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JRC horizon scanning on dual-use civil and military research

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Abstract

This report presents the results of a horizon scanning exercise, carried out by the Joint Research Centre (JRC), aiming to identify 'emerging' issues displaying potential for dual-use research and further applications, namely the use of civilian research outcomes for defence purposes and vice versa. The exercise allowed 14 issues to be identified, 7 of which have been further commented on: 6 were perceived as having a very high level of relevance for dual-use applications in the short to medium term (between now and circa 10 years), and 1 was assessed as emerging in the longer term. Four issues out of these seven fall entirely or partially within the realm of biology: 'Multifunctional materials', 'CRISPR and genetic manipulations', 'Enhancing humans' and 'Synthetic biology'. All together, these thematic issues, which are actually interrelated, show that the manipulation of the living, including that of human bodies, with all its aspects – positive and negative, bright and dark, defensive and offensive – is expected to increase in time and impact. Other issues identified belong, broadly speaking, to space, artificial intelligence and data poisoning.

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1 Introduction

Although the European Commission has had a major role and intervention in security issues for a long time, recently it has been called on to step up its role in defence matters because of concomitant developments in world geopolitics ([1]) and the growing overlap between civilian and military operations. One recent and strong indication of this trend is the creation by the new Commission (2019–2024) of a Directorate-General for Defence Industry and Space, which is in charge of, among other aspects, the implementation of the European Defence Fund. Within this framework, more research will be needed to support the Commission's security and defence initiatives by, in particular, taking dual-use research into greater consideration. This type of research can be defined as research that would generate ideas or develop products, services or technologies potentially addressing the needs of both defence and civilian communities. The Joint Research Centre (JRC), as the Commission's science and knowledge service, will also contribute to this effort.

As a transversal approach, the Commission is also aiming to increase the use of foresight studies in policymaking. The JRC is already strong in this approach, with its JRC strategy 2030 ([2]) advocating a stronger anticipatory culture. Foresight and horizon scanning help us to look into the longer-term impact of policies and technologies and anticipate emerging societal challenges.

It is therefore within this framework that the JRC organised the first horizon scanning exercise on security in 2018 ([3]). In a continuous process, and at the same time as a study on security research projects with dual-use potential funded under Horizon 2020 ([4]), it then organised a second horizon scanning exercise at the end of 2019, this time aiming to identify some 'emerging' issues displaying potential for dual-use research and further applications, namely the use of civilian research outcomes for defence purposes and vice versa. Semantically, it should also be noted that, in the life sciences, the notion of dual-use research tends to mean research in technologies and information that can have both benevolent and malevolent use ([5]), and it is often referred to as dual-use research of concern ([6]). Dual use is also used for items that can be used for both civil and military purposes, including nuclear, in the context of strategic trade control/export control ([7]).

This horizon scanning exercise may also bring fresh ideas and thinking for future orientations and developments of the JRC's work on security and defence research. The results of such foresight activity might also help to frame future calls aiming to select EU-funded research and innovation projects with dual-use potential in emerging areas.

The present document reports the results of this horizon scanning exercise, which was jointly organised by JRC Units E.7 and I.2.

([1]) Between 2016 and 2019, three factors challenged this approach and led to calls for the European Union (EU) to play a greater role in defence: the fact that Europe's neighbourhood has come under threat; increased uncertainty related to the United States' commitment to guaranteeing Europe's security; and Brexit.
Directorate-General for External Policies of the Union, EU's Institutional Framework Regarding Defence Matters, 2020 (https://www.europarl.europa.eu/RegData/etudes/IDAN/2020/603484/EXPO_IDA(2020)603484_EN.pdf).
([2]) JRC (2016).
([3]) Results are published in Bordin et al. (2019).
([4]) Bordin et al. (2020).
([5]) See, for example, Imperiale and Casadevall (2018).
([6]) WHO (2020).
([7]) EU (2009).

2 Methodology

The JRC Competence Centre on Foresight describes horizon scanning as a tool that helps identify emerging issues, weak signals of change and events that could lead to changes in behaviour, strategy or policy ([8]). According to a publication carried out on behalf of the European Commission ([9]), 'horizon scanning is the systematic outlook to detect early signs of potentially important developments. These can be weak (or early) signals, trends, wild cards or other developments, persistent problems, risks and threats, including matters at the margins of current thinking that challenge past assumptions. Horizon scanning can be completely explorative and open or be a limited search for information in a specific field based on the objectives of the respective projects or tasks'. As highlighted by the authors of the abovementioned study, it is important to note that the aim of horizon scanning is not to predict what will happen in the future but rather to gather signals of change that, considered together, provide insights for future developments.

A methodology has been developed at the JRC to implement this foresight tool, and it consists of several consecutive steps ([10]). These steps are summarised below for the current exercise.

1. Gathering information

    (a) **Scanning**. A group of colleagues throughout the JRC volunteer as 'scanners' to collect items from various sources (e.g. scientific articles, press articles, audio-visual programmes, blogs) that refer to the overall subject of the exercise and indicate something new, different and potentially important. Diversity is important, and therefore items may originate from many apparently unrelated domains. For each item provided with an informative title, the scanners indicate their personal opinion on why it could be important for the future. For this exercise, a call was launched to collect items pertinent to dual-use civil and military research during a period of 1 month. The JRC staff who provided the items were working in the areas of nuclear security and safety, energy, health and consumer safety, transport, text and data mining, foresight, space and security.

    (b) **Organising information**. The scanners organise and categorise items in the JRC horizon scanning platform. Each item must have an informative title, a description or summary, a reason why it may be important for the future in regard to the subject, a link to the information source and the date of publication.

    (c) **Sharing information**. Once the period of item collection is over, the organising team checks all the items. Those that are selected are then gathered in a single document and shared with the future participants of the following stage of the process, which is called the 'sense-making session'. In the current exercise, 84 items (given in the annex) were selected to feed the sense-making session.

2. Clustering of information and sense-making analysis

    (a) **Clustering of items**. In advance of the sense-making session – at least 1 week beforehand – each participant ([11]) receives and reads all the items in order to identify possible thematic clusters, usually between four and six, by interrelating or connecting items. These connections and interrelations (also known as 'clusters') could indicate concrete potentially emerging issues. The items are intended to serve as starting points or inspirations to initiate the identification of potential emerging issues, and it is not necessary to use all of them. The intention is not to consider the items 'at face value' but to think about them in a critical way, drawing on personal knowledge and judgement in order to identify concrete emerging issues for the future. There is no relationship between the number of items gathered in a cluster and the importance of that cluster. On the contrary, clusters with more than 10 items tend to be too complex and difficult to define and assess at the next stage of the horizon scanning process.

([8]) https://ec.europa.eu/knowledge4policy/foresight/topic/horizon-scanning_en

([9]) Cuhls et al. (2015).

([10]) Krzysztofowicz et al. (2018), Tsakalidis et al. (2019), White et al. (2017) and Cranfield University and Waverley Consultants (2018).

([11]) The current exercise involved 12 participants from both the JRC (Units C.7, E.4, F.7, G.III.8, G.10, I.3; areas of expertise: energy, nuclear safety and security, nuclear decommissioning, safety and security of buildings, text and data mining) and other EU services and institutions (European External Action Service-European Union Military Staff, European Parliament, Directorate-General for Research and Innovation), including experts in military affairs. The sense-making session took place on 21 November 2019.

(b) **Identification of emerging issues.** During the sense-making session, participants briefly present their clusters. Discussions with other participants strive to reinforce the specific and innovative nature of these clusters so as to identify/refine potential emerging issues. Participants are asked to be creative and open-minded, as eccentric ideas and associations, rather than established trends, are of interest. For the current exercise, the participants agreed on a set of 14 emerging issues.

(c) **Mapping/prioritisation of issues.** The last phase of a sense-making session aims to map and prioritise the common issues by generally displaying their expected importance / impact / likelihood to occur as a function of time. In the current exercise, the 14 issues were mapped and prioritised according to their level of relevance to dual-use research as a function of a time horizon (< 5 years; 5–10 years; > 10 years), that is, when and how intensely a research issue might have an impact on civilian and defence domains. This mapping reflects the overall perception of the participants.

3. Further characterisation of issues

Issues that are the outputs of the sense-making session can then be further studied in order to go deeper into the comprehension of their potential role and impact in the future. In the current exercise, the seven 'top' issues (according to their prioritisation) were further characterised by bringing together information from the sense-making discussions and additional sources identified through desk-based research. Staff from the organising team and one participant in the sense-making session carried this out.

4. Deliverable

The results of the horizon-scanning exercise are presented in a report. For the current exercise, the report was drafted by the organising team, and then reviewed / supplemented by all the participants in the sense-making session.

Note that, in this text, the expression 'dual-use research relevance' is to be understood as qualifying research 'that produces results having potential for civil and military applications'.

3 Results

The first section of this chapter lists the 14 issues identified in the sense-making session. They are enumerated by name and accompanied by a selection of supporting information items and specific topics that were uncovered during the discussion. The schematic style of this section is used on purpose to quickly identify what is at stake. In Section 3.2, the mapping and the prioritisation of items are presented. The issues that emerged as displaying the highest level of relevance to dual-use research in the short to medium term, plus one issue assessed as emerging in the longer term, are further commented on in Chapter 4.

3.1 The 14 common issues

3.1.1 Issue: 'Energy + climate research'

Items that support this issue:

No 1 – Space nuclear renaissance powered by highly enriched uranium

No 6 – Floating nuclear plant

No 24 – DFAB – House built by robots

No 69 – The tech innovations we need to happen if we are going to survive climate change

No 83 – BusBot – Solar powered information technology.

Topics:

- digital revolution and climate change – new technologies; reduce emissions – directly (e.g. non-fossil energy, structural energy retrofit, carbon dioxide (CO_2) capturing) and indirectly (e.g. efficient resource management, construction, food production);
- omnipresent energy – affordable energy, portable energy, energy autonomy, enhancing space and deep-sea exploration, nuclear energy back in the spotlight.

3.1.2 Issue: 'Private companies in sensitive R&D'

Items that support this issue:

No 10 – Musk's satellite project testing encrypted internet with military planes

No 21 – Military eyes hunting for rapidly deployable atomic power

No 29 – New unmanned ship design

No 32 – Europe's aims to clean up the space graveyard

No 36 – Private space companies draw inspiration from successful rocket launch at sea

No 56 – Nuclear micro-reactors powering U.S. DoD infrastructure before 2027

No 62 – Freelance site offers illegal spying services.

Topics:

- Privatisation of research and development (R&D) – as government budgets come under more scrutiny and pressure, private companies step into strategic R&D; hence, what can be done to safeguard public interest?
- Role of private companies in defence and space: hindering or empowering?
- Globalisation of dual-use equipment and technologies: what to watch for; how to control it; preparing a response/reaction rather than control.

3.1.3 Issue: 'CRISPR and genetic manipulations'

Items that support this issue:

No 45 – US military to develop genetically modified plants to spy

No 46 – Big agriculture eyeing genetic tool for pest control

No 47 – Characteristics of microorganisms most likely to cause a global pandemic

No 49 – US military wants to know what synthetic-biology weapons could look like

No 65 – Russian 'CRISPR-baby' scientist has started work.

Topics:

— large-scale genetic manipulations with positive/negative outcomes;

— the fact that insect populations are almost decimated by genetic modification or nuclear technology, but the remaining ones are more resistant and prone to mixing with other species;

— creation of biological weapons through CRISPR (clustered regularly interspaced short palindromic repeats) that targets only humans;

— North Korea using CRISPR and other gene-editing technologies to cater to rich patients and clients while weaponising the technology.

3.1.4 Issue: 'Space technologies'

Items that support this issue:

No 7 – Iridium and OneWeb to collaborate on a global satellite services offering

No 8 – SpaceX plans to start offering Starlink broadband services in 2020

No 9 – France plans lasers to blind enemy satellites

No 10 – Musk's satellite project testing encrypted internet with military planes

No 15 – Drones are becoming a cybersecurity nightmare

No 20 – NASA is going back to the future with nuclear rockets

No 32 – Europe's aims to clean up the space graveyard

No 38 – Russia challenges US defence in space, developing capabilities

No 41 – Plug-And-Play spacecraft take a leap forward

No 67 – The Spaceline – a practical space elevator

No 72 – After the Moon, people on Mars by 2033 … or 2060.

Topics:

— threats to satellites – dual-use technology for disabling satellites;

— threats from satellites – debris management;

— four-dimensional perimeter protection – protection of critical infrastructure and public spaces, drone identification, interception;

— geopolitical competition in space ('space war getting ready') – EU role and capabilities;

— the fact that the race for a future 'playground'/'battlefield' is already here, but the right tools are still missing – precision strike (avoidance of collateral damages), strategic deployment, austere environment currently uncontested (importance of 'first come, first served'), use of unmanned automated platforms.

3.1.5 Issue: 'Artificial intelligence in decision support'

Items that support this issue:

No 2 – A robot puppet hooked up to a human

No 4 – Machine learning for security?

No 5 – Science fiction: The French army recruits writers to prepare for the future

No 13 – Virtual reality for increased safety of nuclear power plant operation

No 17 – ‘Spidey senses’ could help autonomous machines see better

No 18 – Coming soon to a battlefield: Robots that can kill

No 25 – Artificial intelligence can turn brain signals into speech

No 28 – The mirrorworld does not yet fully exist, but it is coming

No 29 – New unmanned ship design

No 43 – DARPA is funding research into AI that can explain what it’s ‘thinking’

No 45 – US military to develop genetically modified plants to spy

No 52 – China sold 30 % of the robots in the world in 2016

No 55 – Cheetah III robot preps for a role as a first responder

No 62 – Freelance site offers illegal spying services.

Topics:

— remote operational control – no human physical displacement;

— coordinated objects – structures, vehicles and living organisms will be more connected and monitored; how to balance optimal performance, security and privacy;

— spying from a distance;

— the fact that winning the race for information superiority (quantum supremacy) is crucial to military success – situational awareness, good, fast and well-informed decision-making, ‘power to the edge’ trend;

— artificial intelligence (AI) decision-making – explaining decisions, picking the right decisions.

3.1.6 Issue: ‘Enhancing humans’

Items that support this issue:

No 2 – A robot puppet hooked up to a human

No 5 – Science fiction: The French army recruits writers to prepare for the future

No 25 – Artificial intelligence can turn brain signals into speech

No 42 – A wearable robotic suit (‘Iron Man’ style) to deal with radioactive waste

No 48 – Highly elastic biodegradable hydrogel for bioprinting of new tissues

No 50 – E-tattoos? 3D printable electronics could make them possible

No 65 – Russian ‘CRISPR-baby’ scientist has started work.

Topics:

— ‘super humans’ – genetically and technologically improved (CRISPR baby, robot puppet (human–machine interface), wearable robotic suit, use of functional materials).

3.1.7 Issue: ‘Brain imaging and stimulation’ (including brain–computer interfaces)

Item that supports this issue:

No 25 – Artificial intelligence can turn brain signals into speech.

Topics:

— brain signals into speech,

— potential mind reader.

3.1.8 Issue: 'Synthetic biology'

Items that support this issue:

No 14 – Blasting *E. coli* bacteria with ionising radiation once a week makes it radiation resistant

No 40 – Synthetic DNA: Four new DNA letters double life's alphabet

No 47 – Characteristics of microorganisms most likely to cause a global pandemic

No 51 – Camouflaged nanoparticles deliver killer protein to cancer cells

No 73 – Renewed alarm about increasing anti-microbial resistance.

Topics:

— alarm about increasing anti-microbial resistance,

— synthetic deoxyribonucleic acid (DNA) to support life, nanosystems targeting cancerous tumours.

3.1.9 Issue: 'Data poisoning'

Item that supports this issue:

No 26 – From drone swarms to modified *E. coli*: say hello to a new wave of cyberattacks.

Topics:

— sabotaging machine learning so that it could misinterpret incoming data;

— a new form of cyberattack – feeding incorrect data to be used by AI into the system (i.e. data poisoning as weapon).

3.1.10 Issue: 'Liquid security'

Items that support this issue:

No 2 – A robot puppet hooked up to a human

No 4 – Machine learning for security?

No 28 – The mirrorworld does not yet fully exist, but it is coming

No 30 – The dark side of our drone future

No 35 – Future technologies and global defence market

No 39 – Wi-Fi signals identify walkers from their gait

No 45 – US military to develop genetically modified plants to spy

No 74 – World first C-ITS cybersecurity system

No 76 – Wearable face projector.

Topics:

— building security – AI, Internet of Things, data sensors;

— civilian security and privacy issues – digital smart technologies;

— AI image recognition, people identification, future technologies.

3.1.11 Issue: 'New sensitive raw materials'

Item that supports this issue:

No 11 – Ford and IBM among quartet in Congo cobalt blockchain project.

Topics:

— blockchain for critical (or other valuable) supplies, for traceability, quality control and certification of origin.

3.1.12 Issue 'Dual-use in social sciences and art'

Items that support this issue:

No 5 – Science fiction: The French army recruits writers to prepare for the future

No 67 – The Spaceline – A practical space elevator

No 69 – The tech innovations we need to happen if we are going to survive climate change

No 77 – Quantum supremacy

No 78 – Psychedelics and biophilia.

Topics:

— giving more attention to social sciences,

— understanding human nature and motivations,

— creativity, imagination and prospective through science-fiction involvement.

3.1.13 Issue: 'Small/portable nuclear reactors'

Items that support this issue:

No 1 – Space nuclear renaissance powered by highly enriched uranium

No 6 – Floating nuclear plant

No 16 – China will soon start building a 30 000-tonne nuclear-powered ship

No 21 – Military eyes hunting for rapidly deployable atomic power

No 56 – Nuclear micro-reactors powering U.S. DoD infrastructure before 2027

No 57 – Nuclear propulsion, critical to Arctic dominance.

Topics:

— re-emerging nuclear power – the need to explore space and the Arctic, and for military purposes;

— whether or not the EU is investing in research into new forms of nuclear energy (as an alternative to small nuclear reactors);

— the fact that EU Member States are concerned with licensing and regulation – it could be wiser to work on a contingency plan.

3.1.14 Issue: 'Multifunctional materials'

Items that support this issue:

No 12 – New ultra-lightweight ceramic material that withstands extreme temperatures

No 24 – DFAB – House built by robots

No 48 – Highly elastic biodegradable hydrogel for bioprinting of new tissues

No 50 – E-tattoos? 3D printable electronics could make them possible

No 59 – Composite metal foam for use in aircraft wings

No 66 – 3D printing to recycle more nuclear material.

Topics:

— materials science and engineering being overlooked in the role of technological revolution: no material means no technology;

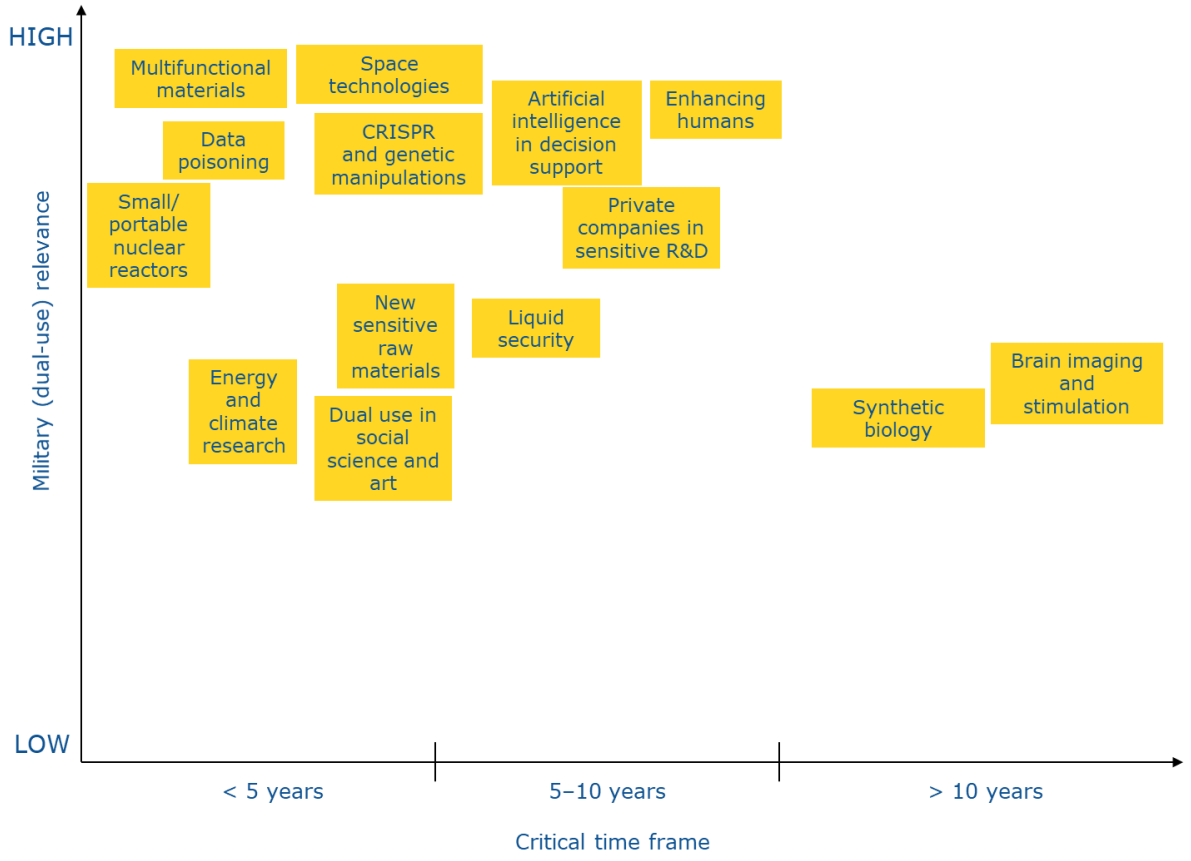
— digital fabrication techniques;

— the fact that, with three-dimensional (3D) printing achievements, it is more likely that equipment for a nuclear weapon programme will be obtained.

3.2 Mapping of issues

The participants at the sense-making session mapped the abovementioned 14 issues onto a graph showing their perceived level of relevance to dual-use research as a function of time (Figure 1). This representation is the outcome of a consensus decision. If an issue is high up on the graph, this means that research on this issue will produce results (whatever they are) that have a high level of potential for applications in both civilian and military domains. In other words, it depicts when and at which intensity level an issue might have an impact on the civilian and defence domains.

Figure 1. Mapping of issues according to their perceived level of relevance to dual-use research as a function of time



Source: Authors.

Six issues have been assessed as having a high level of relevance to dual-use research in the short to medium term. By increasing the time frame, we find 'Multifunctional materials', 'Data poisoning', 'Space technologies', 'CRISPR and genetic manipulations', 'Artificial intelligence in decision support' and 'Enhancing humans'. On the one hand, some novel multifunctional materials with new properties are already available, and more will undoubtedly appear from research in the coming years with multiple civilian and military applications. On the other hand, the prospect of enhancing humans ranges from, for instance, restoring damaged abilities (not currently possible) to transhumanist phantasms or delusions (see Chapter 4).

'Small/portable nuclear reactors' and 'Private companies in sensitive R&D' are also highlighted as having a relatively high level of relevance to dual-use research, with the first one in the very short term and the second in the medium term. However, they are assessed as being less pertinent than the six issues mentioned above.

No issue was labelled as having a low level of relevance to dual-use research, meaning that none should be devoid of impact on security or defence at a certain stage. In the much longer term (over 10 years), two issues were evaluated as displaying relevance: 'Synthetic biology' and 'Brain imaging and stimulation'. It should be noted that the topics covered by the latter issue are largely included in the broader issue 'Enhancing humans'.

4 Description of selected issues

This section describes seven issues in more depth: the six issues expected to be highly relevant to dual-use research, and hence have a high level of potential for dual-use applications, in the short to medium term, and the issue 'Synthetic biology', which was assessed as emerging in the longer term for its relationship with dual-use perspective.

4.1 Multifunctional/advanced materials

In the editorial of the new scientific journal *Multifunctional Materials*, Lendlein and Trask write that 'this is the golden age of materials' ([12]), an age in which multifunctional materials will play a major role. 'They [i.e. the multifunctional materials] are often inspired by a biological analogue but are designed to perform multiple responsibilities through prudent combinations of different functional capabilities. Typically, each function contributes a distinct physical or chemical process that can deliver system-level improvements beyond the status quo' ([12]).

Many scientists agree that acceleration in materials science advancement will be a major element in years to come. Short term is the relevant time frame in which to look at this issue. For instance, in an Organisation for Economic Co-operation and Development publication from 2017, MacDowell states that 'increasing the rate of discovery and development of new and improved materials is key to enhancing product development and facilitating mass customisation based on emerging technologies such as 3D printing. Acceleration of materials discovery and development has been enabled by advances along multiple fronts, including capabilities of scientific instrumentation, high performance computing combined with more predictive computational methods for material structure and properties, and data analytics. Historically it has taken 15 to 20 years from laboratory discovery of new materials to their deployment in products. Systematic methods for accelerated materials discovery and development are still in early stages in the new digital era. Prospects are bright for realising a materials innovation ecosystem necessary to integrate new materials with digital manufacturing technologies to achieve new product functionality' ([13]).

The European Defence Agency also shows considerable interest in the development of new materials and their use at military level and includes them among the fields covered by its R&D funded projects. 'The most disruptive effects are expected to derive from the integration of functionalities such as energy harvesting, camouflage, structural and personnel health monitoring, protection in "super-intelligent" materials for platforms and soldiers. Other potential applications of advanced materials to be explored in the future include the potential of self-healing materials, cyber-protective material (reacting to electromagnetic interference), biomimetic material designs, morphing aerofoils, or the integration of metamaterials' ([14]).

An interesting overview of advanced materials with possible applications in the defence sector has recently been published, addressing topics such as ballistic protection, composite materials, smart materials and structures, nanomaterials and nanostructures, chemical, biological, radiological and nuclear protection, camouflage, and auxetic materials ([15]). However, research of new materials from the military side also opens up possibilities for civil use, as shown, for instance, by cases from the US Army Research Laboratory ([16]). According to recent news from this organisation, 'biologists working for the Army have developed a process that could lead to a class of synthetic polymers that may be used to create new materials such as therapeutics for soldiers. [...] The project, which started in July 2016, explored how to re-engineer biological polymers to work with non-biological building blocks in order to create a route to synthetic polymers. [...] Although the scientists have made strides in their research that could eventually lead to a new class of therapeutics for soldiers, the specific outcomes of the research are still unclear. [...] "Where we see it going specifically, we don't know. What's very interesting about this class of material, ... if we're able to control the structure of the material, then essentially what that allows is for us to be able to make materials that have whatever properties that we want"' ([17]). Such cases also fall under another issue of research, namely 'Synthetic biology' (see Section 4.7). The dual-use perspective is clearly at the core of incoming development in this area.

([12]) Lendlein and Trask (2018).
([13]) McDowell (2017).
([14]) Lopez Vicente (2017).
([15]) Fangueiro and Rana (2020).
([16]) Army Research Laboratory (2018a). Other examples of materials resulting from defence research can be found on the website of TechLink, a centre within Montana State University's Office of Research and Economic Development: available at https://techlinkcenter.org/10-advanced-materials-defense-engineers-deliver-big-results/, accessed on 31 January 2020.
([17]) Mayfield (2020).

4.2 Data poisoning

This issue of data poisoning is of a different nature from all the other issues, as it describes a threat (and not a field as such) that could become a major concern in the very short term. According to Steinhardt et al. from Stanford University, 'machine learning systems trained on user-provided data are susceptible to data poisoning attacks, whereby malicious users inject false training data with the aim of corrupting the learned model' ([18]).

An author such as Ilja Moisejevs distinguishes two types of poisoning attacks: those targeting the availability of data and those targeting their integrity (also known as 'backdoor' attacks) ([19]). In the first type, the attacks aim to inject so many bad data into the system that whatever the model learns becomes useless. The second type is more sophisticated, and the intention is to leave the system functioning exactly as it should, with one exception – a backdoor, which is a type of input that the model's designer is not aware of but that the attacker can leverage to get the machine learning system to do what they want ([19]).

Besides data poisoning, there seems to be two other main types of AI attacks: adversarial (or evasion) attacks and model stealing ([20]). In evasion attacks, adversaries constantly probe classifiers with new inputs to attempt to evade detection. An example of such an attack is designing malicious documents to evade spam filters. According to the same author ([20]), model stealing attacks are the most worrying for machine learning security but also the least likely to occur. Such an attack is used to recover models or information about data used during training.

So far, there is no comprehensive solution available on the market, and many of the mitigations proposed are specific to certain model architecture and are not generalisable ([20]). However, more and more scientific research is being carrying out to find effective measures against data poisoning. An example of such an attempt is that carried out by Ma et al. ([21]), in which they consider differential privacy as a defensive measure against this type of attack.

The increasing use of AI makes such research vital for all sectors of societies, whether civilian or military, which is confirmed by the topics identified during this horizon-scanning exercise, in particular the use of data poisoning as a weapon.

4.3 Space technologies

Europe depends on space for its economy, security and defence, and that dependency will most likely increase in the short term. At the same time, this dependency is already being targeted by China, Russia and the United States. Therefore, space must be better defended, and Europe must strive for strategic autonomy in space and using space. Europe is already strong, with Copernicus, Galileo / European Geostationary Navigation Overlay Service, launchers and satellite communications (SatCom), and is also building up governmental SatCom (GovSatCom) and space situational awareness. Defence and the dual use of space are being actively discussed, and the next EU framework programme for research, Horizon Europe (2021–2027), and the European Defence Fund should increasingly fund space R&D.

Space appears as the new frontier of geopolitics and is a strategic asset for security and defence. Many countries now have counter-space weapons (e.g. China, India, Russia and the United States), and many are also setting space policies and/or forces and units (e.g. China; France, Japan; NATO, United States). However, space is also a place for international science cooperation ([22]).

In October 2019, the EU Institute for Security Studies and the Finnish Presidency of the Council of the EU co-organised a round table focusing on the EU, space and defence. The EU has stressed the idea of 'peaceful access to space', although the EU's approach is not necessarily shared by other space powers (China, the United States or even partners such as NATO) ([23]). It was underlined how space could enhance the EU's strategic autonomy and technological sovereignty, including highlighting the importance of protecting space- and land-based critical space infrastructure from cyber vulnerabilities. From an industrial angle, there is the impression that the EU is lagging behind in relevant technological advancements.

([18]) Steinhardt et al. (2017).
([19]) Moisejevs (2019).
([20]) See, for example, Gupta (2019).
([21]) Ma et al. (2019).
([22]) 12th European Space Conference – New Decade, Global Ambitions: Growth, climate, security & defence, 21-22 January 2020, Brussels (available at https://www.spaceconference.eu/).
([23]) EUISS (2019).

In terms of defence, and according to Handberg ([24]), combat in near-Earth orbit is emerging as a more realistic possibility because of changes in space technologies and political rhetoric. He elaborates on both reasons, describing the evolution of space technologies in weapons and the evolution of the political situation.

Overall, rapid changes in the use of space, which are sometimes referred to as New Space or Space 4.0, are taking place; these changes are characterised by a series of shifts combining new threats and challenges (e.g. an increase in the number of satellites and space debris, space objects crashing to Earth, congestion of popular orbits) and new opportunities (e.g. technological innovations and consequent lowering of costs, the involvement of more private stakeholders, new means of communication) ([25]).

Among these notable changes, the interest of private companies in space has grown exponentially. This also includes providing services to governments, which is a novelty, taking into account the geostrategic role of this sector. This 'privatisation' aspect and concern are also reflected in another issue identified during the horizon-scanning workshop, 'Private companies in sensitive R&D'. This is indeed a very serious matter, and the physicist Jean-Marc Lévy-Leblond is of the opinion that such technological development can become an obstacle to scientific progress, for example the thousands of communication satellites sent into space, which will seriously harm astronomical observations ([26]).

4.4 CRISPR and genetic manipulations

Genome/gene editing is a group of technologies that allow the 'precise' manipulation of DNA in predefined regions. CRISPR-Cas9 is faster, cheaper, more accurate and more efficient than existing genome-editing methods. This editing process has a wide variety of applications, including basic biological research, the development of biotechnology products, crop seed enhancement and the treatment of diseases ([27]).

The first clinical trials launched in Europe using CRISPR targeted two blood disorders: beta-thalassemia and sickle cell disease. In 2018, the US Food and Drug Administration approved the first cellular immunotherapy to treat cancer (more specifically, hard-to-treat T-cell cancers) ([28]). The same year, 'gene drives', a gene-editing technology that results in infertility spreading rapidly among the population (by editing fertility genes) and effectively erasing whole populations, was tested in mammals for the first time ([29]).

In 2018, He Jiankui, a Chinese researcher, announced at the Human Genome Editing Conference in Hong Kong that he had made the world's first gene-edited babies ([30]). Two months later, Denis Rebrikov, head of a genome-editing laboratory at the Kulakov National Medical Research Center for Obstetrics in Russia, announced his intention to use the gene-editing technology CRISPR on human embryos to disable the CCR5 gene, the same one He Jiankui targeted, which is believed to confer immunity to the human immunodeficiency virus (HIV) ([31]). As another example, which is linked to the ongoing coronavirus pandemic, the US Food and Drug Administration has authorised testing for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) using CRISPR technology for emergency purposes ([32]).

The same characteristics that bestow on CRISPR a huge potential to cure and eliminate diseases or improve crop yields have, at the same time, raised concerns about its potential use as a bioweapon. For instance, in 2016, the Director of National Intelligence in the United States included genome editing in a list of weapons of mass destruction and proliferation in the annual Worldwide Threat Assessment report of the US Intelligence Community ([33]). Christiane Woopen from the University of Cologne worries that 'the technology for gene editing is powerful and we must take into account that it can be used for military as well as civilian purposes. You only have to think about those sci-fi scenarios where embryos are edited to become very powerful soldiers who don't need sleep, don't feel pain and go into battle very effectively. Even if such a scenario is biologically unrealistic, there is a risk that people try to do something like this. We are talking about powerful technology that can be significantly harmful to our health and life when it gets into the wrong hands' ([34]).

([24]) Handberg (2018).
([25]) For details, see Bordin et al. (2019).
([26]) Lévy-Leblond (2020).
([27]) Szczesna (2018), Hsu et al. (2014).
([28]) Cooper et al. (2018).
([29]) Callaway (2018).
([30]) Belluz (2019).
([31]) Gent (2019).
([32]) Guglielmi (2020).
([33]) Regalado (2016).
([34]) D'Alessio (2019).

The potential targets for such misuse are easy to identify: humans, disease vectors, disease pathogens, the food chain, water supplies, etc. The main fear is that biological weapons capable of discriminating among target populations based on ethnic, racial or other genetically defined characteristics can be developed in the future. Although at present the technology can only be administered to humans through injection, it has the potential to allow a huge variety of terrifying goals to be achieved, including the following.

— Modify genes to make pathogens either more virulent or more resistant to existing drugs.

— A gene drive has already been used to try to eliminate the anopheles mosquito responsible for the transmission of malaria. However, the experiment resulted in mosquitoes that were more resistant to existing pesticides.

— Modify a specific population to make people sensitive to certain external factors (sun, food, etc.).

— Achieve population segregation – make a group of individuals resistant to a certain pathogen so that they would be the only survivors of an intentional epidemic event.

— Introduce gene modifications to produce weakening diseases (e.g. intractable diarrhoea).

— Spread pests in a country or region to destroy the crop and affect the economy and/or main source of food while protecting your own crops by using gene editing.

— Genetically modify plants to spy.

— Modify the gut microbiome to control fear.

These gene-editing technologies have been assessed as already having potentially significant dual-use impacts, whatever they might be, in the short term.

4.5 Artificial intelligence in decision support

Operational remote-control systems to avoid human physical displacement and harm have been available for military use for years ([35]). So far, humans are in control of these systems; however, in the future, AI might take over from human control. This is a further step that will bring all issues related to the use of AI in decision support to the military level. Particularly secure, trustable and reliable algorithms still allowing human control to overrule them at any time and have the final say will then be needed for this purpose.

In 2002, an American team reported an experiment conducted by the US Army Mission Command Battle Laboratory integrating AI into a military decision-making system ([36]). Since then, very little work has been published on the topic until recently.

A Swedish team working at the Swedish Defence Research Agency has recently reported the use of AI methods in decision support systems in a military context. In its concept paper, it states that, 'in military applications, AI becomes increasingly important in systems used at different military levels, from the combat level to tactical and operational levels. This development has led to decision support systems being used at the battalion and brigade levels'. The team then concludes that 'the benefit of AI for the armed forces is that it can deliver critical system support when time is limited or when the number of choices is too large for people to be able to analyse all alternatives' ([37]).

In 2017, in a concept note on the future of command and control, the UK Ministry of Defence stated that 'we will see a progression beyond the use of machines to support the intelligence cycle, towards human/machine planning, decision-making and mission execution. Ultimately, humans and technology should be parts of the same team. […] Advances in interface technology (including voice activation, virtual immersive environments, command walls and three-dimensional command tables) will provide more natural interaction and improve situational understanding. Machine learning and greater processing power will allow for the generation and critiquing of hypotheses, potential courses of action and outcomes' ([38]). They conclude that 'first adopters of this emerging technology for decision support will achieve significant advantage over adversaries, but users will need to consider the legal, moral and ethical factors surrounding decision automation, particularly relating to creating lethal effects. It is likely that as the use of such systems become more common in everyday life, any potential military application will become less contentious' ([38]).

([35]) See, for example, Quick (2011).
([36]) Rasch et al. (2002).
([37]) Schubert et al. (2018).
([38]) UK Ministry of Defence (2017).

A recent document of the French Ministry of the Armed Forces provides a good overview of the current situation of AI applied to the defence sector. It states indeed that 'military AI applications are being developed incorporating aspects such as computer vision, smart robotics, distributed intelligence, natural language processing, semantic analysis and data correlation. Strategists and military commanders, in their operational and organisational responsibilities, must be able to take advantage of AI and turn it into a decisive factor of operational superiority. The aim here is to gain speed and room for manoeuvre from better recognition and/or detection of targets and hitherto unknown dangers in the field, from faster and better targeted military action, and from deception actions while ensuring compliance with the laws of war' ([39]).

In the context of nuclear deterrence, faster missiles are reducing response times. Timescales that are down to 6 minutes are mentioned, which are shorter than realistic human decision-making times. As a reaction to this, strategists are discussing the use of AI to decide on retaliatory nuclear response ([40]). A 2018 report of Rand Corporation delves deeper into the question 'How might artificial intelligence affect the risk of nuclear war?' and signals far-reaching implications for nuclear deterrence strategies already based on the mere perception of the power of AI ([41]).

But this is a revolution that is not devoid of threats and risks:

Because AI will be inherent in all systems, the threats associated with its use are the corollary of the opportunities it affords and could affect all spheres of interest, from intelligence, command and engagement to maintenance, support and the condition of personnel (state of mind, morale, etc.). AI technologies are not yet mature enough to upset power relations or change the nature of warfare. It is a fast-moving field, however, and the steadily decreasing cost of the technology suggests that new modes of action and disruptions of uses or thresholds will emerge in the short term. Being easily accessible, especially as a result of the diversion of commercial technologies or the use of low-cost robots, these new threats will soon become much more pressing. The fears they raise include: the possibility that adverse AI will be able to predict our modes of action, depriving us of the element of surprise; the paralysis of our command capabilities as a result of the neutralisation, deception or diversion of our technologies; the extension of influence operations and actions targeting the circulation of information (disinformation, undermining media credibility, etc.); the change of scale and the proliferation of high frequency hostile actions in the cybersphere ([39]).

One important aspect in this field is that of quantum technologies, which has for instance been recently discussed by the International Institute for Strategic Studies in its last annual assessment of military capabilities and defence economics worldwide. In the assessment, the institute comments that 'the integration of quantum technologies currently represents one of the most anticipated advances for armed forces, yet their precise impact remains difficult to predict. Although economical applications and widespread use are still years away, there is little doubt that they will have disruptive effect when they are employed at scale. [...] But while quantum technology is expected to eventually have far-reaching effects for military forces, intelligence services and law-enforcement agencies, it is unclear how far it will alter the traditional balance of power among states, or between states and non-state actors' ([42]).

Interestingly, whereas the dual-use nature of research is of prime importance for both civilian and military sectors, it does not cover the whole picture as far as defence is concerned. Let us once more quote the French Ministry of the Armed Forces:

As in the digital sphere as a whole, the defence sector does not necessarily blaze a trail but takes advantage of advances in civilian uses, adapting them to its own particular needs where necessary. The armed forces must thus strike the right balance between benefiting from the things that major private digital firms can offer, without becoming dependent on them, while developing their own military applications. As far as the least specific applications are concerned, especially tools for administrative management optimisation, financial consolidation and human resources management, the Armed Forces Ministry's data and needs are similar to those of any other ministry or large firm. The civilian market already develops and offers products for such uses. Military operational systems, on the other hand, have important specific features, whether in terms of tasks to be performed, the type of data to be manipulated (infrared images, radar or sonar data, etc.) or performance and robustness requirements. Civilian actors do not develop methods for processing these types of military data ([39]).

([39]) French Ministry of the Armed Forces (2019).
([40]) Lowther and McGiffin (2019).
([41]) Geist and Lohn (2018).
([42]) International Institute for Strategic Studies (2019).

Although AI is already used in the civilian and military domains ([43]), its application for decision support in a military context is expected to have a strong impact, and therefore a high level of dual-use relevance, only in the medium term, circa 5–10 years.

4.6 Enhancing humans

Human enhancement refers to the natural or artificial alteration of the human body to enhance physical or mental capabilities. Human enhancement technologies include biotechnology, nanotechnology, information technology and cognitive sciences ([44]).

It means that human enhancement from an overall perspective can be achieved by using, for instance, bionic and prosthetic implants (e.g. upper-body 'exoskeletons', prosthetic limbs, bio-printed organs, and prosthetic and/or bionic eyes ([45])), and chemical (nootropics), genetic or cognitive (brain–computer interfaces) means. Human enhancement pursues both restoring lost or damaged abilities and creating new ones. Like all technologies, there is always the potential for human enhancement to be misused. In the following paragraphs, some examples are described with some further insight.

Nootropics, also known as 'cognitive enhancers' or 'smart drugs', are drugs, supplements and other substances that may improve cognitive function, particularly executive functions, memory, creativity or motivation, by changing the brain's biochemistry in healthy individuals ([46]). There are three function-related types of nootropics: cognitive enhancers (racetam family); stimulants, and alertness and wakefulness-promoting agents (neurogenic family); and memory boosters (cholinergic family). Their use has greatly increased since the release of the American science fiction thriller film *Limitless* ([47]). However, the long-term secondary effects of the majority of these agents are not fully determined, and research is still at an early stage. The regulatory and legal framework depends on the compound and the country. So far, regulatory agencies tend to regard nootropics as dietary supplements, and therefore they are only lightly regulated. Nootropics can be prescribed by physicians to assist in treating, for example, narcolepsy, dementia and attention deficit hyperactivity disorder ([48]). Cognitive enhancers have also been tested on soldiers to measure marksmanship performance and stress ([49]).

Another type of human enhancement may come from the use of brain–computer interfaces. Since early works in the 1970s, a large number of research projects have been devoted to brain–computer interfaces. Whether non-invasive, partially invasive or invasive, many of these interfaces intend to give autonomy to people with mobility limitations, whereas others focus on connecting the brain with the exterior/environment (houses, cars, etc.). Yet, although these technologies seem powerful, they are not commonly used today, for the simple reason that they fail in 30–40 % of cases. Furthermore, there is a large disparity between subjects, with some succeeding the first time and others taking much longer to use technology effectively, making it very difficult to use these interfaces on a regular basis ([50]). Scientists are seeking to improve these brain–machine interfaces by working on different components ([51]) and different uses, such as communication, cognitive enhancement, memory enhancement and situation awareness ([52]). The US Defense Advanced Research Projects Agency has continually funded research in brain–computer interface technologies that focus on restoring neural and/or behavioural function and improving human training and performance of soldiers ([53]).

The use of gene editing and genomics for human enhancement is also already a reality. Gene editing was developed to cure genetic diseases associated with a single mutation (such as beta-thalassemia) ([54]). The first attempt to modify the genetic information of the embryo was made in China in 2018 ([55]). Recently, in a kind of biohacking performance, the first use of gene editing to modify physical appearance was attempted ([56]). In addition, genome-wide association studies are performed to identify genes associated with intelligence and

([43]) OECD (2019).
([44]) Buchanan (n.d.).
([45]) Hellem (2016).
([46]) Frati et al. (2015).
([47]) A feature film directed by Neil Burger (2011).
([48]) Berry (2019).
([49]) Barringer et al. (2018).
([50]) Hôpital Pitié Salpêtrière, Institut du cerveau (2019).
([51]) See, for example, Corsi et al. (2019).
([52]) Cinel et al. (2019).
([53]) Miranda et al. (2015).
([54]) Henderson (2019).
([55]) See footnote 27.
([56]) Zhang (2018).

success in life ([57]). Gene editing allows each of the individual genotypes to be manipulated and modified. It can also be used to specifically target a population with a specific genotype. The possibilities of misuse and related impacts are uncountable (see also Section 3.4 on CRISPR, one of the four gene-editing techniques currently in use).

All these technological trends can also be included in the context of transhumanism, an ideological movement advocating the transformation of the human condition by using emerging technologies that are able to create a new augmented humanity to define a new notion of personhood ([58]), and even believing in the possibility of achieving immortality through some sort of disembodied robotic existence. Many scientists see this movement as an 'empty shell' ([59]) that is not devoid of naive thought; however, one must remain aware that it gathers together people and companies ready to embark on all kind of experiments based on these technologies and involves an enormous amount of funding. Defence is not immune to this matter of a transhumanist vision. According to Alexander Thomas from the University of East London, 'the systemic forces cajoling the individual into being "upgraded" to remain competitive also play a role on a geostrategic level. One area where technology R&D has the greatest transhumanist potential is defence. DARPA (the US defence department responsible for developing military technologies), which is attempting to create "metabolically dominant soldiers", is a clear example of how vested interests of a particular social system could determine the development of radically powerful transformative technologies that have destructive rather than utopian applications' ([60]).

In any case, the possible impacts of misusing technologies such as nootropics, brain–machine interfaces and gene editing are so far unpredictable, even more so in the context of the 'do it yourself' (DIY) trend.

4.7 Synthetic biology

According to the definition given by the journal *Nature*, 'synthetic biology is the design and construction of new biological parts, devices, and systems, and the re-design of existing, natural biological systems for useful purposes' ([61]).

There are two approaches to synthetic biology. The first is the top-down approach, which creates new metabolic pathways to produce desired compounds, such as pharmaceutical drugs ([62]). Generally, this is done by using bacteria or yeast as hosts and combining genes from different organisms that have the functionalities required to achieve the desired product. In the second approach, bottom-up, whole genomes are synthesised from scratch. This approach allows the reshuffling and/or elimination of non-essential genes, thus reducing the size of the chromosome to fit those genes necessary for the production of the desired compound ([63]). Furthermore, synthetic biology foresees the incorporation of non-natural molecules (xenobiology) in the system.

As with other technologies, synthetic biology also has a risk of being misused (the concept of 'dual-use of concern' in life sciences) ([64]). In 2003, US officials urged biologists to vet publications for bioterror risk ([65]). This was triggered by the production of the first synthetic virus ([66]). Since then, a number of viruses have been reproduced, including the poliovirus, the extinct 1918 strain of influenza virus and recently the horsepox virus ([67]). This latest work reopened the debate in 2018, since any method used for the horsepox can be applied to variola. Although the world's known variola stocks are securely stored in Russia and the United States, synthetic biology compromises this approach to securing any agent ([68]).

The risks associated with xenobiology, the introduction of non-natural components, are less tangible at the moment. Although a number of xeno-nucleic acids have been created, the information they store is not visible to natural polymerases, and therefore it is invisible to natural DNA-based organisms. Currently, no living organisms based on such an unnatural nucleic acid exist, and there is little evidence that anything like it will

([57]) Deary et al. (2019), Plomin and von Stumm (2018).
([58]) Porter (2017).
([59]) See, for example, Tritsch and Mariani (2018).
([60]) Thomas (2017).
([61]) https://www.nature.com/subjects/synthetic-biology (accessed on 17 March 2020).
([62]) See, for example, Cameron et al. (2014).
([63]) See, for example, Annaluru et al. (2014).
([64]) Cirigliano et al. (2017).
([65]) Check (2003).
([66]) Wimmer et al. (2009).
([67]) Noyce and Evans (2018).
([68]) WHO (2015).

occur any time soon. However, the combination of an extended genetic code and an adequate novel polymerase could certainly lead to the next step towards implementing an artificial genetic system *in vivo* ([69]).

During the horizon-scanning sense-making session, the issue 'Synthetic biology' was assessed as having a medium level of dual-use relevance/impact in the longer term, namely 10–15 years. This is in line with a recent statement (2018) made by the US Deputy Assistant Secretary of Defense for Chemical and Biological Defense, saying that 'the military's current view is that "synthetic biology is not a major threat issue at the moment" but bears preparing for, in part because defenses like vaccines can take years to develop' ([70]).

The defence sector is quite active in this field of research ([71]), with the US army in particular making it a priority ([72]), notably via the US Army Research Laboratory. A recent example is a study on commandeering microbes that pave the way for synthetic biology in military environments ([73]). Interestingly, these scientists conclude that this research has significant impacts outside the military world, for instance in human health and agriculture ([74]). The field of new advanced materials is also concerned by dual-use research in synthetic biology (please refer to Section 4.1).

In a very recent workshop (July 2019) convened by NATO and co-organised by the École Polytechnique Fédérale de Lausanne (EPFL) and the US Army Engineer Research and Development Center, aiming to answer the question 'Should we be concerned that synthetic biology be used improperly or maliciously?', one working group had the task of discussing 'strategic foresight to identify major biosecurity trends and risks that we may need to respond to in the next 20–30 years and to suggest ways to mitigate risks' ([75]). Concretely, six key questions have to be answered.

— 'What technological developments and applications are we afraid of? Through what new routes or platforms could synthetic biology be misused for the purposes of terrorism or mass disruption?

— How does one forecast carelessness in biological research? Are there bottlenecks or inflection points that, if not properly addressed, could trigger a significant safety threat?

— Will the combination of diffusing technologies, rising geopolitical and economic competition, and cultural diversity vitiate state and non-state biosecurity collaboration?

— Will geopolitical tensions and governance deficits enable free-riding? Over the long term, will international agreements and moratoria against biological weapons hold?

— What policy developments might reduce future risks, or pose new risks?

— What sources of long-term policy-relevant uncertainty are evident? What near-term actions might mitigate uncertainty and inform future deliberations?' ([75]).

Obviously, foresight and ethics will have to go hand in hand in this area ([76]), as in others.

([69]) Herdewijn and Marlière (2009).
([70]) Regalado (2018).
([71]) See, for example, Binder (2013).
([72]) The United States is currently the world's leading nation in the development of synthetic biology; see, for example, Si and Zhao (2016), Tucker (2019)..
([73]) Army Research Laboratory (2018b).
([74]) See, for example, Brophy et al. (2018).
([75]) NATO (2019).
([76]) 4TU.Centre for Ethics and Technology (n.d.).

5 Conclusion

This horizon scanning exercise has allowed the identification of 14 emerging issues displaying a level of relevance to dual-use research, which could potentially lead to applications in both civilian and military environments. On a graph depicting these issues arranged by 'level of dual-use research relevance' (i.e. with potential for dual-use applications) versus 'time frame', six of them appear in the 'top' section, indicating that they have the highest level of relevance to applications in the short to medium term (between now and circa 10 years), whereas for one issue it was assessed that some significant relevance to dual-use applications will show up in the longer term (> 10 years).

It can be noted that four issues out of these seven fall entirely or partially within the realm of biology – 'Multifunctional materials', 'CRISPR and genetic manipulations', 'Enhancing humans' and 'Synthetic biology' – spreading along the whole time frame. All together, these thematic issues, which are actually interrelated, show that the manipulation of the living, including that of human bodies, with all its aspects – positive and negative, bright and dark, defensive and offensive – is expected to increase in time and impact. The other major issues identified belong, broadly speaking, to space, AI and data poisoning.

Further work on foresight applied to dual-use research will continue at the JRC by applying, in addition to more specific horizon-scanning exercises that also involve a quantitative approach ([13]), other techniques to several of the issues identified here and using tools such as Tools for Innovation Monitoring ([77]), to detect emerging technologies or more specific weak signals. In the next phase, two issues will be investigated ([78]): 'Space technologies' and an issue related to life sciences. The increasing role of life sciences in matters related to security and defence is now a fact; however, it needs closer and more accurate attention and monitoring, for which foresight thinking can provide valuable input.

([77]) See, for example, Eulaerts et al. (2019).

([78]) Of course, every issue should be studied in similar detail; however, the availability of staff and resources means that time sequencing needs to be set up, based on both policy priorities and 'looking forward' perspectives.

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Annex: List of items used for the horizon scanning exercise

The items listed below are reported as they were provided by the JRC 'scanners' in the horizon scanning platform. The authors of this report made only spelling corrections.

1. **Space nuclear renaissance powered by highly enriched uranium**

Summary: Congress has directed money to the National Aeronautics and Space Administration (NASA) so that it can work on nuclear thermal propulsion, including USD 125 million in the House version of a fiscal year 2020 spending bill for NASA that calls for a flight demonstration of such technology in 2024. Last year, NASA and the Department of Energy announced the successful test of a prototype small nuclear reactor called the Kilowatt Reactor Using Stirling Technology, or KRUSTY. At that time, NASA said that the success of KRUSTY could lead to a flight demonstration of a Kilopower reactor – perhaps carried to the Moon on a mid-sized lunar lander – sometime in the mid-2020s. The KRUSTY test last year used highly enriched uranium (HEU) at a time when many other terrestrial applications of HEU were being phased out, because that material could be used in nuclear weapons. NASA and the Department of Energy are currently doing trade studies on a 10-kilowatt reactor for surface nuclear power applications. That study, scheduled to be completed in early 2020, is considering both low-enriched uranium (LEU) and HEU fuels.

Why is it important? HEU might be considered for Kilopower reactors in the future, because it would allow the reactors to be smaller and simpler than those that use LEU, which is not suitable for weapons, although it produces less power. An LEU reactor with the same power as an HEU one might not only weigh twice as much but also have a shorter lifetime. It is still an open question if LEU can work for nuclear thermal propulsion systems.

Date: 4 November 2019; source: http://www.thespacereview.com/article/3825/1

2. **A robot puppet hooked up to a human**

Summary: Researchers from the University of Illinois and Massachusetts Institute of Technology (MIT) have created a human–machine interface that maps an operator's movements onto a robot. It works by tracking movements (jumping, walking or stepping) as the operator's feet move on a plate equipped with motion sensors. The system also tracks the movements of the operator's body by using a vest that is also wired up with sensors. The data captured from the torso and legs are then mapped onto a two-legged robot. The system works both ways: it also allows the operator to 'feel' what the robot is feeling. If it bumps into a wall or gets nudged, that sensation is transmitted back to the person at the other end via tactile feedback. This lets the person adjust accordingly, applying more or less pressure as required. This feedback includes safety measures that automatically cut off the power if the robot experiences dangerous levels of force.

Why is it important? Getting robots to move autonomously is the biggest challenge in robotics. This neatly sidesteps that by using the power of the human mind to take in sensory information about the world, process it and then relate it to a control system for tasks such as balancing and stepping. A system such as this could be used to help in robotic clean-up operations, such as the one after the Fukushima Daiichi nuclear power plant disaster in Japan in 2011. Humans could have guided robots to navigate around the site more accurately, from a safe distance.

Date: 30 October 2019; source: https://www.technologyreview.com/s/614649/a-robot-puppet-can-learn-to-walk-if-its-hooked-up-to-human-legs/

3. **AlphaStar beats StarCraft top players**

Summary: AlphaStar, DeepMind's new AI, beat 99.8 % of approximately 90 000 players active enough in the past months to be placed in a league on the European server. This is quite a significant achievement in machine learning, as for the first time a machine has been able to address the complexity and game-theoretic challenges of StarCraft, an online game. (Note: The two previous milestone achievements were when IBM's Deep Blue, a machine, learned to play chess and beat Garry Kasparov in 1997 and when Google's – previously DeepMind's – AlphaGo beat Ke Jie, the best Go player in 2017.)

Why is it important? Techniques used by AlphaStar for neural network architecture, imitation learning, reinforcement learning and multi-agent learning, and their combination could be widely applicable in the future in areas such as military planning and response, and online trading.

Date: 30 October 2019; source: https://www.nature.com/articles/s41586-019-1724-z

4. **Machine learning for security?**

Summary: AI (which is still mostly machine learning) is touted to enable the automatic analysis of big surveillance data to improve our security. Machine learning algorithms are based on analysing many images of how people look and behave. Then they apply what they have learned. However, that will only work as long as the looks and behaviour of people do not change. This may be the case for 'normal' people, but criminals will actively try to evade surveillance. This research shows how easy that is.

Why is it important? The adaptation of the behaviour of criminals to (police) surveillance and operational methods is just the usual cycle of measure and countermeasure. Therefore, ultimately, machine learning may not be very effective in security applications.

Date: 20 March 2019; source: https://www.youtube.com/watch?v=MIbFvK2S9g8

Date: 18 April 2019; source: https://arxiv.org/abs/1904.08653

5. **Science fiction: The French army recruits writers to prepare for the future**

Summary: The French Ministry of the Armed Forces has decided to set up a team of science fiction authors to help the defence sector consider all the scenarios that the future holds for us. This 'Red Team' will be created within the new Defence Innovation Agency (AID), which was set up 1 year ago (with a EUR 1.2 billion budget and 100 staff members). Proponents of this approach argue for an experiment in what could become a new way of working in foresight. Emmanuel Chiva recalls the good returns of the first collaboration between science fiction authors and the ministry at the Utopiales Festival in Nantes 2 years ago: 'We had asked participants to think about what could be a naval surface drone in 2080 and the answers surprised us. They had thought about concepts we had not thought of, like an articulated ship that breaks down into autonomous drones and merges into the marine population'. Chiva continues by saying, 'all is not a technological breakthrough but I am thinking for example of quantum … The arrival of quantum computation and cryptography are things that risk upsetting the equilibrium, especially since the first nations that acquire it will not necessarily tell others. Then there is this acceleration of civil innovation, which must be captured quickly because otherwise there is the risk that our opponents will seize it before us'.

Why is it important? 'We do not know yet if this idea will be relevant but we must try. This is the experimental scientific approach. Ultimately, this could be a new intellectual tool at our disposal.'

Date: 31 October 2019; source: https://www.franceculture.fr/societe/science-fiction-quand-larmee-recrute-des-auteurs-pour-preparer-lavenir

6. **Floating nuclear plant**

Summary: Russia's floating nuclear power plant, the Akademik Lomonosov, has arrived at its remote Arctic destination after sailing 4 700 kilometres from Murmansk, marking a major milestone for Moscow's experiment in portable nuclear reactors. The 140-metre floating plant, which was more than a decade in the making, is equipped with two KLT-40 reactors that provide a combined 70 megawatts of power.

Why is it important? Rosatom, Russia's nuclear corporation, which developed the plant, has estimated that the Akademik Lomonosov can power a city of 100 000 residents. Pevek's population, however, is a mere 4 700, so the bulk of the plant's electricity will power local mining operations and offshore oil drilling rigs. The plant can operate for 12 years before it needs to be refuelled.

Date: 29 April 2019; source: https://www.maritime-executive.com/editorials/russia-s-floating-nuclear-plant-arrives-in-pevek

7. **Iridium and OneWeb to collaborate on a global satellite services offering**

Summary: The OneWeb network will deliver very high-speed broadband connectivity that transfers large amounts of data. It is ideal for applications including in-flight Wi-Fi, and government and maritime networks that require global reach, high speed and low latency. Iridium's cross-linked satellite constellation offers seamless truly global connectivity with highly weather-resilient L-band user terminals, making it uniquely suited to providing safety services for ships, aircraft, vehicles and deployed personnel, and can be a regulation-required capability. The combined power of these two networks can deliver capacity, resiliency and high-speed connectivity to customers anywhere in the world.

Why is it important? The collaboration would leverage the strengths of the participants' respective low-Earth-orbit (LEO) networks. This is the first time that LEO operators have collaborated to deliver services in L-band and Ku-band.

Date: 17 September 2019; source: https://www.oneweb.world/media-center/iridium-and-oneweb-to-collaborate-on-a-global-satellite-services-offering

8. **SpaceX plans to start offering Starlink broadband services in 2020**

Summary: The company caused a stir last week (https://spacenews.com/spacex-submits-paperwork-for-30000-more-starlink-satellites/) when it requested that the International Telecommunication Union approve spectrum for 30 000 additional Starlink satellites so that it can build the world's largest LEO broadband constellation. This was in addition to 12 000 that have already been approved by the US Federal Communications Commission.

Why is it important? Many of the Starlink features are being tested by the US Air Force Research Laboratory under a programme called Global Lightning. SpaceX, in December 2018, received a USD 28 million contract (https://spacenews.com/air-force-laying-groundwork-for-future-military-use-of-commercial-megaconstellations/) to test, over the next 3 years, different ways in which the military might use Starlink broadband services. So far, SpaceX has demonstrated data throughput of 610 megabits per second in flight to the cockpit of a US military C-12 twin-engine turboprop aircraft.

Date: 22 October 2019; source: https://spacenews.com/spacex-plans-to-start-offering-starlink-broadband-services-in-2020/

9. **France plans lasers to blind enemy satellites**

Summary: France will use powerful lasers to blind satellites that threaten its own assets in space and plans to deploy patrols of 'nano-satellites' by 2023, as part of its military strategy against enemies in orbit.

Why is it important? A French parliamentary report on space defence published in January warned that the country needed to upgrade its capabilities, given the proliferation of competitors and potential enemies. 'If space has always been used for military ends, it was until now in support of land, sea or air operations. Henceforth, it is clear that the space powers see space as a theatre of war in its own right,' said the report's authors, National Assembly members Olivier Becht and Stéphane Trompille.

Date : 25 July 2019 ; source: https://www.ft.com/content/4d88d6f2-aef3-11e9-8030-530adfa879c2

10. **Musk's satellite project testing encrypted internet with military planes**

Summary: The United States Air Force is using SpaceX's fledgling satellite network to test encrypted internet services for a number of military planes. SpaceX's so-called Starlink constellation, a planned network of up to 30 000 satellites in LEO intended to beam broadband internet globally, is crucial to generating the cash to fund the development of Musk's heavy-lift Mars rocket, dubbed Starship.

Why is it important? The US military has become increasingly dependent on satellites to determine what it does on the ground, guiding munitions with space-based lasers and satellites, as well as securing such assets from satellite-jamming technology from China and Russia.

Date: 22 October 2019; source: https://www.reuters.com/article/us-spacex-starlink-airforce/musks-satellite-project-testing-encrypted-internet-with-military-planes-idUSKBN1X12KM

11. **Ford and IBM among quartet in Congo cobalt blockchain project**

Summary: Starting with industrially mined cobalt in Congo, this project will be monitoring supplies all the way up to lithium-ion batteries for Ford vehicles. For the pilot project, which should be completed around the middle of 2019, cobalt from Huayou's industrial mine will be placed in secure bags, entered into a blockchain, and traced from the mine and smelter to LG Chem Ltd's cathode and battery plant in South Korea and then on to a Ford plant in the United States. Because minerals are often combined with metals from various sources when they are smelted, they are particularly difficult to track. IBM said it was exploring the potential of chemical analysis using AI to pinpoint the origin of cobalt and ensure clean cobalt was not smelted with minerals sourced less responsibly.

Why is it important? Supplies of cobalt, which are expected to be needed in huge quantities for electric vehicles and electronic devices, are concentrated in Congo, a sprawling, volatile nation that has been racked by civil war and political tension. Companies are under pressure from consumers and investors to prove that

minerals are sourced without human rights abuses; however, tracking raw materials throughout their journey is challenging.

Date: 16 January 2019; source: https://www.reuters.com/article/us-blockchain-congo-cobalt-electric-idUSKCN1PA0C8

12. **New ultra-lightweight ceramic material that withstands extreme temperatures**

Summary: Researchers from the University of California, Los Angeles, and collaborators at eight other research institutions have created an extremely light, very durable ceramic aerogel. The material could be used for applications such as insulating spacecraft, because it can withstand the intense heat and severe temperature changes that space missions endure. When it is heated, the material contracts rather than expanding like other ceramics do. It also contracts perpendicularly to the direction in which it is compressed, which is the opposite of how most materials react when compressed. As a result, the material is far more flexible and less brittle than current state-of-the-art ceramic aerogels: it can be compressed to 5 % of its original volume and fully recover, whereas other existing aerogels can be compressed to only about 20 % and fully recover. It withstood up to hundreds of exposures to sudden and extreme temperature spikes when the engineers raised and lowered the temperature in a testing container between 900 °C and –198 °C over just a few seconds. In another test, it lost less than 1 % of its mechanical strength after being stored for 1 week at 1 400 °C.

Why is it important? Despite the fact that more than 99 % of their volume is air, aerogels are solid and structurally very strong for their weight. They can be made from many types of materials, including ceramics, carbon and metal oxides. Compared with other insulators, ceramic-based aerogels are superior in blocking extreme temperatures, and they have ultralow density and are highly resistant to fire and corrosion – all qualities that lend themselves well to reusable spacecraft. However, current ceramic aerogels are highly brittle and tend to fracture after repeated exposure to extreme heat and dramatic temperature swings, both of which are common in space travel.

Date: 14 February 2019; source: https://phys.org/news/2019-02-ultra-lightweight-ceramic-material-extreme-temperatures.html

13. **Virtual reality for increased safety of nuclear power plant operation**

Summary: The Finnish utility company Fortum has developed the world's first fully dynamic and interactive virtual reality (VR) control room for training operators at its Loviisa nuclear power plant. The company says the cost of a full-scale, full-scope VR simulator is a fraction of that to build a physical simulator. Operators of plants in safety-critical facilities – such as nuclear power plants – are traditionally trained in a physical simulator – an exact, functional replica of the plant's control room. Fortum eSite is the company's internal venture, founded earlier this year, to develop industrial-grade VR solutions to safety-critical environments and the process industry in general. Fortum eSite has used the VR-1 headset developed by the Finnish technology company Varjo for its VR training room. This headset, launched in February, has a resolution of over 60 pixels per degree – the equivalent of 20/20 vision. The cost of a VR simulator is about one tenth of the cost of building a physical simulator.

Why is it important? This item illustrates the potential to use new digital technologies to improve skills of operating personnel and contribute to a higher level of operational and nuclear safety in nuclear power plants.

Date: 30 August 2019; source: https://www.world-nuclear-news.org/Articles/Fortum-develops-high-definition-VR-simulator

14. **Blasting *E. coli* bacteria with ionising radiation once a week makes it radiation resistant**

Summary: DNA repair is a cellular process by which all organisms are able to piece back together bits of DNA that are broken by stresses such as ionising radiation. This type of radiation is high energy in nature and is associated with nuclear radiation and elements such as uranium and plutonium. Astronauts are also exposed to this form of radiation in space. It is encountered at lower doses in some cancer therapies and in some medical imaging, such as X-rays. Sequence analysis conducted by the University of Wisconsin–Madison team's collaborators at the Joint Genome Institute, a facility at the US Department of Energy, showed mutations in several genes that are responsible for more efficient DNA repair in *Escherichia coli* (*E. coli*) that can help confer resistance. Another mutation was in ribonucleic acid (RNA) polymerase, the enzyme responsible for transcribing RNA into DNA, which is ultimately used to make important proteins. Although the overall mechanisms, such as enhanced DNA repair, are the same as those in naturally resistant bacteria, many of the mutations that caused those changes have never been seen before.

Why is it important? Beyond DNA repair and changes to RNA polymerase, entirely new ways of becoming resistant could arise. Radiation-resistant bacteria could potentially be administered as probiotics to help alleviate some of the side effects of cancer therapies and could aid clean-up at nuclear waste sites. In addition, NASA is concerned about astronauts' exposure to radiation in space, and work in this area might uncover a mechanism by which they could be better protected.

Date: 26 February 2019; source: https://phys.org/news/2019-02-radiation-resistant-coli-evolved-lab-view.html

15. **Drones are becoming a cybersecurity nightmare**

Summary: With drones costing from as little as USD 30 to USD 10 000 or more for specialist professional models, they can be used for any number of different style attacks. Low cost and easy to use, drones can deliver a payload to carry out surveillance, capture data or disrupt networks. Making matters worse, drones are hard to detect and defeat. There are plenty of reports of individuals or organisations building or modifying drones to carry radio frequency (RF)-based payloads, including Wi-Fi tracking, and capture and access capabilities – predominantly using Raspberry Pi and Wi-Fi Pineapple devices, but also 2G/3G/4G network devices. Bluetooth sniffing is also possible. Putting a Wi-Fi access point on top of a building or inside its perimeter could allow hackers to listen in on data traffic. Drone operators could also drop a sophisticated microphone into a restricted area for eavesdropping purposes if technicians can overcome issues of power, weight and range.

Why is it important? Security teams need to develop new techniques to monitor drones and keep sensitive information safe. Good information technology (IT) security practice, including scanning for unauthorised access points, will help. However, organisations will also need to look at everything from keeping window blinds closed to how to detect and disrupt drones. The main security risk from drones is still their ability to bypass traditional physical controls by breaching fences or accessing the top floor of an office.

Date: 22 March 2019; source: https://threatpost.com/drones-breach-cyberdefenses/143075/

16. **China will soon start building a 30 000-tonne nuclear-powered ship**

Summary: China General Nuclear Power Group (CGN) has invited bids for a contract to build a vessel 152 metres long (498 feet), 30 metres wide and 18 metres in depth, with a displacement of 30 000 tonnes (33 069 tons). The specification is small for an aircraft carrier, but a military affairs expert said it would help develop China's shipbuilding ability. At present, its only nuclear-powered vessels are submarines. The ship will be able to be fitted with two 25-megawatt compact pressurised water reactors with a thermal power output of 200 megawatts, which could propel the ship to a maximum speed of 11.5 knots, according to CGN's project description. It does not specify the use of the ship, referring to it only as an 'experimental ship platform'.

Why is it important? Having an icebreaker is important to China, as it expands its operations in the Arctic Ocean. Its first domestically built, conventionally powered polar icebreaker, Xuelong 2, was launched last year to boost China's polar research and expedition capacity. The ship will enter service later this year. If experiments using icebreakers go well, the technology and experience could be used for next-generation aircraft carriers. Besides aircraft carriers, nuclear reactors can be fitted to other large surface vessels – both civilian and military. These include cargo ships, science survey ships and tracking vessels such as the Yuanwang-class ships deployed at long distances by the Chinese navy to track satellites, transmit space communications and monitor intercontinental ballistic missiles.

Date: 20 March 2019; source: https://www.scmp.com/news/china/military/article/3002455/china-build-30000-tonne-nuclear-powered-ship-described

17. **'Spidey senses' could help autonomous machines see better**

Summary: Better sensing capabilities would make it possible for drones to navigate in dangerous environments and for cars to prevent accidents caused by human error. Current state-of-the-art sensor technology does not process data fast enough; however, nature does. Researchers at Purdue University have built sensors inspired by spiders, bats, birds and other animals, whose actual spidey senses are nerve endings linked to special neurons called mechanoreceptors. The nerve endings – mechanosensors – only detect and process information that is essential to an animal's survival. They come in the form of hair, cilia or feathers. Many biological mechanosensors filter data – the information they receive from an environment – according to a threshold, such as changes in pressure or temperature. However, the sensors they developed do not just sense and filter at a very fast rate – they also compute, and without needing a power supply.

Why is it important? These artificial mechanosensors are capable of sensing, filtering and computing very quickly because they are stiff. The sensor material is designed to rapidly change shape when activated by an external force. Changing shape makes conductive particles within the material move closer to each other, which then allows electricity to flow through the sensor and carry a signal. This signal informs how the autonomous system should respond. The idea would be to integrate similar sensors straight into the shell of an autonomous machine, such as an aeroplane wing or the body of a car.

Date: 20 May 2019; Source: https://phys.org/news/2019-05-spidey-autonomous-machines.html

18. **Coming soon to a battlefield: Robots that can kill**

Summary: Lethal, largely autonomous weaponry is not entirely new – a handful of such systems have been deployed for decades, though only in limited, defensive roles, such as shooting down missiles hurtling towards ships. However, with the development of AI-infused systems, the military is now on the verge of fielding machines capable of going on the offensive, picking out targets and taking lethal action without direct human input. The fact that machines can act and react much more quickly than we can is becoming more relevant as the pace of war speeds up. In the next decade, missiles will fly near the Earth at a mile per second, which is too fast for humans to make crucial defensive decisions on their own. Drones will attack in self-directed swarms, and specialised computers will assault one another at the speed of light. Humans might create the weapons and give them initial instructions, but after that many military officials predict that they will only be in the way. In 2016, China unveiled the Junweikejiwei, its new military R&D agency modelled on the United States' Defense Advanced Research Projects Agency (DARPA). Similarly, Russia has the Skolkovo Institute of Science and Technology, located outside Moscow, which defence-intelligence sources describe as another DARPA clone. Skolkovo was originally founded in partnership with MIT, but the university backed out of the arrangement in early 2019 after the Russian billionaire who funded the project, Viktor Vekselberg, was sanctioned by the United States for suspected connection with Russian meddling in the 2016 election.

Why is it important? Until now, militaries seeking to cause an explosion at a distant site have had to decide when and where to strike; use an aeroplane, missile, boat or tank to transport a bomb to the target; direct the bomb; and press the 'go' button. However, drones are removing humans from the transport aspect, and computer algorithms are learning how to target. The key remaining issue is whether or not military commanders will let robots decide to kill, particularly at moments when communication links have been disrupted – a likely occurrence during wartime.

Date: 3 September 2019; source: https://www.theatlantic.com/technology/archive/2019/09/killer-robots-and-new-era-machine-driven-warfare/597130

19. **DARPA to develop new gamma ray inspection technology**

Summary: DARPA has announced its gamma ray inspection technology (GRIT) programme. GRIT seeks novel approaches to achieve high-intensity, tunable and narrow-bandwidth sources of gamma ray radiation in a compact, transportable form factor that would enable a wide range of national security, industrial and medical applications. GRIT aims to provide a source of tunable, pure X-rays and gamma rays from tens of kilo-electron volts to over 10 mega-electron volts. Currently, tunable and narrow-bandwidth gamma ray sources only exist at highly specialised user facilities best suited for basic research and are not able to support broad practical applications. Shrinking these photon sources to a transportable system is a major goal and challenge of the GRIT programme.

Why is it important? GRIT technology could make a range of new inspection and diagnostic protocols possible. In medical and industrial radiography. For example, GRIT could enable specific elemental and material content to be revealed, such as calcium in bones and specific metals in cargo. A typical X-ray only shows differences in density in the object being inspected – whether that be a piece of luggage at an airport or an individual in a doctor's office. If successful, a GRIT X-ray source could be tuned to detect and quantify the concentration of specific elements of interest, such as the amount of calcium in a given bone X-ray, enabling radiologists to actually see bone composition.

Date: 14 June 2019; source: https://www.darpa.mil/news-events/2019-06-14

20. **NASA is going back to the future with nuclear rockets**

Summary: Tucked into the recent spending bill that was passed by Congress is a line item for USD 100 million for NASA to develop nuclear thermal rocket engines. A nuclear thermal rocket superheats liquid hydrogen in a nuclear reactor and shoots the resulting plasma out of a rocket nozzle. Nuclear thermal propulsion (NTP) is far more efficient than a chemical rocket, as it reduces flight times to destinations such as Mars and requires less

fuel. Astronauts would be subjected to less radiation and less time in microgravity when using NTP. Even uncrewed space probes would be able to reach their destinations more quickly, opening up the solar system to further exploration.

Why is it important? NTP will mean the difference between a deep-space exploration programme consisting of sorties that land on Mars and visit other destinations, do a lot of good science and then return, and one that expands human civilisation throughout the solar system. Nuclear rockets will be as game-changing for space travel as the steam engine was for ocean voyages.

Date: 1 March 2019; source: https://thehill.com/opinion/technology/432153-nasa-is-going-back-to-the-future-with-nuclear-rockets

21. **Military eyes hunting for rapidly deployable atomic power**

Summary: US military researchers are surveying industry to find companies able to develop a small mobile nuclear reactor for forward-deployed fighting forces on land and at sea. Officials of the Washington Headquarters Services Acquisition Directorate in Arlington, Virginia, issued a request for information (RFI) on Friday (RFI-01182019-RD-WHS019) for the small mobile nuclear reactor project. The Washington Headquarters Services issued this RFI on behalf of the US Office of the Under Secretary of Defense for Research and Engineering. This deployable atomic power plant should produce from 1 to 10 megawatts of electricity; weigh no more than 40 tons; be deployable by truck, ship or C-17 cargo aircraft; use passive air cooling; and be inherently safe such that a core meltdown is impossible if power and cooling is lost.

Why is it important? It is an example of decentralised/mobile/private use of nuclear power.

Date: 21 January 2019; source: https://www.militaryaerospace.com/articles/2019/01/mobile-nuclear-reactor-deployable-atomic-power-semiautonomous-operation.html

22. **Nuclear technology to suppress mosquito populations**

Summary: A combination of the nuclear sterile insect technique (SIT) and the incompatible insect technique (IIT) has led to the successful suppression of mosquito populations for the first time, a promising step in the control of mosquitoes that carry dengue, the Zika virus and many other devastating diseases. The results of the recent pilot trial in Guangzhou, China, carried out with the support of the International Atomic Energy Agency (IAEA) in cooperation with the Food and Agriculture Organization of the United Nations, were published in *Nature* on 17 July 2019. The IAEA said in a statement that the results of the pilot trial, using the SIT in combination with the IIT, demonstrate the successful near elimination of field populations of the world's most invasive mosquito species, *Aedes albopictus* (Asian tiger mosquito).

Why is it important? The use of a nuclear technique to eliminate dangerous insects that have the potential to create pandemics could be a way to promote nuclear science and technology among the public.

Date: 18 July 2019; source: https://www.iaea.org/newscenter/news/mosquito-population-successfully-suppressed-through-pilot-study-using-nuclear-technique-in-china

23. **Borophene is the new wonder material**

Summary: Stronger and more flexible than graphene, a single-atom layer of boron could revolutionise sensors, batteries and catalytic chemistry. The reason for the excitement is the extraordinary range of applications for which borophene would be suitable. Electrochemists think borophene could become the anode material in a new generation of more powerful lithium-ion batteries. Chemists are entranced by its catalytic capabilities, and physicists are testing its abilities as a sensor to detect numerous kinds of atoms and molecules. Hydrogen atoms also stick easily to borophene's single-layer structure, and this adsorption property, combined with the huge surface area of atomic layers, makes borophene a promising material for hydrogen storage. Theoretical studies suggest borophene could store over 15 % of its weight in hydrogen, significantly outperforming other materials.

Why is it important? Chemists have some work to do before borophene can be more widely used. For a start, they have yet to find a way to make borophene in large quantities. In addition, the material's reactivity means it is vulnerable to oxidation, so it needs to be carefully protected. Both factors make borophene expensive to make and hard to handle. As a result, there is work ahead.

Date: 5 April 2019; source: https://www.technologyreview.com/2019/04/05/239331/borophene-the-new-2d-material-taking-chemistry-by-storm/

24. **DFAB – House built by robots**

Summary: The DFAB House (https://dfabhouse.ch/dfab-house/) is a three-level building near Zurich that features 3D-printed ceilings, energy-efficient walls, timber beams assembled by robots on site and an intelligent home system. Developed by a team of experts at ETH Zurich university and 30 industry partners over the course of 4 years, the DFAB House, measuring 2 370 square feet (220 square metres), needed 60 % less cement and has passed the stringent Swiss building safety codes.

Why is it important? DFAB is not the first building project to use digital fabrication techniques. In 2014, the Chinese company WinSun demonstrated the architectural potential of 3D printing by manufacturing 10 single-storey houses in 1 day (https://www.bbc.com/news/blogs-news-from-elsewhere-27156775). A year later, the Shanghai-based company also printed an apartment building and a neoclassical mansion (https://qz.com/334629/you-may-soon-be-living-in-a-3d-printed-apartment/), but these projects remain in the development phase (https://www.3dprintingmedia.network/winsun-works-with-chinese-academy-on-standardization-of-construction-3d-printing/). Beyond the experimental structure in Switzerland, Matthias Kohler and Benjamin Dillenburger explain that they are interested in fostering a dialogue with the global architecture and construction sectors. They have published their open-source data sets (https://dfab.ch/dataset-index) and have organised a travelling exhibition titled 'How to Build a House: Architectural research in the digital age' (http://cooper.edu/architecture/events-and-exhibitions/exhibitions/how-build-house-architectural-research-digital-age), which opens at the Cooper Union in New York on 12 September 2019.

Date: 12 September 2019; source: https://qz.com/1705386/the-dfab-house-exhibit-opens-in-new-york-city/

25. **Artificial intelligence can turn brain signals into speech**

Summary: Neuroengineers have crafted a breakthrough device that uses machine-learning neural networks to read brain activity and translate it into speech. When we speak our brains light up, sending electrical signals zipping around. If scientists can decode those signals and understand how they relate to forming or hearing words, then we get one step closer to translating them into speech. With enough understanding – and ample processing power – we could create a device that directly translates thinking into speaking, and that is what the team is attempting to do – create a 'vocoder' that uses algorithms and neural networks to turn signals into speech.

Why is it important? The human–computer framework could eventually provide patients who have lost the ability to speak with an opportunity to use their thoughts to verbally communicate via a synthesised robotic voice.

Date: 30 January 2019; source: https://www.cnet.com/news/scientists-train-ai-to-turn-brain-signals-into-speech/

26. **From drone swarms to modified *E. coli*: Say hello to a new wave of cyberattacks**

Summary: Data attacks are the nuclear weapon of the 21st century. Far more important than who controls territory is the fact that whoever controls data has the capacity to manipulate the hearts and minds of populations. AI-driven algorithms can corrupt data to influence beliefs, attitudes, diagnoses and decision-making, with an increasingly direct impact on our day-to-day lives. Data poisoning is a new and extremely powerful tool for those who wish to sow deception and mistrust in our systems. The risk is amplified by the convergence of AI with other technologies: data poisoning may soon infect country-wide genomics databases and potentially weaponise biological research, nuclear facilities, manufacturing supply chains, financial trading strategies and political discourse. Unfortunately, most of these fields are governed in silos, without a good understanding of how new technologies might, through convergence, create system-wide risks at a global level.

Why is it important? Policymakers need to start working with technologists to better understand the security risks emerging from a combination of AI and other dual-use technologies and critical information systems. If not, they must prepare for large-scale economic and social harms inflicted by new forms of automated data poisoning and cyberattacks. In an era of increasing AI-cyber conflicts, our multilateral governance system is needed more than ever.

Date: 1 May 2019; source: https://www.weforum.org/agenda/2019/05/cyber-attacks-ai-artificial-intelligence-drone-swarms-data-poisoning/

27. **In search of a SpaceX for nuclear power**

Summary: The Nuclear Innovation Alliance (NIA) has hosted a meeting on Capitol Hill about how to enhance the development of nuclear power by learning from recent space programme advancements and breakthroughs. This is related to the NIA's new publication *In Search of a SpaceX for Nuclear Energy*. A number of useful insights were identified from the successful space Commercial Orbital Transportation Service (COTS) programme that could enhance nuclear power development. For example, COTS was driven by a clear national mission; it was a backup to the primary NASA programme; it was able to do 'pay for performance' or milestone-based funding; it was supported by non-financial assistance from NASA; it took advantage of highly flexible government contracts – other transaction agreements; and it was able to facilitate a significant opportunity for cost savings (e.g. reusable rocket). The fact that there was a significant opportunity for cost saving stems from the fact that the cost of nuclear power plant construction exceeds over 100 times the cost of materials. One key difference identified between nuclear power and the space programme is there is a much higher level of regulation for nuclear power.

Why is it important? Significant progress and breakthroughs are not characteristics of nuclear power R&D. Looking for insights proven in other industries and technologies might be able to change that. Learning from the space programme advancements and breakthroughs might be very beneficial for the faster development of new nuclear power solutions.

Date: 13 September 2019; source: https://www.jdsupra.com/legalnews/nia-in-search-of-a-spacex-for-nuclear-46076/

Date: 5.2019; source: https://www.nuclearinnovationalliance.org/report-calls-new-approach-us-advanced-reactor-demonstration

28. **The mirrorworld does not yet fully exist, but it is coming**

Summary: Someday soon, every place and thing in the real world – every street, lamp post, building and room – will have its full-size digital twin in the mirrorworld. It is already under construction. Deep in the research labs of tech companies around the world, scientists and engineers are racing to construct virtual places that overlay actual places. Crucially, these emerging digital landscapes will feel real; they will exhibit what landscape architects call place-ness. The Street View images in Google Maps are just facades – flat images hinged together. However, in the mirrorworld, a virtual building will have volume, a virtual chair will exhibit chairness, and a virtual street will have layers of textures, gaps and intrusions that all convey a sense of 'street'. Eventually, we will be able to search physical space as we might search a text. We will hyperlink objects into a network of the physical, just as the web hyperlinked words, producing marvellous benefits and new products.

Why is it important? The first big technology platform was the web, which digitised information, subjecting knowledge to the power of algorithms; it came to be dominated by Google. The second great platform was social media, running primarily on mobile phones. It digitised people and subjected human behaviour and relationships to the power of algorithms, and it is ruled by Facebook and WeChat. We are now at the dawn of the third platform, which will digitise the rest of the world. On this platform, all things and places will be machine readable, subject to the power of algorithms. Whoever dominates this grand third platform will become among the wealthiest and most powerful people and companies in history, just as those who now dominate the first two platforms have. In addition, similar to its predecessors, this new platform will unleash the prosperity of thousands more companies in its ecosystem, and a million new ideas – and problems – that were not possible before machines could read the world.

Date: 12 February 2019; source: https://www.wired.com/story/mirrorworld-ar-next-big-tech-platform/

29. **New unmanned ship design**

Summary: The first commercial crossing of the channel by an uncrewed ship has taken place, marking a breakthrough for the sector. The ship is capable of doing a range of tasks, such as hydrographic surveys and environmental missions. The vessel's unique modular design means that it can be easily and cost-effectively configured to a wide range of maritime tasks for various sectors. The vessel can be transported in a single 40-foot container, drastically reducing the mobilisation costs, and being truly uncrewed means SEA-KIT can conduct its missions without placing any human personnel in harm's way and at a significantly reduced rate. The mission was designed to showcase SEA-KIT's uncrewed navigation capabilities through the Global Positioning System (GPS) and satellite communication, including marine traffic avoidance in what is one of the world's busiest shipping routes.

Why is it important? It involves unmanned shipping and a reduced risk for shipping crews.

Date: 13 May 2019; source: https://www.hydro-international.com/content/news/remotely-controlled-unmanned-ships-crossing-dover-strait

30. **The dark side of our drone future**

Summary: If hacked, drones could be put to insidious uses by criminal gangs, or even other nations, that wish to gather data or spread misinformation. In August 2019, for example, hackers attending the annual Defcon conference in Las Vegas managed to demonstrate how a simple off-the-shelf quadcopter drone, fitted with a radio transmitter, could hover above a home and take control of its smart TV. The drone transmitted a signal 'more powerful than the one broadcast by legitimate TV networks, overriding the legitimate signal'. This may seem harmless, but such a technical capability could allow a hacker to 'display phishing messages that ask for the viewer's passwords, inject keyloggers that capture the user's remote button presses, and run cryptomining software'. The drone could even broadcast its own material. In Ukraine, Russian-backed forces have already used fixed-wing drones, alongside ground-based systems, 'to conduct electromagnetic reconnaissance and jamming against satellite, cellular and radio communication systems along with GPS spoofing and electronic warfare attacks'. One of the tactics in Ukraine was to send menacing messages to Ukrainian troops on the ground, urging retreat. US Immigration and Customs Enforcement officials have raised concerns that Chinese drones manufactured by DJI 'may be sending sensitive information about American infrastructure back to China'. Broader worries soon surfaced, leading the US Army to ban the use of all drones made by DJI. As *Foreign Policy* reported in August, the army 'may soon ban all Chinese-built drones and Chinese-manufactured components from military use'. Very few airports have any countermeasures or even processes in place to detect and defeat drones, and many existing technologies are underperforming or too risky to use.

Why is it important? As a drone future approaches, policymakers, industry leaders, security forces and technology innovators must prioritise key questions: How will national governments secure emerging drone infrastructure as it grows exponentially over the next few years? How will data be kept secure? Can the hacking of drones and spread of disinformation be prevented? And, in the face of the most advanced drones, how will counter-drone systems react?

Date: 4 October 2019; source: https://thebulletin.org/2019/10/the-dark-side-of-our-drone-future/

31. **Emerging EU policies take a harder look at Chinese investments**

Summary: Like the Belt and Road initiative, foreign direct investment from China now has a much broader reach than Beijing's own backyard. It is well known that Washington is actively working towards mitigating US vulnerabilities to Chinese investments in strategic sectors, and those that contain critical technologies and infrastructure.

Why is it important? China, unlike Russia, does not seek to destabilise the European project, despite its preference for dealing with EU Member States bilaterally (or within multilateral frameworks that China leads, such as the '16 + 1' initiative). However, China's industrial strategy is a legitimate concern for both the European economy and Europe's collective national security.

Date: 18 January 2019; source: https://jamestown.org/program/emerging-eu-policies-take-a-harder-look-at-chinese-investments/

32. **Europe's aims to clean up the space graveyard**

Summary: The amount of space junk around Earth has hit a critical point at which it now poses risks to other spacecraft and satellites and has started to trigger human efforts to combat the security threat in outer space.

Why is it important? 'We are at a crucial moment because so far we have been able to operate in space without having to worry about the impact of human activity,' said Moranta of the European Space Policy Institute. 'And now we have to think realistically about killer factors in space.'

Date: 3 September 2019; source: https://www.euractiv.com/section/global-europe/news/europes-aims-to-clean-up-the-space-graveyard/

33. **Remaining relevant in the global defence innovation competition**

Summary: While technological changes are transforming the global defence and strategic environment, Europe risks lagging behind because of structural and ideological factors. In the current revolution, speed of action is everything, and Europe is just starting to realise the changes it has undergone.

Why is it important? 'Beyond the vertiginous impact it has on "old" European societies, it is an exceptional opportunity to gather all of the continent's energies. But this will only be possible if Europe is able to set itself a clear vision, disrupt its decision-making mechanism and break the increasingly irrelevant barriers between the civil and military, private and public spheres, and demonstrate that integrated European approaches can work.'

Date: 5 June 2019; source: http://www.gmfus.org/publications/europes-sputnik-moment-remaining-relevant-global-defense-innovation-competition

34. **House appropriators take aim at some of the Pentagon's most ambitious tech ideas**

Summary: A data cloud costing USD 10 billion, giant ray guns in space and a sixth-generation fighter jet are just some of the biggest ideas to come out of the Pentagon in the last several years. However, they have failed to impress the House Appropriations Committee, which released its version of the 2020 defence spending bill report on 21 May 2019.

Date: 22 May 2019; source: https://www.nextgov.com/it-modernization/2019/05/house-appropriators-take-aim-some-pentagons-most-ambitious-tech-ideas/157205

35. **Future technologies and global defence market**

Summary: Energy storage, hypersonic propulsion, 5G, metamaterials – future technological advancements will be increasingly interlinked, wherein the advancements in one technology will spur the development of adjacent and complementary technologies. Anticipating the future of the armed forces requires the tracking of all these interlinked technologies, as a breakthrough in any technology can have a positive or negative impact on related technology. As commercially developed technologies are not dependent on defence funding, they usually cross over into different sectors. These companies may not even be aware of the implications that their technology would have on the defence sector; hence, it is not the technology that determines technological superiority on the battlefield, but rather the doctrine that deploys these technologies that exploits them to their maximum potential.

Why is it important? Potential future technologies need to be assessed early in a new product development and production cycle to maximise the impact and minimise the risk. This means current technological trends and developments need to be constantly monitored and evaluated, with a broad enough focus to venture beyond immediate defence research and cross over into civilian research with dual-use potential. The convergence of multidisciplinary technologies, such as information technologies, robotics, AI, nanotechnology, and metamaterials, will have a wide variety of civilian and military applications.

Date: 11 July 2019; source: https://www.prnewswire.com:443/news-releases/impact-of-future-technologies-on-the-global-defense-market-2029---growth-opportunities-in-energy-storage-hypersonic-propulsion-5g-metamaterials-300883349.html

36. **Private space companies draw inspiration from successful rocket launch at sea**

Summary: China's 'CZ-11 WEY' rocket was successfully launched at sea for the first time on 5 June 2019, giving a much-needed boost to the country's space industry. Although the rocket was designed and built by the China Academy of Launch Vehicle Technology – part of a state-owned space conglomerate – the country's private rocket companies enthusiastically cheered its successful launch.

Why is it important? Since the State Council, China's cabinet, issued a directive in 2014 encouraging the private sector to participate in research, production and launch services for commercial satellites – a move that opened the doors of China's space field to the private sector – the number of private companies related to this field has grown from 80 to 141 in the past 3 years, according to a report released by a Chinese industry think tank, Futureaerospace, in May. These companies provide services such as satellite manufacturing, rocket manufacturing and satellite launches. The report said that China will have sent about 3 100 commercial satellites into space by 2025, with the satellite manufacturing market size reaching CNY 13.6 billion (USD 1.97 billion).

Date: 9 June 2019; source: https://www.globalsecurity.org/space/library/news/2019/space-190605-globaltimes01.htm

37. **Trump's space programme to counter strategic threats and advance innovation**

Summary: President Donald Trump said, on 13 March, that space has become a warfighting domain and that, to face this threat, the US military may need a Space Force. Trump, speaking with troops at the Marine Corps Air Station Miramar in San Diego, stated: 'My new national strategy for space recognises that space is a warfighting domain, just like the land, air, and sea.'

Why is it important? 'The Chinese projection into space is, first and foremost, a military projection,' said Richard Fisher. He went on to say that 'when China goes to the Moon, possibly in the early 2030s, it will not just be China going to the Moon. It will be the PLA [People's Liberation Army] going to the Moon. And it will seek dual-use exploitation of the Moon'.

Date: 13 May 2019; source: https://www.theepochtimes.com/the-space-force-and-mission-to-mars-aim-to-quell-threats-and-advance-us-innovation-2_2470029.html

38. **Russia challenges US defence in space, developing capabilities**

Summary: The US Defense Intelligence Agency said, in a new assessment entitled 'Challenges to Securities in Space', that Russia is probably pursuing directed energy weapons, including lasers that could take out enemy satellites.

Why is it important? Moreover, the document also claims that Russia is developing enhanced on-orbit dual-use technology that can be used to attack and permanently disable satellites. 'Russia continues to research and develop sophisticated on-orbit capabilities that could serve dual-use purposes', said the report on 11 February 2019. It also said that 'inspection and servicing satellites [...] could also be used to approach another country's satellite and conduct an attack that results in temporary or permanent damage'.

Date: 12 February 2019; source: https://nation.com.pk/12-Feb-2019/russia-challenges-us-defense-in-space-developing-capabilities

39. **Wi-Fi signals identify walkers from their gait**

Summary: Researchers in the United States have used Wi-Fi signals to detect the gait of people through walls and match it to video footage to identify individuals. It works by measuring the way a person's gait interferes with the signal from two Wi-Fi transceivers. This signal is then compared with a simulated signal extracted and translated from pre-existing video footage. 'Our proposed approach makes it possible to determine if the person behind the wall is the same as the one in video footage, using only a pair of off-the-shelf Wi-Fi transceivers outside,' said research lead Yasamin Mostofi. 'This approach utilises only received power measurements of a Wi-Fi link. It does not need any prior Wi-Fi or video training data of the person to be identified. It also does not need any knowledge of the operation area.' From video footage, the system uses a human mesh recovery algorithm to extract the 3D mesh describing the outer surface of the human body as a function of time. Electromagnetic wave approximation then simulates the RF signal that would have been generated if this person had been walking in a Wi-Fi area. Next, a time-frequency processing approach extracts key gait features from both the real Wi-Fi signal and the simulated signal from the video. The two signals are then compared to determine if they match. In experiments, the technology successfully identified subjects between 80 % and 90 % of the time.

Why is it important? According to those behind the technology, known as XModal-ID, it could potentially be used to identify criminals inside buildings in which pre-existing video footage of the suspects is available. The system builds on previous work in the Mostofi Lab, which has investigated sensing with RF signals since 2009.

Date: 1 October 2019; source: https://www.theengineer.co.uk/wifi-walls-walkers-gait

40. **Synthetic DNA: Four new DNA letters double life's alphabet**

Summary: The DNA of life on Earth naturally stores its information in just four key chemicals: guanine, cytosine, adenine and thymine, commonly referred to as G, C, A and T, respectively. Now scientists have doubled this number of life's building blocks, by creating for the first time a synthetic, eight-letter genetic language that seems to store and transcribe information just like natural DNA. In a study published on 22 February in *Science* (https://www.nature.com/articles/d41586-019-00650-8#ref-CR1), a consortium of researchers led by Steven Benner, founder of the Foundation for Applied Molecular Evolution in Alachua, Florida, suggests that an expanded genetic alphabet could, in theory, also support life. Benner's team, which includes researchers from various US companies and institutions, created the synthetic letters by tweaking the molecular structure of the regular bases. The letters of DNA pair up because they form hydrogen bonds: each contains hydrogen atoms, which are attracted to nitrogen or oxygen atoms in their partner. Benner explains that it is a bit like Lego bricks that snap together when the holes and prongs line up. By adjusting these holes and prongs, the team has come up with several new pairs of bases, including a pair named S and B, and another called P and Z.

Why is it important? First, the work shows that life could potentially be supported by DNA bases with different structures from the four that we already know, which could be relevant in the search for signatures of life elsewhere in the universe. Second, with more diversity in the genetic building blocks, scientists could potentially create RNA or DNA sequences that can do things better than the standard four letters, including functions beyond genetic storage. For example, Benner's group previously showed that strands of DNA that included Z and P were better at binding to cancer cells than sequences with just the standard four bases (https://www.nature.com/articles/d41586-019-00650-8#ref-CR3). In addition, Benner has set up a company that commercialises synthetic DNA for use in medical diagnostics. Third, the researchers could potentially use their synthetic DNA to create novel proteins as well as RNA.

Date: 21 February 2019; source: https://www.nature.com/articles/d41586-019-00650-8

41. **Plug-and-play spacecraft take a leap forward**

Summary: The York Space Systems platform is a three-axis stabilised spacecraft that can carry payloads of up to 85 kilograms in mass. In future, it will be the backbone spacecraft type for constellations and also ride-sharing, which is a popular option to cut costs for launches. (Ride-shares see smaller satellites piggyback on a larger, main satellite that might be for government or military purposes.) Its strength is being able to pivot to all sorts of different missions. The S-CLASS platform can also be moved to any orbit inclination or orientation, without expensive redesigns, which means it could be used for anything from military surveillance (which tends to require polar orbits) to monitoring ship traffic near the equator. It can even zoom up to geosynchronous orbit (a common orbit for communications satellites), although that would require extra propulsion modules to deorbit out of these valuable slots, which are highly coveted worldwide. The protocol is for companies to move their satellites away when the platforms exhaust fuel. Their customers are analytics customers that use machine learning and AI to pull 'new things' out of the data collected from space. Using technology instead of people to parse the data will reduce costs.

Why is it important? Although traditional satellite series such as Landsat tend to make their data available for free, as information becomes more specialised it will also be more valuable. Therefore, many commercial companies will prefer to sell their data as another revenue stream.

Date: 2 April 2019; source: https://www.forbes.com/sites/elizabethhowell1/2019/04/02/plug-and-play-spacecraft-take-a-leap-forward/#a6f477471725

42. **A wearable robotic suit ('Iron Man' style) to deal with radioactive waste**

Summary: Researchers from the University of Bristol, who have been working with Sellafield Ltd since 2013, have developed a concept for an 'Iron Man' type suit that would incorporate a wearable exoskeleton and a protective body covering made from composite materials. Workers at Sellafield currently wear air-fed polyvinyl chloride suits. These suits are completely safe to use, but they can usually only be worn for a few hours at a time because of the heat stress they cause on workers' bodies. The benefit of a wearable robotic suit is that it would reduce any physical stress on the individual wearing it, especially when working in awkward or constrained positions, such as working in small areas and having to lift objects. The composite materials would also be easier to decontaminate and would provide a better shield against radiation levels in some plant areas that contain radioactive contamination. Other technologies to be evaluated by the project include eye movement tracking, for better detection of worker fatigue; printable electronics, to avoid wiring in the suit; and hand-mounted systems, for improved detection of radiation and nuclear materials.

Why is it important? Space and nuclear are both safety-critical industries. Just as space suits enabled transformational outcomes, making it possible for humans to go into space, further development of these suits could result in game-changing improvements in decommissioning safety and performance at Sellafield and other nuclear decommissioning sites across the world.

Date: 29 November 2018; source: https://phys.org/news/2018–11-iron-style-world-biggest-nuclear.html

43. **DARPA is funding research into AI that can explain what it's 'thinking'**

Summary: On 20 July 2018, DARPA, a Department of Defense (DoD) agency focused on breakthrough technologies, announced its AI exploration programme. This programme will streamline the agency's process for funding AI R&D with a focus on third wave AI technologies – the kinds that can understand and explain how they arrived at an answer. A system in the third wave of AI will not only be able to do what a second wave system can do (for example correctly identify a picture of a dog) but also be able to explain why it decided that the image is that of a dog. For example, it might note that the animal's four legs, tail and spots align with its understanding of what a dog should look like.

Why is it important? This is the latest example of the US military's growing interest in AI. Recent projects include everything from AI that analyses footage to improve drone strikes to systems that function like the human brain. In June 2018, the DoD launched the Joint Artificial Intelligence Center, a centre designed to help the department integrate AI into both its business and military practices.

Date: 24 July 2018; source: https://futurism.com/third-wave-ai-darpa/

44. **Revolutionary design: A plane with no moving parts driven by electricity**

Summary: The first ever 'solid state' plane, with no moving parts in its propulsion system, has successfully flown for a distance of 60 metres, proving that heavier-than-air flight is possible without jets or propellers. A new MIT plane is propelled via ionic wind. Batteries in the fuselage (the tan compartment in the front of a plane) supply voltage to electrodes (blue/white horizontal lines) strung along the length of the plane, generating a wind of ions that propels the plane forward. Unlike propeller-driven drones, the new design is completely silent. The aircraft, which weighs about 5 pounds and has a 5-metre wingspan, carries an array of thin wires that are strung like horizontal fencing along and beneath the front end of the plane's wing. In the prototype plane, wires at the leading edge of the wing have 600 watts of electrical power pumped through them at 40 000 volts. This is enough to induce 'electron cascades', ultimately charging air molecules near the wire. Those charged molecules then flow along the electrical field towards a second wire at the back of the wing, bumping into neutral air molecules on the way and imparting energy to them. Those neutral air molecules then stream out of the back of the plane, providing thrust. The end result is a propulsion system that is entirely electrically powered, almost silent, and with a thrust-to-power ratio comparable to that achieved by conventional systems such as jet engines.

Why is it important? This has potentially opened new and unexplored possibilities for aircraft that are quieter and mechanically simpler, and that do not emit combustion emissions. Solid state things lend themselves to scaling down quite well, creating extremely small flight vehicles that serve uses we cannot imagine.

Date: 21 November 2018; sources: https://www.theguardian.com/science/2018/nov/21/first-ever-plane-with-no-moving-parts-takes-flight; http://news.mit.edu/2018/first-ionic-wind-plane-no-moving-parts-1121

45. **US military to develop genetically modified plants to spy**

Summary: The US military wants to deploy plants as 'the next generation of intelligence gatherers'. Genetically modified plants could be employed as self-sustaining sensors to gather information in settings unsuitable for more traditional technologies. DARPA, which is responsible for the development of emerging technologies in the US military, has called for scientists to submit ideas for how to harness the power of plants. However, in this new initiative, termed the advanced plant technologies (APT) programme, the agency is looking to the natural world for help.

Why is it important? 'Plants are highly attuned to their environments and naturally manifest physiological responses to basic stimuli such as light and temperature, but also in some cases to touch, chemicals, pests and pathogens,' said Dr Blake Bextine, the manager of the APT programme. 'Emerging molecular and modelling techniques may make it possible to reprogramme these detection and reporting capabilities for a wide range of stimuli, which would not only open up new intelligence streams, but also reduce the personnel risks and costs associated with traditional sensors,' said Dr Bextine.

Date: 23 November 2018; source: https://www.independent.co.uk/news/science/us-military-gm-plants-spy-gentically-modified-research-development-sensors-environments-a8071646.html

46. **Big agriculture eyeing genetic tool for pest control**

Summary: A controversial and unproven gene-editing technology touted as a silver bullet against malaria-bearing mosquitos could wind up being deployed first in commercial agriculture, according to experts and a non-governmental organisation report published on Tuesday. What are called gene drives force evolution's hand, ensuring that an engineered trait is passed down to all or most offspring, and from one generation to the next. If that trait is being male or female, for example, genetically altered specimens released into the wild could lead to the local extinction of a targeted species within a dozen generations. 'We could see every interest group in the agro-food industry editing the genome of those they call pests, spreading various mutations through gene drive and causing long-term effects on the ecological dynamics of ecosystems – along with the human populations depending on them,' Virginie Courtier-Orgogozo, a biologist at the Jacques Monod Institute in Paris, wrote recently in the journal *EMBO Reports*.

Why is it important? Critics calling for a moratorium on the release of gene drives in the wild fear that they could mutate, jump to other species or spread far beyond target areas.

Date: 16 October 2018; source: https://phys.org/news/2018-10-big-agriculture-eyeing-genetic-tool.html

47. **Characteristics of microorganisms most likely to cause a global pandemic**

Summary: Infectious disease preparedness work focuses predominantly on an historical list of pathogens derived from biological warfare agents, political considerations and recent outbreaks. In doing so, this work fails to account for the most serious agents not currently known or without historical precedent, according to scholars from the Johns Hopkins Center for Health Security in a new report on the traits of microorganisms with high pandemic potential. The report, *The Characteristics of Pandemic Pathogens*, establishes a framework for identifying naturally occurring microorganisms that pose a global catastrophic biological risk (GCBR) and makes broad recommendations for improving GCBR preparedness efforts. GCBRs are events in which biological agents could lead to a sudden, extraordinary, widespread disaster beyond the collective capability of national and international governments and the private sector to control. No exhaustive catalogue of GCBR culprits exists, leaving the health security community to rely on historical examples (e.g. the 1918 Spanish flu) to guide their preparedness priorities.

Why is it important? 'Health security preparedness needs to be adaptable to new threats and not exclusively wedded to historical notions,' said Amesh Adalja, MD, who is the project lead and a senior scholar at the centre. 'A more active-minded approach to this problem will, in the end, help guard against a GCBR event occurring'.

Date: 28 May 2018; source: https://www.eurekalert.org/pub_releases/2018-05/jhcf-ric052518.php

48. **Highly elastic biodegradable hydrogel for bioprinting of new tissues**

Summary: Researchers at the University of Texas at Arlington (UTA) have developed a highly elastic biodegradable hydrogel for bioprinting materials that mimic natural human soft tissues. Bioprinting uses live cells within the scaffolding of the new tissues and could potentially transform cell printing. A provisional patent application has been filed on this new material that will be able to generate multiple types of human soft tissues, including skin, skeletal muscles, blood vessels and heart muscles. 'Soft tissue bioprinting suffers from significant challenges as the hydrogels were often brittle and un-stretchable and could not mimic the mechanical behaviour of human soft tissues,' said Yi Hong, a UTA professor of bioengineering and the leader of the project. 'To overcome these challenges, we developed a simple system using a single cross-linking mechanism activated by visible light to achieve a highly elastic and robust, biodegradable and biocompatible hydrogel for cell printing,' Hong added.

Why is it important? 'Polycaprolactone and poly (ethylene glycol) are already widely used in Food and Drug Administration–approved devices and implants, which should facilitate quick translation of the material into pre-clinical and clinical trials in the future,' said Hong. 'The tunability of the mechanical properties of this hydrogel to match different soft tissues is a real advantage,' he added.

Date: 3 May 2018; source: https://www.eurekalert.org/pub_releases/2018-05/uota-heb050318.php

49. **US military wants to know what synthetic-biology weapons could look like**

Summary: A study ordered by the US DoD has concluded that new genetic engineering tools are expanding the range of malicious uses of biology and reducing the amount of time needed to carry them out. The new tools are not in themselves a danger and are widely employed to create disease-resistant plants and new types of medicine. However, rapid progress by companies and university labs raises the spectre of 'synthetic-biology-enabled weapons', according to a 221-page report. The report, issued by the National Academies of Sciences, is among the first to try to rank national security threats made possible by recent advances in gene engineering, such as the gene-editing technology CRISPR. 'Synthetic biology does expand the risk. That is not a good-news story,' says Gigi Gronvall, a public health researcher at Johns Hopkins University and one of the report's 13 authors. 'This report provides a framework to systematically evaluate the threat of misuse.' Experts are divided on the perils posed by synthetic biology, a term used to describe a wide set of techniques for speeding up genetic engineering. In 2016, the US intelligence community placed gene editing on its list of potential weapons of mass destruction.

Why is it important? Among the risks that the authors termed those of 'high concern' is the possibility that terrorists or a nation state could recreate a virus such as smallpox. This is a present danger, because technology for synthesising a virus from its DNA instructions has previously been demonstrated.

Date: 19 June 2018; source: https://www.technologyreview.com/2018/06/19/66749/us-military-wants-to-know-what-synthetic-biology-weapons-could-look-like/

50. **E-tattoos? 3D printable electronics could make them possible**

Summary: In April 2018, Michael McAlpine, a mechanical engineering professor at the University of Minnesota, published a study in the journal *Advanced Materials* in which he demonstrated a way to print electronics directly onto the skin. The device – cheap, accessible and compact – already offers groundbreaking applications for the military and medicine. In the future, it could completely change how we interact with the world around us. We are expanding the capabilities of 3D printing beyond hard plastic and towards what are called 'functional materials'. This means printing materials that have some practical use – electronic materials, soft polymers and even biological materials such as cells – on a single platform.

Why is it important? The team has printed cells onto the wound of a mouse. It collaborated with the dean of the medical school, Jajub Tolar, who is working on a rare skin disease whereby the epidermal layer flakes off as a result of a genetic disease. The team was able to print regenerative cells onto the mouse's wound while the mouse was moving.

Date: 25 September 2018; source: https://geneticliteracyproject.org/2018/09/25/e-tattoos-3d-printable-electronics-could-make-them-possible/

51. **Camouflaged nanoparticles deliver killer protein to cancer cells**

Summary: A biomimetic nanosystem can deliver therapeutic proteins to selectively target cancerous tumours, according to a team of researchers at Pennsylvania State University (Penn State). Using a protein toxin called gelonin from a plant found in the Himalayan mountains, the researchers caged the proteins in self-assembled metal-organic framework (MOF) nanoparticles to protect them from the body's immune system. To enhance the longevity of the drug in the bloodstream and selectively target the tumour, the team cloaked the MOF in a coating made from cells from the tumour itself. 'We designed a strategy to take advantage of the extracellular vesicles derived from tumor cells,' said Siyang Zheng, an associate professor of biomedical and electrical engineering at Penn State. 'We remove 99 percent of the contents of these extracellular vesicles and then use the membrane to wrap our metal-organic framework nanoparticles.'

Why is it important? The researchers believe their nanosystem provides a tool for the targeted delivery of other proteins that require cloaking from the immune system. Penn State has applied for patent protection for the technology.

Date: 19 June 2018; source: https://www.sciencedaily.com/releases/2018/06/180615094843.htm

52. **China sold 30 % of the robots in the world in 2016**

Summary: China is developing specialised robots for firefighting, disaster relief, security monitoring and military applications. In some cities, robots are already roving big shopping malls and residential areas to detect suspects or potential danger. Focusing on specialised robots as a core technology, a Chinese intelligent equipment manufacturing enterprise, CITIC HIC Kaicheng Intelligence Equipment Co Ltd, has developed a type of specialised robot for nuclear radiation detection. This robot can be used in environments with nuclear, biological or chemical contamination. Collaborating with Finland, Germany and Russia, the institute's Ground Unmanned Platforms Research and Development Centre has modified a Russian robot that was used for nuclear disposal at the Chernobyl nuclear power plant, developing it for use in disaster rescue. A 'robotic security guard' developed by Beijing Aerospace Automatic Control Institute attracted great attention at the World Robot Conference. It moved around freely like a human guard but with greater competence.

Why is it important? As China takes the lead in the robotic industry, the collaboration opportunities entail a complex dilemma – although collaborating with China to develop robots for emergency response may save the lives threatened by those emergencies, the knowledge transferred or acquired by China through this collaboration might end up being used for coercion and repression.

Date: 23 August 2018; source: https://www.manilatimes.net/chinas-specialised-robots-are-ready-to-counter-potential-nuclear-leaks-military-threats/

53. **Beijing plans an artificial intelligence nuclear Atlantis for the South China Sea**

Summary: China is planning to build a deep-sea base for unmanned submarine science and defence operations in the South China Sea, a centre that might become the first AI colony on Earth, according to officials and scientists involved in the plan. Like a space station, the undersea complex will have docking platforms. Project engineers will need to develop materials to withstand the water pressure at such great depths. Robot submarines will be sent to survey seabeds, record life forms for cataloguing and collect mineral samples. As a self-contained laboratory, the station will analyse those samples and send reports to the surface. Although the base will depend on cables connected to a ship or a platform for power and communication, its powerful 'brain' and sensors will allow it to carry out autonomous missions. China is proposing several marine facilities, including the world's first manned deep-sea station, a habitat capable of housing dozens of people for up to 1 month at a time at 3 kilometres (1.9 miles) beneath the sea. Beijing also plans to build 20 floating nuclear power plants, with the first expected to be sent into the South China Sea by 2020, to support commercial and military activities.

Why is it important? The South China Sea is probably the most disputed waterway on the planet, with seven territories making conflicting claims over it.

Date: 26 November 2018; sources: https://www.scmp.com/news/china/science/article/2174738/beijing-plans-ai-atlantis-south-china-sea-without-human-sight

54. **Using diamonds to recharge civilian drones in flight**

Summary: A small lab-grown diamond measuring a few millimetres on each side could one day enable civilian drones to be recharged in mid-flight through a laser. Thanks to the diamond, the laser beam can remain strong enough over a long distance to recharge photovoltaic cells on the drones' surface. This system, which poses no threat to human health, is being developed by the EPFL spin-off LakeDiamond. It could also be used to transmit both power and data to satellites and in 2018 was included in the 10 projects that the Swiss Space Office would support for 2 years.

Why is it important? Drones are being used for a growing number of purposes. Their designs are ever more efficient, and techniques for flying them are being further refined all the time. However, drones still have the same weak point: their battery. One way of addressing this limitation without weighing the drones down would be to recharge them while they are aloft by using a power beaming system – an energy-rich laser beam that is guided by a tracking system and that shines directly onto photovoltaic cells on a drone's exterior. This energy transmission system is also interesting for other areas of application. It can, for example, be used for charging and transmitting data to satellites.

Date: 7 November 2018; source: https://phys.org/news/2018-11-diamonds-recharge-civilian-drones-flight.html

55. **Cheetah III robot preps for a role as a first responder**

Summary: The dog-sized Cheetah II can run on four articulated legs at up to 6.4 metres per second, make mild running turns and leap to a height of 60 centimetres. The robot can also autonomously determine how to avoid or jump over obstacles. Sangbae Kim is now developing a third-generation robot, Cheetah III. Instead of improving the Cheetah's speed and jumping capabilities, Kim is converting the Cheetah into a commercially viable robot with enhancements such as a greater payload capability, wider range of motion and a dexterous gripping function. Cheetah III will initially act as a spectral inspection robot in hazardous environments such as a compromised nuclear plant or chemical factory. It will then evolve to serve other emergency response needs. 'We believe the Cheetah III will be able to navigate in a power plant with radiation in two or three years,' says Kim. 'In five to 10 years it should be able to do more physical work like disassembling a power plant by cutting pieces and bringing them out. In 15 to 20 years, it should be able to enter a building fire and possibly save a life.'

Why is it important? In situations such as the Fukushima nuclear disaster, robots or drones are the only safe choice for reconnaissance. Drones have some advantages over robots, but they cannot apply the large forces necessary for tasks such as opening doors, and there are many disaster situations in which fallen debris prevents drone flight. Looking beyond disaster response, Kim envisages an important role for agile, dynamic legged robots in health care: improving mobility for the fast-growing elderly population. Numerous robotics projects are targeting the elderly market with chatty social robots. Kim is imagining something more fundamental.

Date: 27 March 2018; source: https://phys.org/news/2018-03-cheetah-iii-robot-preps-role.html

56. **Nuclear micro-reactors powering US DoD infrastructure before 2027**

Summary: The *Roadmap for the deployment of micro-reactors for U.S. Department of Defense (DoD) domestic installations* report lays out a clear path towards deploying small (< 10 megawatts electric – MWe) nuclear reactors at DoD installations in potentially as little as 5 years. Both Congress and the DoD have identified energy security as a key issue for the US Armed Forces. As the military becomes more reliant on advanced computing and networking for its mission-critical tasks and moves towards the deployment of advanced weapons with large power demands, it has become critically dependent on resilient sources of electricity. General Atomics is developing a mobile nuclear power supply that is truck/air shippable and would fit in a standard military shipping container. This modular, autonomous system has a load-following generating capacity of up to 10 MWe and a refuelling period greater than 10 years.

Why is this important? The use of very small nuclear reactors for resilient power in remote locations is an increasingly popular option that is also being examined by other nations. Both Canada and the United Kingdom have advanced government programmes under way, with the goal of deploying small reactors within the next decade.

Date: 4 October 2018; source: https://www.marketscreener.com/news/General-Atomics-Joins-the-Nuclear-Energy-Institute-in-Support-of-a-Department-of-Defense-Micro-React--27371736/

57. **Nuclear propulsion, critical to Arctic dominance**

Summary: The Northeast Passage through the Arctic would dramatically shorten sea routes between Europe and Asia, which could cut transit times by 2 weeks compared with the Suez Canal Passage. Those reduced travel times translate into savings of 40 % on both fuel and shipping costs, and would lower CO_2 emissions by 52 %. However, the Northern Sea Route (NSR) along the Russian Arctic coast – a key leg of the Northeast Passage – has historically been traversable only from July to October. Russia has used nuclear power on its icebreakers since the 1970s. However, the reactors of these early ships (at 90–170 megawatts thermal – MWt) were not strong enough to allow bigger ships to power through the thickest ice sheets. The icebreakers were just 30 metres wide at most, with a displacement of 25 000 tonnes, and could only clear the way for small freighters of up to 70 000 tonnes. A new generation of icebreakers could break through those limitations. These ships can leverage 175–315 MWt of energy and are almost 50 metres wide, with a displacement of 70 000 tonnes that would meet the needs of the biggest tankers. These ships would make the passage navigable all year round. Russia occupies a leading position in small nuclear technologies more generally and is already marketing its onshore and floating plants based on 55-MWe and 6.6-MWe small modular reactors (SMRs). China is expected to come up with its own indigenous floating 50-MWe SMR by 2020 and onshore 100-MWe systems in the coming decade. These countries will have a head start once the scramble for the Arctic begins in earnest.

Why is it important? Western countries are some way behind. China and Russia are investing billions in the development of the NSR, with similar progress not being seen in the alternative Northwest Passage off the coast of Canada. Although a Danish ship, the Vesta Maersk, was the first of a new 42 000-tonne ice-class vessel to sail the NSR in late September 2018, the Chinese have been sending smaller cargo vessels of up to 19 000 tonnes through the passage since 2013.

Date: 11 December 2018; source: https://oilprice.com/Alternative-Energy/Nuclear-Power/Nuclear-Power-Becomes-Critical-To-Arctic-Dominance.html

58. **Food delivery drone services**

Summary: Uber has unveiled a new look for its food delivery drone, which utilises 'innovative rotating wings with six rotors' to better enable the transition between vertical take-off and forward flight. The drone's rotors are positioned vertically for take-off and landing, but they can then rotate into the forward position for increased speed and efficiency during cruise flight. The cargo capacity for the drone is a meal for two, and it is designed to perform a maximum delivery leg in 8 minutes, including loading and unloading. Its cruising altitude will be below 400 feet (approx. 122 meters) to comply with existing drone rules. It will have a total flight range of 18 miles (29 kilometres) without a delivery and 12 miles (19 kilometres) with a delivery. Uber expects to perform test flights in 2020, with a commercial launch scheduled for 2023.

Why is it important? It conserves energy and reduces congestion.

Date: 28 October 2019; source: https://www.theverge.com/2019/10/28/20936410/uber-eats-food-delivery-drone-design

59. **Composite metal foam for use in aircraft wings**

Summary: The leading edges of aircraft wings have to meet a very demanding set of characteristics. New research shows that a combination of steel composite metal foam (CMF) and epoxy resin has more desirable characteristics for use as a leading-edge material than the aluminium that is currently in widespread use. CMF is a foam that consists of hollow, metallic spheres – made of materials such as stainless steel and titanium – embedded in a metallic matrix made of steel, aluminium or metallic alloys. For this study, the researchers used steel-steel CMF, meaning that both the spheres and the matrix were made of steel. Previous work has found that the metal foam is remarkably tough – it can withstand .50 calibre rounds, resist high temperatures and block blast pressure from high-explosive incendiary rounds.

Why is it important? It provides improved erosion performance for aircraft.

Date: 21 October 2019; source: https://www.sciencedaily.com/releases/2019/10/191021111852.htm

60. **New advances to deliver the room-temperature superconductor**

Summary: The frigid conditions required by existing superconductors have tended to limit their use to niche applications such as magnetic resonance imaging machines and particle accelerators. Historically, researchers discovered new superconductors through trial and error; however, recent breakthroughs have come from theoretical algorithms that use new tools, such as machine learning, to predict novel superconducting materials. There is a possibility that a room-temperature superconductor at ambient pressure could be created because of the way new superconductors and pairing mechanisms keep cropping up. Phonon-mediated pairing tends to be stronger in wobblier atomic lattices (a perfectly rigid lattice could not support conventional superconductivity, which requires the lattice to pull towards an electron). Therefore, the exceptionally robust pairing needed for high-temperature conventional superconductivity seems to demand a special type of crystal structure, analogous to the elaborate designs that engineers employ in modern bridges to keep them sturdy, despite their flexing with the wind. Machine-learning algorithms are computer programs that modify themselves as they receive more data. In 2018 one such algorithm, trained on a database of thousands of materials, developed the ability to identify superconductors (conventional and unconventional) in another data set with 92 % accuracy and estimate their critical temperatures. Experimentalists, instead of testing 10 compounds and taking 1 year to do this in a laboratory, are going to test 10 000 compounds on the computer and take only a few weeks.

Why is it important? A room-temperature superconductor might be put to new uses, including transporting solar and wind energy to greater distances than is currently practical, increasing the capacity of power grids, making batteries that never lose their charge, and countless other uses in computers and medicine.

Date: 1 October 2019; source: https://www.scientificamerican.com/article/new-clues-in-the-hunt-for-a-room-temperature-superconductor/

61. **Gut microbes control fear in mice**

Summary: Chemicals released by bacteria in the gut seem to influence how mice recover from fear – an ability linked to chronic anxiety and post-traumatic stress disorder. Mice that were trained that a certain sound meant a painful shock were able to forget the association after some time with a painless version of the tone. However, mice treated with antibiotics to wipe out the microbiome were never able to get over the learned fear. When researchers looked closer, the bacteria-free mice had experienced changes to their brains and had different chemicals flooding their bodies.

Why is it important? Researcher suggests that there are connections between the microbes in our intestines and those in our brain. Gut bacteria probably influence conditions ranging from depression to autism. The study on how mice overcome fear could provide new insight into several mental disorders.

Date: 23 October 2019; source: https://www.sciencemag.org/news/2019/10/chemicals-released-bacteria-may-help-gut-control-brain-mouse-study-suggests

62. **Freelance site offers illegal spying services**

Summary: The freelancer site Fiverr is where a company can hire a short-term app developer, a logo designer or someone to help with their social media accounts. Fiverr is also a site where you can buy malware to illegally spy on your spouse (https://www.vice.com/en_us/article/53vm7n/inside-stalkerware-surveillance-market-flexispy-retina-x), pay someone to place a GPS tracker on a car or hire an unlicensed private investigator (https://www.vice.com/en_us/article/nepxbz/i-gave-a-bounty-hunter-300-dollars-located-phone-microbilt-zumigo-tmobile), according to Fiverr listings. 'I have undetectable spyware to monitor your cheating spouse, staffs "sic" and kids gadgets,' reads one listing on Fiverr found by Motherboard. For USD 5, customers can apparently buy malware that will record keystrokes and websites visited, and for USD 400 they can buy software that will allegedly steal a target's passwords and email content. The quality of the malware on offer is unclear. Another listing offers to 'covertly deploy [a] tracking device to a vehicle'.

Why is it important? The news highlights how the struggle to moderate content is not limited to large social networks and platforms such as Facebook (https://www.vice.com/en_us/article/xwk9zd/how-facebook-content-moderation-works), Twitter (https://www.vice.com/en_us/article/ywy5nx/twitter-researching-white-supremacism-nationalism-ban-deplatform) and YouTube. Other sites, such as Fiverr, also have trouble policing their platforms. 'We use advanced algorithms, automated tools, and filters that we are constantly updating and improving in order to actively remove services that violate our terms of use,' a spokesperson said, describing how Fiverr moderates its own platform.

Date: 26 August 2019; source: https://www.vice.com/en_us/article/a35vzj/freelance-site-fiverr-offers-illegal-private-spying-services

63. **Africa–Russia Summit and issues on the discussion table**

Summary: On 23–24 October 2019, the Africa–Russia Summit took place in Sochi. Over 50 African leaders and over 3 000 delegates were invited. It was an attempt to re-empower relationships to compete with Africa's relationships with the United States, the EU and even China.

Why is it important? The summit had not only economic but also technological and military issues on the table. According the Stockholm International Peace Research Institute data, from 2012 to 2017, Russia's sales of weapons to African countries doubled. Through economic ties, Russia is protecting its own interests well, as its exports are far higher than its imports. Its hard powers are well complemented by its soft power influence: visa-free entrance to South Africans and scholarships to the most talented African students (about 15 000 students from Nigeria, Angola, Morocco and Tunisia are currently studying in Russia).

Date: 11 October 2019; source: https://qz.com/africa/1726464/russia-africa-summit-marks-growing-influence-with-presidents/

64. **One step closer to a useful quantum memory**

Summary: An important missing element in the exploitation of quantum phenomena for IT is a really good memory, one that would allow bits of information encoded in quantum states ('qubits') to be recorded, read and erased as easily as classical bits are today. Not only would quantum memory be an enabler for quantum computing, but it would also, probably on a shorter timescale, be very important for overcoming critical limitations of quantum communications. Quantum information cannot pass the repeaters used to boost the power of light pulses in fibre optic communications networks, so it is not possible to just plug two quantum cryptography devices into the telephone network and use them to exchange information securely. Special links

are needed that do not contain any repeaters and cannot be more than about 100 kilometres long. Satellite links might be an alternative, but they also have major difficulties, not least cost. Schemes do exist for devices that exploit quantum entanglement to extend the distance that quantum information can be sent in fibre, but the most promising ones require the qubit to be held in memory at one end until the photon has propagated along the link. Progress in developing this idea has been blocked by the absence of a quantum memory that can hold the information for long enough. A 2019 pre-print (https://arxiv.org/abs/1910.08009) from the renowned group at the University of Geneva describes a quantum memory with a storage life of half a second, realised in a solid-state device using spin-resonance techniques and a 'frequency comb': an optical spectrum with a set of lines at equally spaced frequencies. The technique avoids the need for very strong magnetic fields but does require cooling to 4 K. So far, the efficiency of the memory is only 3 %, so it is not yet a viable technology for fielding, but the long storage life is a significant advance.

Why is it important? The Directorate-General for Communications Networks, Content and Technology, with help from the Joint Research Centre and the Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs and experts from Member States, are currently in the process of planning an EU quantum communications infrastructure. If a viable quantum repeater were to be available soon, it might be possible to complete this project with terrestrial links only. It would also bring us a little closer to the long-term dream of a large-scale network of quantum processors – a quantum internet.

Date: 23 October 2019; source: https://ec.europa.eu/digital-single-market/en/faq/frequently-asked-questions-quantum-communication-infrastructure

65. **Russian 'CRISPR-baby' scientist has started work**

Summary: The biologist Denis Rebrikov says that he has started gene editing human eggs as a step on the path towards becoming the second scientist to make genome-edited babies. Rebrikov announced in 2019 that he wants to follow in the controversial footsteps of He Jiankui, who edited a gene linked to HIV resistance. Rebrikov has said that he is working with five deaf couples and hopes to eventually edit a gene linked to deafness, called 'GJB2', in their babies (although the eggs he is practising on now were donated by women who are not deaf).

Why is it important? Rebrikov responds bluntly to those who argue that clinical research with edited embryos should slow down until international frameworks are in place. In an email to *Nature*, he said, 'Are you serious? Where did you see the researcher willing to slow down?'

Date: 18 October 2019; source: https://www.nature.com/articles/d41586-019-03018-0?utm_source=Nature±Briefing.

66. **3D printing to recycle more nuclear material**

Summary: Advances in 3D printing are poised to transform the nuclear industry as scientists reap the benefits of creating flexible materials, parts and sensors layer by layer. Additive manufacturing can even help us recycle used nuclear fuel more efficiently, according to a new pivotal breakthrough by scientists at the US Department of Energy's Argonne National Laboratory. We can recycle waste from nuclear reactors in several ways, including one method developed by Argonne scientists in the 1970s. With these approaches, nuclear engineers can recycle 95 % of the spent nuclear fuel from a reactor, leaving only 5 % to be stored as long-term waste. However, now, for the first time, Argonne scientists have printed 3D parts that pave the way to recycling even more nuclear waste.

Why is it important? This additional step may reduce the length of storage almost one thousandfold, and breaking down that nuclear material in a fourth-generation fast reactor would generate additional electricity. The more we can separate the actinides, the more we can reduce the impact they have on the public and environment.

Date: 11 October 2019; source: https://phys.org/news/2019-10-degrees-nuclear.html

67. **The Spaceline – A practical space elevator**

Summary: Perhaps the biggest hurdle to mankind's expansion throughout the solar system is the prohibitive cost of escaping the Earth's gravitational pull. In its many forms, the space elevator provides a way to circumvent this cost, allowing payloads to traverse along a cable extending from the Earth to orbit. However, modern materials are not strong enough to build a cable capable of supporting its own weight. The Spaceline is an alternative to the classic space elevator that is within reach of modern technology. By extending a line, anchored on the Moon, to deep within the Earth's gravity well, we can construct a stable, traversable cable

allowing free movement from the vicinity of the Earth to the Moon's surface. With current materials, it is feasible to build a cable extending close to the height of geostationary orbit, allowing easy traversal and construction between the Earth and the Moon.

Why is it important? 'The spaceline makes the Earth Moon Lagrange point effectively stable. In this gravity free environment we can construct habitats and equipment of arbitrary mass. It is a pristine and gravity free environment, with no great hindrance to developing space constructions on a scale that would seem impossible otherwise. Having only a small team of scientists and engineers at such a base camp would allow hand construction and maintenance of a new generation of space based experiments – one could imagine telescopes, particle accelerators, gravitational wave detectors, vivariums, power generation and launch points for missions to the rest of the solar system.'

Date: 25 August 2019; source: https://arxiv.org/pdf/1908.09339.pdf

68. **Cybersecurity/US regulator facing 'mass exodus' of experts**

Summary: The US Nuclear Regulatory Commission (NRC) is facing a mass exodus of cybersecurity experts in the years ahead, which could limit its ability to ensure the nation's nuclear power plants are safe from digital attacks, according to an internal watchdog. Nearly one third of the NRC's cybersecurity inspectors will be eligible for retirement by the end of fiscal year 2020, and agency officials are worried that they are not training enough people to take their place, according to the NRC Inspector General. Auditors have said that, with nuclear power stations becoming possible targets for online adversaries, the shortage of cybersecurity expertise could leave the agency struggling to do its job. 'If staffing levels and skill sets do not align with cybersecurity inspection workload requirements, the NRC's ability to adapt to a dynamic threat environment and detect problems with [nuclear power plants'] cybersecurity programmes could be compromised,' wrote the auditors in a recent report. They also urged the NRC to collaborate with the nuclear industry to develop and implement suitable cybersecurity performance measures. In 2009, the NRC started explicitly requiring nuclear power stations, most of which are privately owned, to defend their IT infrastructure against cyberattacks. Plants were expected to have protection in place by the end of 2017, and the agency is in the midst of verifying that facilities met the deadline.

Why it is important? It is another example of the decline in nuclear potential in the United States.

Date: 14 June 2019; source: https://www.nucnet.org/news/us-regulator-facing-mass-exodus-of-experts-6-5-2019

69. **The tech innovations we need to happen if we are going to survive climate change**

Summary: Innovation is not enough to avert the worst consequences of climate change, but there are solutions at hand that are commonplace and cost effective. However, we desperately need more. Here is a look at the things engineers have checked off their list, and the sticky problems left to solve:

- today's renewables – solar and wind,
- improving the grid – interconnection and storage,
- next-generation nuclear,
- managing carbon – sequestration.

Why is it important? Eliminating the carbon emitted in the production of electricity is a crucial step towards keeping the world from heating to dire levels. It is also among the most straightforward, largely thanks to the innovations of the past few decades, which were driven by a combination of ingenuity, research funding and policy incentives.

Date: 12 September 2019; source: https://time.com/5669039/technology-fight-climate-change/

70. **Employees connect nuclear plant to the internet so they can mine cryptocurrency**

Summary: Ukrainian authorities (Secret Service, SBU) investigated a potential security breach at a nuclear power plant after employees connected parts of its internal network to the internet so that they could mine cryptocurrency. The investigation is looking at the incident as a potential breach of state secrets because of the classification of nuclear power plants as critical infrastructure. 'Investigators are examining if attackers might have used the mining rigs as a pivot point to enter the nuclear power plant's network and retrieve information from its systems, such as data about the plant's physical defences and protections.'

Why is it important? Unwanted exposure of the nuclear power plant to the external internet could reduce security. Even if this is outside the process part of the plant, it could allow access to critical safety or security information.

Date: 22 August 2019; source: https://www.zdnet.com/article/employees-connect-nuclear-plant-to-the-internet-so-they-can-mine-cryptocurrency/

71. **Singapore partners to offer citizens free fitness trackers (with a catch)**

Summary: Under the country's national health programme – Live Healthy SG – hundreds of thousands of Singapore residents are able to register to get a free Fitbit Inspire HR. The activity band itself, which has a price tag of USD 99, will not cost a dime. However, in exchange, users will have to subscribe to Fitbit's premium coaching service, which costs USD 10 a month, for a year, according to CNBC (https://www.cnbc.com/2019/08/21/fitbit-to-supply-trackers-to-hundreds-of-thousands-in-singapore.html). On top of that, Singaporeans will have to agree to share whatever data the Fitbit collects with the country's health board. Singaporeans can pre-register for Live Healthy SG in September, and the programme is officially slated to debut in late October.

Why is it important? 'We intend to work with industry innovators, such as Fitbit, on additional efforts to use technology to provide Singaporeans with personalized health advice and nudges, so that they can take control of their own health,' said Zee Yoong Kang, the chief executive officer of the country's Health Promotion Board. The monthly fee quickly adds up to being higher than the cost of the fitness tracker itself and represents Fitbit's larger push towards subscription services, as it struggles to stand its ground in the hardware space amid competitors such as Apple, Xiaomi and Huawei. 'We think this program could reach up to one million people. It's an indication hopefully to investors and other potential customers that the transformation that we have talked about in our business model is becoming real,' said Park. Speaking with CNBC (https://www.cnbc.com/2019/08/21/fitbit-to-supply-trackers-to-hundreds-of-thousands-in-singapore.html), Park also revealed that Apple was one of the bidders and that negotiations were 'highly competitive'.

Date: 22 August 2019; source: https://www.digitaltrends.com/health-fitness/fitbit-singapore-health-contract-fitness-trackers/

72. **After the Moon, people on Mars by 2033 … or 2060**

Summary: On 11 December 2017, US President Donald Trump signed a directive ordering NASA to prepare to return astronauts to the Moon 'followed by human missions to Mars and other destinations'. The dates fixed by the space agency are 2024 for the Moon and 2033 for Mars, but according to experts and industry insiders reaching the Red Planet by then is highly improbable barring a Herculean effort on the scale of the Apollo programme in the 1960s. From the design, manufacture, and testing of the required rockets and spaceships to learning the best way to grow lettuce: all the groundwork remains to be done. Key tasks include finding a way to shield astronauts from prolonged exposure to solar and cosmic radiation, said Julie Robinson, NASA's chief scientist for the International Space Station. Techniques to exploit Martian resources to extract water, oxygen and fuel, all of which are necessary for humans to live there, do not yet exist and must be tested on the Moon by the end of this decade. AI must also be developed to assist and guide the astronauts.

Why is it important? A researcher commissioned by NASA to study the likelihood of getting to Mars by 2033 concluded that the objective was 'infeasible'. For Bhavya Lal, the more realistic time frame is 2039.

Date: 18 May 2019; source: https://phys.org/news/2019-05-moon-people-mars.html

73. **Renewed alarm about increasing antimicrobial resistance**

Summary: Globally, drug-resistant diseases cause some 700 000 deaths per year. Unless fast and effective action is taken by 2050, this toll could rise to 10 million deaths per year, warns the report *No Time to Wait: Securing the future from drug-resistant infections* (https://www.who.int/antimicrobial-resistance/interagency-coordination-group/final-report/en/) by the United Nations ad hoc Interagency Coordination Group on Antimicrobial Resistance (https://www.who.int/antimicrobial-resistance/interagency-coordination-group/en/). In some countries, it is estimated that up to 82 % of infections are resistant to at least one of the most commonly used antibiotics. By 2030, antimicrobial resistance could force up to 24 million people into extreme poverty.

Why is it important? Highlighting the interconnectedness among human, animal, food and environmental health, the report calls for a coordinated, multisectoral 'One Health' approach to overcome antimicrobial resistance. The recommendations include increased investment in research and innovation to combat

antimicrobial resistance, the urgent phase-out of the use of critically important antimicrobials as growth promoters in agriculture, and better regulations and programmes for the responsible use of antimicrobials by professionals in human, animal and plant health.

Date: April 2019; source: https://www.who.int/antimicrobial-resistance/interagency-coordination-group/final-report/en/

74. **World first Cooperative Intelligent Transport Systems cybersecurity system**

Summary: California-based Integrity Security Services (ISS) has delivered the world's first production-grade root certificate authority (CA) that is based on the European Telecommunications Standards Institute Cooperative Intelligent Transport Systems (C-ITS) standards, which will now be used in Australian connected vehicle projects.

The root CA was created under the WebTrust for CAs' auditing framework, the same framework used to assure the secure and safe operations of the underlying security of internet e-commerce activity. Together with the ISS Enrollment Authority and Authorization Authority, the system will be collectively known as the C-ITS Security Credential Management System (CCMS). The new CCMS will provide the cybersecurity needed to deploy C-ITS technology along roadways and in vehicles throughout Australia. Australia's experiences and knowledge can help inform the use of C-ITS systems around the world, as well as help guide global technical and operational standards.

Why is it important? It supports the roll-out of C-ITS services and increases vehicle security.

Date: 16 October 2019; source: https://www.traffictechnologytoday.com/news/cybersecurity/world-first-c-its-cybersecurity-system.html

75. **Putting the 'I' in science**

Summary: Citizen science is booming. Today, anyone with a computer or a smartphone can participate in research in astronomy, oceanography, medicine, zoology and beyond. With such studies no longer the exclusive realm of an elite few, communities of amateur and professional scientists have joined together to democratise the discipline, harnessing mutual enthusiasm and collective wisdom to gather and analyse data. In recent years, we have seen an explosion of new opportunities, in fields such as cetology, linguistics and space archaeology. Zooniverse emerged from the success of Galaxy Zoo, Lintott's first citizen-science venture. In 2007, faced with the daunting task of classifying millions of galaxies imaged by the Sloan Digital Sky Survey telescope in New Mexico, Lintott and colleagues solicited help through a brief slot on BBC radio's morning current affairs programme. The response was beyond anyone's wildest dreams. Within a few days, volunteers were classifying 70 000 galaxies every hour on their own computers.

Why it is important? One of Lintott's key messages is that citizen science is much more than free labour. Many such projects exploit the human brain's ability to recognise patterns or spot unusual features in data that even the most sophisticated computer algorithms can miss. Collaborations between professional and amateur researchers also increase public understanding of science and have produced a growing list of publications in peer-reviewed journals. At the same time, there are more and more interconnections between neophytes and specialists and an increase in interacting topics due to new interacting media (social networks) – before, these interactions concerned only politics, whereas now they concern techniques, education, knowledge and even cutting-edge sciences. One main concern during these interactions is the trust that people have in the 'elite' or specialists because of the gap in competences and knowledge between these groups. Increasing and extending these types of collaborations and associated feedback could lead to reinforcing of the trust perception of public opinion while people participate and see – their own contribution in – achievements.

Date: 16 October 2019; sources: https://www.nature.com/articles/d41586-019-03051-z?WT.ec_id=NATURE-20191017&utm_source=nature_etoc; https://arxiv.org/abs/0804.4483; https://www.zooniverse.org/

76. **Wearable face projector**

Summary: A small beamer projects a different appearance onto your face, giving you a completely new appearance.

Why is it important? In the future, an advertisement could call your name when you walk along the street. Companies will know your personal interests and may set different retail strategies for you. This could be convenient for customers, but personal thoughts and opinions should be kept private. A wearable face projector protects you from this privacy violation.

Date: 4 April 2017; source: http://jingcailiu.com/?portfolio=wearable-face-projector

77. **Quantum supremacy**

Summary: A recent paper (https://www.inverse.com/article/59507-full-quantum-supremacy-paper) from Google's quantum computing lab announced that the company had achieved quantum supremacy.

Why is it important? In 2012, John Preskill proposed the term 'quantum supremacy' to describe the point at which quantum computers can do things that classical computers cannot, regardless of whether or not those tasks are useful. The catch, as the Google team acknowledges, is that the problem their machine solved with astounding speed was carefully chosen just for the purpose of demonstrating the quantum computer's superiority. It is not otherwise a problem of much practical interest. In brief, the quantum computer executed a randomly chosen sequence of instructions, and then all the qubits were measured to produce an output bit string. This quantum computation has very little structure, which not only makes it harder for the classical computer to keep up but also means that the answer is not very informative. By checking that the output of their quantum computer agrees with the output of a classical supercomputer (in cases in which it does not take thousands of years), the team has verified that they understand their device and that it performs as it should. Now that we know that the hardware is working, we can begin the search for more useful applications.

Date: 2 October 2019; source: https://www.quantamagazine.org/john-preskill-explains-quantum-supremacy-20191002/

78. **Psychedelics and biophilia**

Summary: Modern research is adding scientific weight to the hypothesis that psychedelics are tools for enhancing 'biophilia', a term (https://www.hup.harvard.edu/catalogue.php?isbn=9780674074422&content=reviews) popularised by the biologist E. O. Wilson in the 1980s meaning an innate human tendency to seek connection to nature and appreciate other forms of life. In a recent survey (https://slideslive.com/38898554/ecodelia-towards-a-transpersonal-ecopsychology-through-psychedelics) of 150 psychedelic users, everyone reported that biophilia was enhanced. Likewise, a meta-analysis (https://www.ncbi.nlm.nih.gov/pubmed/20855349) of eight double-blind placebo-controlled studies found that more than one third of participants taking psilocybin reported enduring positive changes in their relationship with the environment 8–16 months after taking the drug. It was noted in other studies examining the long-term effects of psilocybin that the increase in connection to nature appears to be an enduring shift in perspective. At Imperial College London, researchers found (https://journals.sagepub.com/doi/full/10.1177/0269881117748902) a marked increase in measures of nature-relatedness post psilocybin; the effect was sustained at least 1 year after the experience.

Why is it important? 'The most important variables are psychological, above all how we see ourselves and each other, whether we feel connected or threatened, and the size of the collective with which we identify. Not all of us can go to space to experience the overview effect that made such a powerful impact on astronauts in the Apollo programme. But the recent resurgence in psychedelic treatments offers powerful hope for the emergence of an alternative route to a similar destination.'

Date: 17 September 2019; source: https://aeon.co/essays/psychedelics-can-have-the-same-overview-effect-as-a-space-journey

79. **Saudi Aramco drone attack**

Summary: An attack on 14 September 2019 struck the world's biggest crude-processing facility in Abqaiq and Saudi Arabia's second-biggest oil field in Khurais, exposing a vulnerability at the heart of the global oil market. The estimated 5.7 million barrels a day of lost Saudi oil is the single biggest sudden disruption ever, surpassing the loss of the Kuwaiti and Iraqi supply in August 1990 and Iranian output in 1979 during the Islamic Revolution, according to data from the International Energy Agency. All eyes were on how fast Saudi Arabia could restore production after the weekend's devastating strike on key facilities, which knocked out

roughly 5 % of global supply and triggered a record surge in oil prices. Over the weekend, people who are familiar with the matter said that significant volumes could come back within days, adding that it could still take weeks to restore full capacity. The industry consultant Energy Aspects estimated that the country would be able to restore almost half the lost production as early as Monday.

Why is it important? 'No matter whether it takes Saudi Arabia five days or a lot longer to get oil back into production, there is but one rational takeaway from this weekend's drone attacks on the Kingdom's infrastructure – that infrastructure is highly vulnerable to attack, and the market has been persistently mispricing oil,' wrote Citigroup Inc.'s Ed Morse in a research note.

Date: 16 September 2019; source: https://www.bloomberg.com/news/articles/2019-09-15/saudis-race-to-restore-oil-output-after-crippling-aramco-attack?srnd=premium

80. **Randonauts**

Summary: A small but quickly growing online community believes that transforming randomly generated numbers into clusters of location data could help us tunnel out of reality. The Fatum Project was born as an attempt to research unknown spaces outside predetermined probability tunnels of the holistic world and has become a fully functional reality-tunnel creating machine that digs rabbit holes to wonderland. The community is utilising the Fatum Project's quantum random location generator telegram bot to generate random coordinates to travel the multiverse. Log into the Telegram messaging app and send the command '/getattractor' along with your location to @shangrila_bot (formerly, you could also message @Randonaut_bot). The bot will plot out thousands of nearby geolocation points using a quantum random number generator (https://qrng.anu.edu.au/) and spit out the area with the highest concentration of points near you.

Why is it important? 'All things in the world are causally connected with each other and everything that happens, including our thoughts, is usually determined by the sum of all environmental factors. This makes the world close to deterministic. The patterns arising in the network of these relations, reduce even random actions to a limited set of possible outcomes. This means that no matter what choices you make, and no matter how many variations on how your day may pass, there are always some places where you simply cannot be, because none of the chains of your decisions leads there. Next was the question of what were long-term consequences of a researcher staying in a place where he should never have been. How much can determinism be broken? Will the clockwork of the universe fail from changing its gear position? Will the objects found in these places or the images seen generate cascades of events drastically changing everything around?'

Date: 27 August 2019; sources: https://theoutline.com/post/7881/i-became-a-randonaut-to-try-to-glitch-the-simulation-and-all-i-got-was-a-bottle-of-pee; http://randonauts.com/ and https://www.reddit.com/r/UnitiveConsciousness/comments/b21re8/fatum_project_theory/

81. **Fifth-generation mobile networks threaten weather forecasts**

Summary: Next-generation 5G mobile wireless technology could trick Earth-observing satellites into making inaccurate observations (https://nature.us17.list-manage.com/track/click?u=2c6057c528fdc6f73fa196d9d&id=3ac9a74f8c&e=7aa10297e1). Water vapour in the atmosphere emits a faint signal at the 23.8-gigahertz frequency. A 5G station transmitting at nearly the same frequency would send a false signal that would be indistinguishable from natural vapour, leading to less accurate weather forecasts. 'This is the first time we have seen a threat to what I'd call the crown jewels of our frequencies – the ones that we absolutely must defend come what may,' says the meteorologist Stephen English.

Why is it important? Our society is more dependent on weather forecasts than we might think. Erroneous weather forecasts could have a big impact, especially considering the extreme weather generated by climate change.

Date 26 April 2019; source: https://www.nature.com/articles/d41586-019-01305-4

82. **Should cybersecurity be more chameleon, less rhino?**

Summary: 'Moving target security' is a way of scrambling the names, locations and references of each file and software application in a computer's memory to make it harder for malware to get its teeth stuck into your system. The mutation occurs each time the computer is turned on so that the system is never configured the same way twice. The most effective way to secure a computer is to isolate it from local networks and the internet completely, known as air gapping. You would need to gain physical access to the computer to steal

data. The obvious way to attack an air-gapped machine is to compromise it during the supply chain when it is being built. In 2018, Bloomberg Businessweek alleged that Chinese spies had managed to insert chips into servers made in China that could be activated once the machines were plugged in overseas. The servers were manufactured for the US firm Super Micro Computer Inc. In 'co-operative cybersecurity', co-operating firms give a piece of data to each other. They do not know what the data is that they are protecting, but they hold it on their networks. To access sensitive information from any of the firms, attackers would need to hack all the networks and work out which piece of data is missing, to be able to make any sense of the files stolen. The concept is called 'crypto-splitting', and it involves encoding each sequence of data as thousands of numbers and then dividing these cryptographic puzzles between the companies.

Why is it important? The more secure and hack-proof a computer is, the less practical it is in a networked world. The concern for the cybersecurity industry is that, as the nascent 'Internet of Things' develops, powered by 5G mobile connectivity, the risk of a cyberattack will only increase. In addition, as AI becomes more widespread, it will become just another tool that hackers can exploit.

Date: 9 April 2019; source: https://www.bbc.com/news/business-47724438

83. **BusBot – Solar powered information technology**

Summary: Papercast's digital bus stops use e-paper technology, which is ideal for outside use, with unbeatable screen visibility. With exceptionally low power consumption, the displays can be entirely solar powered. Couple this with wireless connectivity and the units can be installed anywhere, within an hour – no power or connectivity cables are required. The displays are controlled remotely by Papercast's sophisticated cloud-based content management system, and live BusBot arrival times are generated by Papercast's fully integrated BetterETA data feed. This advanced technology adjusts Computer Aided Dispatch/Automatic Vehicle Location data in real time to improve the accuracy of arrival predictions.

Why is it important? It provides an improved transport management system for passengers and improved transport efficiency.

Date: 3 February 2019; source: https://markets.businessinsider.com/news/stocks/futuristic-transport-service-launched-in-new-south-wales-with-papercast-technology-1027918498

84. **Hyundai unveil a 'walking' car design**

Summary: Car maker Hyundai has unveiled a concept vehicle named Elevate, which blends the technology found in electric cars with that found in robots to help it cover terrain beyond the limitations of even the most capable off-road vehicle. Elevate is part of Hyundai's 'Centre for Robotic-Augmented Design in Living Experiences' (Cradle). The legs of the vehicle, which can 'walk' like a mammal or reptile, also fold up into a stowed drive-mode, whereby power to the joints is cut, and the use of an integrated passive suspension system maximises battery efficiency. Its applications include first response in disaster zones and improved ease of access for disabled people.

Why is it important? It has improved first response and increased accessibility.

Date: 8 January 2019; source: https://www.independent.co.uk/life-style/gadgets-and-tech/hyundai-elevate-robot-electric-car-disaster-zones-rescue-humanitarian-aid-a8717406.html

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