Science, Technology and War. An Interview with Prof. Christian Kehrt

By Christian Kehrt and the Editors

Technology has played a paramount role since the First World War. Can we say the same about previous wars, even ancient ones? To what extent was technology important in pre-modern conflicts?

Technology was and ever will be important for the conduct of warfare. Many major changes in military technology before the modern period are crucial to understanding battles and the transformations of warfare. Some of them are even considered "revolutionary". For example, the introduction of the stirrup in medieval times, according to the historian Lynn White, allowed better and more stable use of bow and lance while riding the horse, which was a precondition for the birth of the feudal system. Since military technologies are always related to the enemies' capabilities, this interdependence makes warfare and the development of military technologies highly dynamic and complex. The construction of faster, better and more powerful weapons, as well as increased protection and armament of the soldier, is paramount in the long and intertwined global history of technology and warfare, from the stone age until today. Technology, in this sense, could be understood as an anthropological dimension of warfare in any historical period.

The crucial connection between technology and warfare is often neglected by historical research and writing. Historians of science and technology seldom address issues of military history, while in this latter field, many aspects related to science, knowledge, and experiences with technology are not systematically investigated. However, the observation that technology was paramount in ancient or premodern times does not necessarily help to better understand the specific historical dynamics and meaning of warfare technology. Simple innovation-centric histories and narratives of technological determinism cannot explain the complex relationship between warfare, technology, society and the military. I would argue that a broader view of the structure of the societies involved is necessary, for example industrial or information-based societies, if historians want to explain specific changes and meanings of technologies such as trains, airplanes, or computers and their military application. In this sense, the co-construction of technology and the military has to be considered, and

historians should look at its social, political, and cultural meaning.

In modern times, the scale and dimensions of warfare as well as the structures of the military changed fundamentally. In the sixteenth century, the use of gunpowder, firearms, and cannons, as well as the development of faster ships, transformed warfare in Europe. Thus, the difference between the modern and premodern uses of technology should be considered. This relates in particular to the realm of production, logistics, and transport as well as to new scientific knowledge as relevant aspects of modern technology. The breechloader revolution in the nineteenth century and the use of steamships enabled the military establishment of British and French colonial empires among others. The train played a major strategic role in the nineteenth century and was at the heart of the so-called Schlieffen plan, which affected the then-failed German strategy for World War I. The unforeseen dynamics of World War I, with the heavy use of artillery and machine guns in trench warfare, the introduction of gas, aerial photography, as well as the increased demand for resources for ammunition production on the home front, triggered a substantial change towards the idea of "total war" that became a characteristic of both world wars.

In recent history, what were the most significant milestones in the relationship between humans and machines in war?

I would argue that the automation of warfare and the development of whole systems of surveillance and control as well as the introduction of intercontinental nuclear missiles define a "milestone" in modern warfare as it was practiced in the Cold War between the NATO and Warsaw pact members, with particular reference to the United States and the Soviet Union. The introduction of "push button" warfare with computers and nuclear missiles changed the military in the 1950s and 1960s. Nuclear missiles, fission and hydrogen bombs, combined several revolutionary developments in science and technology: microelectronics and computer science, as well as nuclear physics and chemistry. High-precision, long-distance weapons are based on processes of miniaturization and electronics, semiconductors, microprocessors, and computers as they were developed by the military-industrial-academic complex in the Silicon Valley. The knowledge for a- and h-bombs was provided by the generation of scientists such as Enrico Fermi, Werner Heisenberg, Leo Szilard, Hans Bethe, Edward Teller, Stanislaw Ulam, Robert Oppenheimer and John von Neumann. These experts mobilized their know-how in the Second World War and the Cold War to create highly destructive strategic weapons. For the

military that meant that new expertise was required not only to develop but also to integrate, appropriate, monitor, and use these science-based weapon systems. This knowledge came from outside the military system and had to be introduced by new learning processes and non-military advisors, experts, and professionals.

The intensification and extension of warfare in the twentieth century increased the danger and lethality for soldiers at the front, as well as for civilians at the home front. Poisonous gas, radioactivity, shells and bombs harmed, destroyed and contaminated people, infrastructures, as well as the natural environment way beyond the limited period of the violent conflict at stake. In this sense, cities and landscapes, water, rivers, geographic, meteorological and climatic factors were irreversibly and for a long time altered through the intensive use of modern, highly lethal and poisonous weapons. In the Cold War warzones extended over all parts of the globe including the deep sea, the polar regions, deserts and jungles as well as the higher atmosphere and even outer space. The need to control these extreme environments motivated the desire to protect the soldier's body through special equipment, protective clothing, artificial systems, pressure chambers, life maintenance systems, bunkers and capsules or to fully automatize warfare in these inhospitable regions without the direct presence of soldiers. Nonetheless, modern hi-tech weapon systems did not really help in colonial or postcolonial settings, where ground troops, often disguised as civilians, pursued guerrilla tactics over a longer period of time. If we look at the actual war in Ukraine, we see that flexible high precision weapons and drones can make a difference on the battlefield and that intelligent communication and surveillance systems are necessary to conduct warfare in a combined way. Still is not clear, which approach will be successful: a war of attrition with permanent, and massive brute force on cities, civilians and infrastructures or flexible tactics and high precision targeting of enemy soldiers, weapons and supply lines. At least we can observe a surprising combination of old-fashioned, even simple tactics and low-tech weapons with hi-tech means and intelligence that seem to alter or even define the way this war is fought.

In sum, it is rather misleading to speak of "milestones" independent of specific contexts of battles, armies, nations or societies. Technology should always be embedded in historical situations and settings. To follow or establish simple linear narratives of technological "milestones" or genealogies of weapons does not contribute to a better understanding of the historical role of weapons and war machines. Many important technologies of today – jet planes, rockets, machine guns, tanks etc. – stem from the Second or even the First

World War. One of the most important infantry weapons of the German *Wehrmacht* – the *Karabiner 98*, abbreviated as K.98, which was mass-produced between 1934 and 1945 – was already introduced into the German army before 1900. The conduct of warfare still relies on ordinary weapons such as handguns that are not necessarily hi-tech. Or to use a pointed phrase from David Edgerton's book *Shock of the old*: "The horse made a greater contribution on Nazi conquest than the V2." This lesson was also learned in colonial and postcolonial conflicts, especially after the Cold War, when asymmetrical warfare caused bitter experiences for modern armies.

Can weapons be considered an extension of the warrior's body? Is the relationship between the fighting human and the machine symbiotic?

Weapons extend the realm and limits of the soldiers' bodies and aim at injuring the enemy. In the Second World War, for example, pressurized cabins and oxygen systems, as well as special fuels and engines, increased the flight altitude. Radar systems, autopilots and radio communication allowed to fly at night with little or no sight. Yet, the development of weapons cannot be explained as simple causal extensions of the human body, in the sense that every weapon could be deciphered by or even reduced to bodily functions and organs such as eyes, hands, legs etc. To speak of aerial reconnaissance as "the eye of the army" is a metaphor, which, in my view, should not be taken too literally. Anthropological approaches alone or even ideas of technology that refer to Ernst Kapp's ideas of technology as "organ projections" from the nineteenth century are not necessarily helpful to achieve a better understanding of the manifold relationship between weapons and the soldier's body. Rather, we should ask how the vulnerable human body was protected, what kind of body-machine relations existed, and how soldiers and armies perceived body-machine interactions in order to better understand modern and premodern forms of warfare. How did soldiers use specific weapon systems, and which skills, knowledge, training and bodily experiences were required in battle situations? Certainly, a closer look at the human-machine interactions can provide more profound insight into specific practices and technical experiences of warfare. Can we, therefore, assume that these relationships were symbiotic, in the sense that a new entity was born from the interaction of the soldier with the machine, where man or women are functional parts or operators of a cybernetic, self-controlled system?

Post-phenomenological approaches in particular suggest closely looking at the body-machine interactions to understand technology-mediated military

practices and their meaning. Neither the soldier nor the machine alone determines combat action but the integration of all parts of an all-encompassing social-technological network or system. Therefore, to use the phrase of Bruno Latour: it is not simply the gun that kills people, nor do just people, but a hybrid mix of technical, social, and human components is involved in shooting other people. In military aviation, these enabling social-technical networks go beyond the cockpit. They include not only pilots, flight instruments or on-board weapons but the whole infrastructure of flight – maintenance, mechanics and airports. I would argue that these hybrid and complex men-machine networks and interactions are not symbiotic. In this sense, flying cannot be seen as a mythical new experience between combat pilot and machine as it is evoked by the popular imagery of the cyborg or World War I success stories of aerial combat. I would rather point to the many limits and failures that occur in man-machine interactions that determine the daily use of modern weapon systems. Pilots were confronted with technical failures, accidents and enemy interferences. They inhaled smoke, had to fix the motor, suffered from cold, noise, shooting, fatigue and anxiety. These technical problems and frictions can be observed also in the Cold War. In Germany, there was a high accident rate in the context of the introduction of a new weapons system called the "Starfighter" (F104G). These accidents were related to a whole bundle of failures from organizational issues, the introduction of new flight instruments and questions of training. So, to claim that this new weapon system was a cybernetic organism is true on the one hand because the pilot was only a part of a system that regulated itself. On the other hand, ignoring all the many defects and malfunctions would paint a symbiotic human-machine system, which history disproves. Therefore, military history should look more carefully at the processes of training, testing, failures, and maintenance of modern weapon systems.

How does technology modify the ethical relationship between humans and war?

Acts of violence, atrocities and war crimes are not necessarily related to technology. However new technologies such as aerial warfare, gas, nuclear bombs or drones pose new threats to soldiers and civilians and thus had to be regulated by new conventions and international law. Especially modern warfare tends to transgress any ethical limit to the total use of violence, especially if a large number of combatants and the civilian population are involved in the conflict. This problem was clearly seen even at the beginning of

the nineteenth century by Carl von Clausewitz in his highly influential theory of war. Attempts to regulate and limit modern warfare can be found in the history of the Red Cross, the Hague Land Warfare Convention, the Geneva Conventions, the new laws and rules established by the United Nations as well as specific peace or disarmament treaties. These tried to counteract and limit the excesses of violence in the nineteenth and twentieth centuries that witnessed the death of millions of soldiers, prisoners of war and civilians.

Since new technologies open up new realms of action and create new potential for violence, there are often no laws at hand to limit and close this gap between what is and what should be possible in warfare. The question is whether, in the long and bloody history of warfare, the conduct and experience of war were guided or limited by ethics at all. In too many cases, the introduction of new technology violated the laws of warfare and human rights. The use of aerial bombing against open cities or U-Boats against passenger ships in World War I are good examples of how warfare transgressed and violated existing laws and ethics and stirred up international reactions and moral scandals. The history of aerial warfare shows a permanent violation of *ius in bello* since open cities and civilians, especially children were and still are bombed and killed. In some regions declared international, non-military zones – for example, Antarctica, the open sea, or outer space – weapons should not be used. Nevertheless, space warfare was already imagined by the Strategic Defense Initiative of the Reagan Administration in the 1980s. Now, new forms of star wars conducted by means of satellites and ballistic rockets may be very likely to happen in the near future. The US introduced space forces as a new branch of the US Air Force in 2019. China has and Russia had space forces and both countries, like the USA, are deeply involved in the militarization of outer space and the development of space policies.

There are some examples of disarmament processes and the prohibition of certain kinds of weapons and ammunition. The fact that nuclear weapons were not used after Hiroshima and Nagasaki can be seen as a successful example of deterrence, as some Cold War historians argue. However, to assume that this fragile logic always holds is not valid. The philosopher Günther Anders clearly saw the ethical dilemma that the atomic bomb irreversibly created for mankind. The drop of the fission bomb on Hiroshima on the 6th of August 1945 meant that from that day on the threat that mankind might be annihilated will exist until the end of mankind. The history of the invention of the atomic bomb can therefore be read as a moral history, where scientists and societies struggle with the political and ethical consequences of these weapons of mass destruction.

Science and technology are two different fields of human thought and action. In the context of war, do they play different roles? Do they pursue different ends?

From a systems perspective, science is about the production of knowledge that is justified and true. Warfare is, if we follow Clausewitz's still valid classical definition, about defeating the enemy as a physical act of violence aimed at achieving political goals. At the same time, both sides benefit from each other, and science and warfare are closely interrelated, as one can see during the Cold War. Therefore, to separate science as a peaceful international endeavour from warfare as a violent and aggressive nationalistic act does not fully take into account the close and manifold interrelation of science, technology, the military and warfare. Furthermore, I cannot see the point of why "science" and "technology" should *a priori* play different roles or pursue different ends. Of course, there are differences between "science" and "technology", and the historical divergences should be carefully investigated. Handy notions of "technoscience" should also be considered critically. But to simply understand technology as "applied science" or to categorically separate both realms would be wrong. The history of the technology-based practice of science rather shows that distinctions between "applied" and "fundamental" science mostly fail in favour of more fluid relations between science and technology. There is a whole field of technology-oriented research such as aerodynamics that lies between basic and applied science. Experts like Fritz Haber, for example, made Nobel Prize contributions. But they also used their basic skills and knowledge for the development of gas weapons and technologies like gas masks, or to contribute in the battle against bugs and lice, or the Haber-Bosch process for the large-scale production of ammonia. At the same time, Nobel prizes and new scientific theories and insights contributed to increasing national prestige without direct applications. Already in the nineteenth century that was the case in Germany with the foundation of the Kaiser-Wilhelm-Institutes. The states had an interest in founding new research institutes and funding basic research to increase their military strength and possibilities. In the Cold War, the military was the main sponsor of research in the United States and related to the military-industrial-academic complex. This knowledge was basic and applied, often technology oriented. To separate *a priori* science from technology would be a mistake. Rather it is important to understand the historical ideologies behind certain positions and discourses, when and why people speak of "science" or "technology", "basic" or "applied" science etc.

Could you tell us about robotics applied to war? Is it science fiction or a real scenario?

I would say that "robotics" is no novelty, as it was introduced into modern warfare a long time ago. The history of automation or "cybernetics" is much older than people think and not an issue of future warfare alone. There are many instances of fully or semi-automatized, "robotized" war machines: for example self-steering and controlled devices such as torpedoes, flying bombs, or high-precision artillery systems were deployed already in the first half of the twentieth century. A good example of "robotic devices" are autopilots of airplanes or ships or sophisticated target-finding mechanisms that steer a torpedo or a rocket intelligently and flexibly to the target. These could be called "fighting robots" and were developed on the basis of gyros already around 1900. Later on, these intelligent machines were implemented through analogic and digital computers, and algorithms. Cruise missiles are "robots", and so are drones, which can find their targets automatically or shoot and change their path by themselves. Secret drones in the depth of the sea scan the oceans looking for enemy submarines and ships. The same holds for satellites and drones, which can fly and change their course independently or at least by remote control.

Of course, there are different degrees of "intelligence" and complexity in the history of these war machines. I would call them "robots" when there is a high degree of self-acting mechanisms and systems control reached. The automatic terrain-following radar with which the Tornado was equipped in the 1970s, for example, allowed high-speed flight at very low altitudes, which a pilot would never be able to realize without such a technological support. In this sense, then, a supersonic fighter jet would be a "robot" flying by itself while carrying a pilot on board.

Science fiction sometimes thinks ahead of scientists. Can you mention some examples of military technology that has been foreseen by Sci-Fi?

Works of science fiction can be seen as thought experiments where the possibilities of actual or future technologies are imagined. However, to argue that literature or movies really foresee technological development is not fully convincing, from my point of view as a historian of technology. Of course, it is stunning to see that ideas of quantum teleportation were already "invented" by the TV series *Star-Trek* or that novel forms of wireless communication can be

found already in literary science fiction at the beginning of the twentieth century. Some works of fiction published around 1900 better understood the disastrous defensive impact of the machine gun than most of the military strategies of the time. However, I do not support ahistorical *ex-post* arguments that look back and find predictions for the future. I would rather say that science fiction draws its nourishment from the imagination and problems of a given period. There are always examples of science fiction anticipating certain instances of warfare while other predictions were just plain wrong.