reduces energy consumption and carbon emissions during manufacturing of solar panels. China has developed into a global player and prices have fallen significantly for solar energy systems. The same goes for batteries and LED lighting. The need for energy storing of renewable energy is however also increasing. The market for energy storage is still relatively limited but more technologies is expected to reach commercial stage over the coming years.[109, 110]

There are a lot of things to take into consideration if you want to put solar panels on your roof. Using its high resolution satellite imagery and huge trove of mapping data, Google has created a tool to help you determine whether you should get solar panels. All you need to do is enter your address into Project Sunroof.[111, 112]

Renewable energy in operations

Military and Crises management operations make increasingly use of solar power, sometimes in combination with other renewable energy sources such as wind or biogas (i.e. creating hybrid systems). A recent report looks into the current and future prospects from solar energy and review cases studies from operational use of solar power in the field.[113]

Behavioural change

Changes to how the military sector in particular uses energy has momentous implications simply because it uses so *much* of it. For instance, the US Department of Defense is the single biggest user of energy in the U.S. Changes in technology however needs to be coupled with behavioural changes. Estimations by the US Marine Corps is that through behavioural changes alone, such as changing the ways that the Marine Corps drive their vehicles, power their outposts, handle their equipment can increase the battle strength with up to five additional days.[114]

2.5.2 Tesla batteries and Gigafactory

The company Tesla Motors aims to accelerate the world's transition to sustainable transportation. With a planned production rate of 500,000 electric cars a year, Tesla alone will need the entire world production of lithium ion batteries in the year 2020. For this reason, Tesla is building the “Gigafactory” to be able to deliver enough batteries to meet the expected demand.[115]

In May 2015, the electric car company Tesla announced its entry into the energy market, unveiling a suite of low-cost solar batteries. The lithium-ion batteries are designed to capture and store up to 10kWh of energy from wind or solar panel. The reserves can be

[108] IEA (International Energy Agency, 2014) Technology Roadmap Solar Photovoltaic Energy https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapSolarPhotovoltaicEnergy_2014edition.pdf

[109] MPower (2015) Market for Energy Storage Systems Set for Growth, December 1, 2015, https://www.mpower.com.au/blog/2015/12/01/market-for-energy-storage-systems-set-for-growth

[110] IVA (Kungliga Ingenjörsvetenskapsakademien, 2015) Energilagring- Teknik för lagring. IVA-projektet Vägval http://www.iva.se/globalassets/info-trycksaker/vagval-el/vagval-el-lagring.pdf

[111] Mohdin, A. (2015) Should You Get Solar Panels? Ask Google, IFL Science, August 21, 2015, http://www.iflscience.com/technology/should-you-get-solar-panels-ask-google

[112] See https://www.google.com/get/sunroof#p=0

[113] Waleij, A. Westerlund, D. Liljedahl, B (2015) Studie om erfarenheter av användning av solceller i fält. FOI-R-4204-SE. FOI, Stockholm, Sweden

[114] Mooney, C. (2015) The next energy revolution won’t be in wind or solar. It will be in our brains. Washington Post, January 22, 2015, https://www.washingtonpost.com/news/energy-environment/wp/2015/01/22/the-next-energy-revolution-wont-be-in-wind-or-solar-it-will-be-in-our-brains/

[115] The name Gigafactory comes from the factory's planned annual battery production capacity of 35 gigawatt-hours (GWh)

drawn on when sunlight is low, during power cuts or at peak demand times. This might be on particular interest for remote located places, with lack of energy infrastructure. The batteries are slim, and can be mounted on a wall.

In cooperation with various strategic partners, Gigafactory plans to manufacture batteries at significantly lower cost, thanks to economies of scale, innovative manufacturing, reduction of waste and the optimization resulting from the greater part of the manufacturing process are gathered under the same roof. The cost per kWh for batteries is expected to be reduced by over 30%. Gigafactory will also be powered by renewable energy sources, with the goal to eliminate the deficit in the energy balance.[116, 117]

2.5.3 Energy saving applications

In addition to alternative energy sources, energy saving applications and devices brings additional value.

Conserving water

Low pressure shower heads, water recycling and showers that changes colour with the amount of water consumed are a few examples of water and ultimately also energy saving devices.[118, 119]

Lithium-air batteries

Current design of lithium-air batteries normally uses lithium peroxide. Lithium peroxide is not the most efficient, though, as it binds very tightly with lithium, so researchers have been looking for an alternative approach. A new prototype that instead stores energy in lithium superoxide has been developed, which can break down more easily, producing greater efficiency and a good battery life.[120]

Light- transmitting metamaterials

A metamaterial is a substance that has properties not observed in nature. In this case, a new metamaterial, developed by the developed at Harvard's School of Engineering and Applied Sciences, has a refractive index of zero, which means that the light phase in the material can travel infinitely fast. Details has been published in Nature Photonics.[121]

2.5.4 Cyber-hacking of energy facilities

Cyber-hacking capability is rapidly increasing, amongst individuals as well as terror networks and cyber-security is today an established tool in the military defence. At the same time, for rational, economic and efficiency reasons, increasingly larger parts of civil society's infrastructure, and to a certain extent also the military component, is based on IT and, at some occasions, also linked into 'the cloud'. This raises questions about potential new health hazards. The topic has been further developed in a separate report, exploring among other things cyber threats on energy infrastructure, and the implications thereof.[122]

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[116] Se https://www.teslamotors.com/sv_SE/gigafactory

[117] Mooney, C. (2015) Why Tesla's announcement is such a big deal: The coming revolution in energy storage. Washington Post, May 1, 2015, https://www.washingtonpost.com/news/energy-environment/wp/2015/04/30/why-teslas-announcement-could-be-such-a-big-deal/

[118] Shower of the future. Today. https://orbital-systems.com/en-eu/

[119] Johnson, M. (2016) This color-changing shower tells you how much water you're wasting, Tech Insider, January 26, 2016 http://www.techinsider.io/color-changing-shower-tracks-water-waste-2016-1

[120] Carpineti, A (2016) New Lithium Battery Is Five Times Better Than Current Ones, IFL Science, January 23, 2016, http://www.iflscience.com/technology/new-lithium-battery-5-times-better-current-ones

[121] Carpineti, A. (2015) New Metamaterial Transmits Light With No Energy Loss, IFL Science, October 22, 2015, http://www.iflscience.com/new-metamaterial-transmits-light-no-energy-loss

[122] Liljedahl, B. Berglind, R. Grahn, H. Holm, H. Koch, B. Liljedahl, L. Lindahl, D. Sandström, B. Waleij, A, Westring, E. Wikström, P.(2016) Cyber-attacks on industrial and critical infrastructure. An emerging health threat? FOI-RH-1602-SE, *forthcoming*

2.5.5 Micro grids

Despite the best efforts of electricity grid planners and operators, the number of major electrical blackouts around the world is growing year on year, whether caused by natural disaster or human triggered events. These blackouts often come at incredible cost. By relying on a variety of generators, a micro grid system avoids many of the single-point-of failure issues of the traditional electricity grid. By relying on a variety of generators, a micro grid system avoids many of the single-point-of-failure issues of the traditional electricity grid. A recent White Paper from International Electro-technical Commission (EIC) considers necessary preparation for, and recovering from, major electricity outages, reviews recent major electrical outages around the world and discusses best practices regarding micro grid use.[123]

[123] IEC (International Electrotechnical Commission, 2014) White Paper Microgrids for disaster preparedness and recovery with electricity continuity plans and systems, http://www.iec.ch/whitepaper/microgrids/?ref=extfooter

3 Discussion and recommendations

Evolving technologies may provide new opportunities to manage health concerns during operations. This holds true for both military and civilian operations, and several tools such as unmanned aerial vehicles (drones) and additive manufacturing (AM, or 3D-printers) are already operationalized for various purposes. At the same time, new threats with potential health implications may rise from the rapidly developing "new normal" of technologies.

An initial quick scanning of some evolving technologies was performed. The conclusion so far suggests that new health threats indeed may arise, and new health management procedures therefore may be required. This applies for all the stages of a mission's life cycle, from planning to deployment to downsizing and drawback. It might thus be valuable to make a more in depth evaluation with focus on of potential health hazards and opportunities from evolving technologies. On that note, a fictive mission scenario (described in Appendix 1) developed in order to possibly further elaborate on the topic.

In the continuous work with environmental and health hazards in operations, key challenges identified are the repeated malfunction in waste management, water-, and wastewater treatment, and operational energy management. Remotely located camps in combination with limited logistic support options, often result in a turnaround time of several weeks to months of critical spare parts. Meanwhile, dispersion of biological and chemical effluents repeatedly causes health hazards for deployed personnel as well as the local population.

Another identified health concern, is the health impact and musculoskeletal disorders on troops from equipment, and need for cheap, fast constructions of various infrastructure.

Would it be possible to use 3D-printers in logistically remote areas and by downloading of blueprints from the internet to print broken parts, thus ensuring swift access to 'temporary spare parts' while waiting for the original to arrive? And could individualized 3D-scanning and printing of critical equipment help to reduce injuries and musculoskeletal disorders?

These are some of the questions that most likely will warrant further attention.

3.1 Recommendations

It is suggested, that a joint seminar, with the Swedish Armed Forces medical stake holders, CBRN stakeholders and the Swedish Defence Material Administration (FMV) possibly a structured workshop, is conducted to highlight potential way ahead regarding this matter.

During this seminar, or workshop, a discussion on potential new health threats, and opportunities for operational health management, based on the fictive scenario, presented in Appendix 1, might be conducted.

Areas that may warrant further study, if not already addressed, include

- Access to download of blue print drawings of spare parts via internet to be 3D-printed in remote areas – to reduce hazardous pollution during missions
- Individualized 3D-scanning of e.g. individual seize of staff – to reduce equipment related injuries and musculoskeletal disorders.
- Potential use of mini-drones for reconnaissance and surveillance purposes
- Potential use of mini-drones for medical support to remote troops
- CBRN detection systems for early warning and identification of potential intrusion via drones

Appendix 1

Fictive scenario

To facilitate a discussion on potential opportunities and challenges with emerging technologies for military and/or civilian missions, a fictive scenario has been developed to be used as 'food for thoughts'. The scenario is fictive, but build upon health related experiences from the last decades military and civilian operations in e.g. Afghanistan, Iraq, Mali, Somalia and DRC.

Scenario Mission X

In support to a newly established UN peacekeeping mission, deployment is done to a non-permissive, remote area. The mission hence faces logistic challenges with limited fixed wing and helicopter resources, poor road quality and lack of local infrastructure. Due to climate conditions, several parts of the equipment are worn down, and leakage from diesel generators as well as waste water treatment becomes a problem in both military and civilian camps. Also, the water purification system lacks a vital gasket. The agreed UN logistic support is delayed (6 months +) due to escalating conflicts in other regions. The task includes patrolling on 1-3 days distance from the base camp. A number of challenges are reported, as listed below.

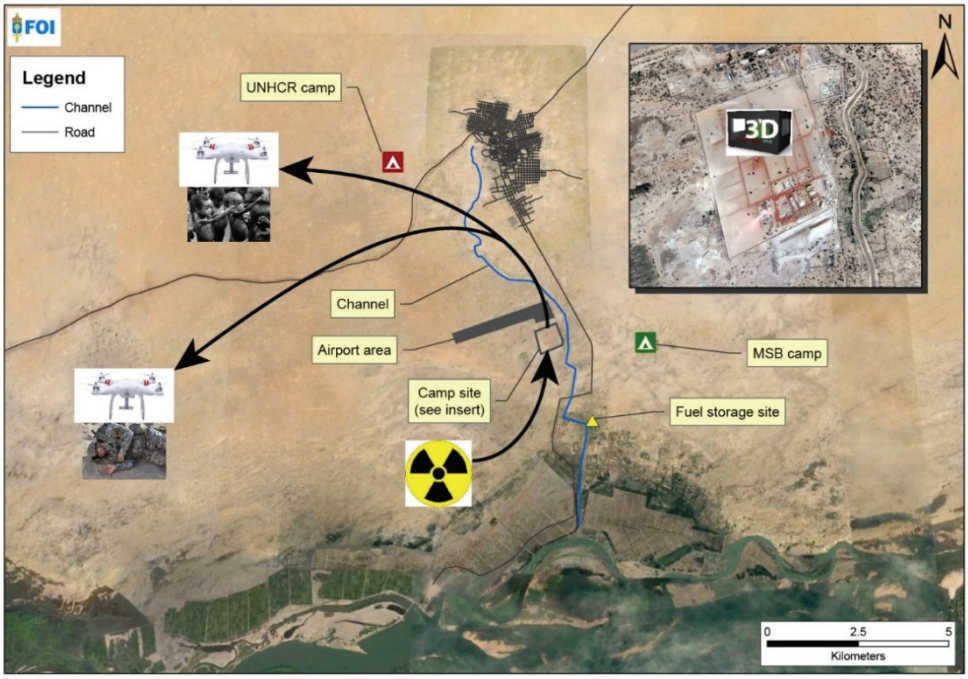

Figure 1. Fictive scenario based discussion on potential operational health hazards and opportunities from evolving technologies; Operational Phase

Military

- Patrols has to be reduced due to lack of MEDEVAC capability in the mission
- Concerns about potential disease outbreak due to malfunctioning water and wastewater treatment systems (e.g. concern about the potable water quality due to lack of the gasket)

- The camp perimeter is ‘temporary’ due to delays in the UN logistics support chain, impacting the security

Civilian

- Food distribution is hampered due to rain season and bad roads
- Frequent attacks and rapes in remote villages
- A large, unexpected influx of refugees and IDP’s due to the security situation

In addition

- Unidentified CBRN related objects are found in in both military and civilian camps at dawn

Question 1. Could emerging technology be useful to address health related problems for the military and/or civilian mission? Is so, what steps are needed to be taken to ensure this? (Who, what, when and how in mission planning)

Question 2. Could emerging technology pose a threat with health implications for the military and/or civilian mission? If so, what steps are needed to be taken to prevent this? (Who, what, when and how in mission planning).

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