Trier, Saarbrücken, 22.1.2021

Early Warning and Decision Support Systems for defence

Karl-Hans Bläsius, Jörg Siekmann

https://www.hochschule-trier.de/informatik/blaesius/ , http://siekmann.dfki.de/de/home/

Link to this document: www.fwes.info/fwes-21-1-en.pdf

German Version: www.fwes.info/fwes-21-1.pdf

See also: www.unintended-nuclear-war.eu

Summery

The risk of an accidental nuclear war has increased greatly in recent years. Developments in computer science and artificial intelligence (AI) contribute to the potential danger, since early warning and decision support systems (EWDS) are based on very complex computer systems and networks for predicting and evaluating possible attacks by nuclear missiles. This may involve false alarms caused by sensors, hardware or software failures. Errors in the interpretation, processing, or routing of data can lead to a false attack message and thus to a very critical situation. In particular, an EWDS may contain AI-based functions that automatically make decisions for certain subtasks, which can be wrong. Cyberattacks can also have dangerous and incalculable interactions with early warning and decision-making systems, significantly increasing the risk of a nuclear war by accident.

Climate change is likely to make entire regions uninhabitable, leading to increased climate refugees causing political crises. In such a tense situation, it is easy to make incorrect assessments, as these always depend on the political situation.

Some of the content of this article is based on earlier publications on this topic ([BS85] and [BS87]).

1 Nuclear Threats

Ever since the first use of an atomic bomb in Hiroshima, there has been a fear of nuclear war with devastating consequences. In particular, the U.S. and Russia have accumulated such a huge arsenal of nuclear weapons that an extensive use of these weapons could lead to the extinction of mankind. Moreover, other countries also possess nuclear weapons, and the danger of a nuclear war has therefore increased significantly.

In the event of a massive attack with nuclear weapons, there is the danger that its own missile silos and possibly also the military and political leadership will be hit and eliminated. A counter-reaction would be difficult or impossible. For this reason, there have been repeated threats to launch one's own missiles before the impact of the enemy missiles. Such a strategy is called "launch on warning" or "launch under attack". In the catchphrase: “Whoever shoots first dies second”.

The prerequisite is that a nuclear attack is recognized as early as possible, and hence huge early warning systems have been built for this. However, the reaction times in the event of an attack report are extremely short, because intercontinental missiles can hit the enemy after a flight time of less than 30 minutes, submarine-launched missiles in even shorter periods. Thus, in the event of an attack being detected by an early warning system, there are only a few minutes to decide on a counterattack, as waiting until impact may result in no counter-reaction being possible.

There have also been threats that if an attack is detected by an early warning system, a counterattack will be triggered by a computer decision. At least for certain subtasks, decisions are made by software components. Therefore, instead of the term "early warning system", the term "early warning and decision support system" (EWDS) is often used. For simplicity just the term EWDS or “early warning system” is used in the following.

The mutual threats of nuclear weapons between NATO and the Eastern Bloc countries were particularly intense in the 1980s. On the basis of the "NATO Double Decision treaty", new medium-range missiles were deployed, which led to political protests and large demonstrations, which made the peace movement strong and influential. It contributed successfully to the disarmament negotiations and détente in the mid-1980s. In 1987, the INF Treaty (INF stands for Intermediate Range Nuclear Forces) was set up and signed by Reagan for the United States and Gorbachev for the Soviet Union. The treaty prohibited the construction and possession of land-based intermediate-range nuclear missiles within a range of 500 and 5500 km and the existing ones were destroyed. This process was completed in 1991. New intermediate-range missiles were no longer allowed to be produced and tested. This and other disarmament agreements between the U.S. and the Soviet Union led to a reduction of their nuclear weapons from 70,000 to 15,000.

However, the INF Treaty of 1987 and other peacekeeping treaties such as the Open Skies Treaty have since been terminated and a new arms race has begun. The risks of a nuclear conflict are as great today as they were during the Cold War, and there is some evidence that the risks are even higher today (see Chapter 8).

In the following chapters, we focus primarily on the influence of computer science and AI on the risk of a nuclear war by accident.

2 Early Warning and Decision Support Systems

Early warning systems are a central component of defence for nuclear powers and they have been further developed in recent years, including Russia, China and other states.

The structure and functioning of the American early warning systems have become known through various investigative reports and publications. The main command centre of the U.S. early warning system is NORAD (North American Aerospace Defence Command), a joint U.S.-Canada facility whose operations began as early as 1957. NORAD is based on a complex computer system that contained about ten million lines of code as early as 1983.

Major components of a missile warning system include:

- Sensors to detect a nuclear attack,
- Computer centres and communication networks for analysing and transmitting data,
- Command centres to assess warning information and to plan and order countermeasures.

The Defence Support Program (DSP) of the US, which uses satellites with infrared telescopes, is an important basis for detecting missile launches. The satellites also have sensors to detect nuclear explosions. Radar stations have been built to observe and calculate trajectories, and acoustic sensors are distributed over the strategically important areas of the world's oceans to detect the movements of submarines.

The data from the sensors are processed in highly complex, redundant computer networks, detailed descriptions can be found in [BS87] and [Sch13].

3 Errors of early Warning Systems

At the beginning of the 1980s some reports about false alarms of early warning systems became known to the public and stoked fears of a nuclear war by accident from computer errors, because some of these cases led to critical situations. As a result, the U.S. Senate formed an investigative committee whose report by Gary Hart and Barry Goldwater ([HG80]), among other documents, was released to the public. (e.g. [GAO81]). Although much has changed till now, the essence of the danger potential of early warning systems is still there today.

3.1 Potential Errors

Errors occur in highly complex systems and it is impossible to implement a large system without errors. However, errors in early warning systems can mean that an attack with nuclear missiles is reported although there is no real threat, and such an error can lead to dangerous situations and possibly even to a nuclear war.

Some possible types of errors are described below:

- Errors from sensor data
- Computer errors
- Human mistakes

Errors from sensor data:

The starting point for the detection of a missile attack are the sensor data and its automatic interpretation. Examples are:

- The airspace is used for civil and military purposes and thus contains a large variety of different objects that must be correctly classified. Especially with new, previously unknown objects, there is the danger for misinterpretation. Even flocks of birds have led to errors in early warning systems.
- The detection of certain objects may depend on the current light conditions. Unusual constellations of solar radiation can be misinterpreted and have already led to false alarms.
- In certain weather situations, radar beams can be deflected and lead to false sensor data.

Computer Errors:

When operating an early warning system, the failure of a computer system is rather uncritical, since sufficient redundancies are implemented. Critical is a situation where incorrect data is transmitted to a computer leading to incorrect conclusions regarding a threat. This can be caused by hardware, software or specification errors.

Hardware errors have been reported, for example, due to local overheating or errors during maintenance and repair. More common, however, are software errors, the probability of which can be reduced by various methods and tests. Sometimes several systems have been implemented in parallel checking the results for consistency. This has also been done for early warning systems. However, such approaches must be based on a uniform specification, which again may contain errors and the same is true for program verification. According to today's state of the art it is not possible to realize large scale error-free software.

An important method in software development is testing, but early warning and decision support systems cannot be tested under real conditions. In particular, it is not possible to predict how an early warning and decision support system will behave in conflict and crisis situations.

Human errors:

When an early warning system reports an attack, this must be examined and evaluated within a few minutes and the potentially far-reaching decisions can cause enormous stress in such a situation and the risk of mistakes is high. Besides the risk of human error due to an overload of stress and time constraints, there are also risks due to negligence, mental disorders or sabotage. Dumas reports in [Dum80] that in the period 1975 to 1977, about 5,000 persons were discharged annually from the nuclear forces, for alcohol or drug abuse, mental disorders, abnormal behaviour, or other misconduct.

For example, the Germanwings airplane crash on March 24, 2015, which was intentionally caused by the co-pilot, shows how the mental disorder of an individual can lead to serious consequences. In a highly complex system, such as an early warning system, many people are required for system maintenance and repair. This entire group of individuals is potentially capable of deliberate tampering or sabotage. In Chapter 15, "Nuclear Command and Control," of [And20], a computer science textbook on IT security, Ross Anderson describes in detail the communication, authentication, and control issues associated with nuclear weapons systems. He also provides some examples of human error hazards and analyses how an attack on a communication channel could result in an unauthorized deployment order.

3.2 Documented False Alarms in 1979 - 1980

In the Hart and Goldwater report to the Senate, a total of 147 cases of indications of a threat to the U.S. that triggered Alert Level 1 (called Missile Display Conference), out of three possible alert levels were reported for the period 1/1/1979 to 6/30/1980. The following five cases led to the second Alert Level (called Threat Assessment Conference):

- 3.10.1979: A radar responsible for detecting submarine-launched missiles detected a missile in low orbit, causing a false alarm and a hit report.
- 9.11.1979: A mass nuclear missile attack was reported, the cause of which was a simulation program for testing system components that was activated in NORAD's missile warning system without informing the operators.
- 15.3.1980: Four missiles were launched from submarines during Soviet exercises. One of these missiles developed a trajectory that appeared to yield a target in the United States.
- 3.6.1980 und 6.6.1980: A mass missile attack on the US was reported. The reason was a defective chip in a communication unit, which permanently sent data, where normally zeros must be at certain positions. As a result of the hardware error, other values were sent at these points, and thus attacking missiles were reported.

Based on the error analyses of these incidents, enormous efforts were made to eliminate the defects that had occurred. The measures taken are described in [GAO81], but the authors also conclude that no system can be implemented that takes all special cases into account. Therefore, it will always happen that faulty indications of rocket launches are reported.

3.3 Measures in case of false alarms

In their report to the Senate, Senators Hart and Goldwater also describe what actions are taken in response to alerts ([HG80]). If there are indications of a real threat, various command units start an official conference procedure to assess the situation. There are three stages in total. The first stage regularly deals with unclear data coming from sensors. For example, if an infrared signal is detected, it is compared with the infrared signals assigned to earlier enemy missiles. But since there are always changes in missile technology, as well as changes in other physical phenomena in the atmosphere or on the earth's surface, there must be continuous adjustments to the settings for the detection of missile launches in order to classify sources correctly. In 1979, there were 1,544 routine "Missile Display Conferences" to evaluate unclear sensor signals and in 78 of these conferences, indications of a threat were deemed possible. Hart and Goldwater describe similar results for 1980.

The five alerts quoted above led to Alert Level 2, the so-called "Threat Assessment Conference." At Alert Level 2 the Air Command Post in Hawaii will take off, so that they can assume key command functions in case the command posts on the ground are hit and taken out.

At Alert Level 3, the U.S. president will be called and involved in the decision-making process.

The sequence of events for the first two alert levels will be illustrated using the alert from 3.6.1980:

On 6/3/1980, the screens at a command post indicate a launch of two submarine based missiles toward the United States, and 18 seconds later, the systems indicate a further growing number of submarine-launched missiles. Command post personnel call the NORAD command post, but there was no indication of missile launches there. Nevertheless, standby pilots are ordered to get into their planes and start their engines in preparation for launch. Shortly afterwards the signs of imminent submarine missiles have disappeared, and the aircrews are instructed to switch off the engines but remain in the aircraft. Shortly thereafter, however, the screens show that Soviet intercontinental ballistic missiles have been launched toward the United States and after a brief pause, there are again indications that submarine-launched missiles have been fired toward the United States.

Checks reveal that the alerts are coming from miscalculations of the computer systems and not from the sensors, but because of the ambiguity, a "Threat Assessment Conference" is convened anyway. As a standard response to this second alert, the Air Command Centre in Hawaii prepares to launch, and as the alert continues, the Air Command Centre takes off. The commander of NORAD later confirms that there is no threat, and the alert levels are terminated. The crews return to their quarters.

3.4 Other alerts

Some further alarm messages are listed here as examples:

- 5.10.1960: An American radar reports dozens of missiles heading for the USA, which leads to a high alert level. Since the Soviet president is in New York at this time, this message seems very unlikely and it is declared as a false alarm. The cause of the alarm is a misinterpretation of the rising moon over Norway by a radar system.
- 28.10.1962: During the Cuban Missile Crisis there are two false warnings of nuclear attacks on this day, each of which is quickly recognized as false.
- 23.5.1967: U.S. radar systems for detecting missile attacks show intense signals that are interpreted as intentional interference and thus as an act of war. Aircraft loaded

with nuclear weapons are put on alert. The reason for the disturbance was a solar storm (a very strong eruption).[1]

- 26.9.1983: A satellite of the Russian early warning system reports five attacking intercontinental missiles. Since the correct operation of the satellite was established, the Russian officer on duty, Stanislav Petrov, should have passed on the warning message according to his regulations. However, he considers an attack by the Americans with only five missiles unlikely and therefore decides that it must be a false alarm before this could be verified. The incident occurred during a volatile political situation: medium-range missile rearmament was pending, and a few weeks earlier the Soviets had shot down a Korean passenger plane over international waters. Later it turned out that the false alarm, which almost triggered a nuclear war, was caused by special reflections of the sun. For his decision not to pass on the alert, Petrov has become quite famous and he is referred to in the Western press as "the man who saved the world". He received the German Media Prize in February 2012 and the Dresden Prize in February 2013.[2] He received the World Citizen Award by the United Nations as well as an award from the Future of Life Institute in October 2018.[3] Petrov died in May 2017.
- 2. - 11.11.1983: A NATO exercise simulating a nuclear attack on the Soviet Union is interpreted by the Soviets as the preparation for an attack. The Soviets set nuclear missiles on alert and prepared them for launch and only later did the Americans realize how dangerous this situation was. This incident is covered in the documentary "The Brink of Apocalypse" and was probably one of the most dangerous situations since World War II.[4]
- 25.1.1995: The launch of a Norwegian research rocket leads to an attack message in the Russian early warning system. Although the Norwegians had informed Russia about the launch of the research rocket, this information was not passed on correctly and the Russian army went on high alert. Russian President Boris Yeltsin activated the nuclear suitcase and provided launch codes in preparation for a retaliatory strike.[5]
- 14.2.2017: A missile warning is issued at the U.S. base at Spangdahlem in the Eifel, a region of Germany, with the request to seek shelter immediately. A missile message

---

1 Süddeutsche Zeitung from 12.8.2016, page 14

2 https://de.wikipedia.org/wiki/Stanislaw_Jewgrafowitsch_Petrow and http://www.faz.net/aktuell/gesellschaft/menschen/offizier-petrow-im-gespraech-der-rote-knopf-hat-nie-funktioniert-12084911.html

3 https://futureoflife.org/2018/09/26/50000-award-to-stanislav-petrov-for-helping-avert-wwiii-but-us-denies-visa

4 https://docuwiki.net/index.php?title=1983:_The_Brink_of_Apocalypse

5 [Sch13], page 539

sent for test purposes accidentally appears on all screens. After eight minutes the all-clear is given.[6]

- 13.1.2018: In Hawaii, a warning is issued of an attack by an intercontinental ballistic missile and the emergency notification is sent to the entire population via mobile phones. There are conflicting reports about the causes. First, it is said that an employee of the Civil Protection had accidentally pressed a wrong button. A few days later, there is information that the person responsible for the alarm actually believed in an attack on the USA. Due to the mutual nuclear threats between North Korea and the USA, this action could also have been understood by North Korea to mean that the USA was planning an attack on North Korea and wanted to protect its citizens from the expected North Korean counterattack.[7]
- 12.12.2020: In Germany at the U.S. military base in Ramstein, the warning message system informs personnel of a real missile launch and the message is also transmitted via a loudspeaker system. After a few minutes, the missile launch is classified as part of an exercise and the alert is terminated. Four intercontinental ballistic missiles were launched from a Russian submarine, this was detected by a satellite of the American early warning system which triggered the alarm, although the Russian exercise was announced. Why the alarm was triggered is unknown.[8]

3.5 Risks of large-scale technology

Catastrophic failures have often occurred in large-scale plants, even though previous safety analyses and risk assessments said that this was impossible. A failure analysis then finds usually that several events led to a chain of unlikely coincidences and finally to a serious accident. Such risks of large-scale engineering are described in [Per92] and [Sch16]. Some examples of such accidents are given below.

---

6 Trierischer Volksfreund, 17.2.2017

7 Süddeutsche Zeitung 15.1.2018, page 3 - 4, and 31.1.2018, page 7

8 https://edition.cnn.com/2020/12/14/politics/russia-missile-drill-false-alarm-us-base/index.html and https://www.independent.co.uk/news/world/americas/us-ramstein-air-base-missile-alert-b1774453.html

The 1979 accident at the Three Mile Island (Harrisburg) nuclear power plant began with an equipment failure and subsequent operator errors led to the known serious consequences. Previous safety analyses certified that such an accident could not practically occur.[9]

On September 19, 1980, a nuclear missile exploded in Damascus, Arkansas (USA). The cause was a dropped screw nut by a maintenance technician. Mounted on the missile was a nuclear warhead that was thrown more than 200 meters, but fortunately did not explode. This incident is described in great detail in [Sch13], alongside with many other serious accidents related to nuclear weapons, which even led to a few deaths. In addition, many (about 50) nuclear weapons are considered missing, some have sunk into the sea. Officially, the US is missing eleven nuclear weapons.

On December 3, 1984, a chemical disaster occurred in Bhopal, India, with several thousand deaths. The catastrophe was triggered by an unfortunate chain of events during cleaning work.[10]

The Chernobyl disaster in 1986 was caused by serious violations of safety regulations by operators during an experiment simulating a total power failure.[11]

3.6 Large-scale technology with adversaries

Early warning systems are highly complex systems too, which are difficult to control and a momentous "accident" is possible, in particular if there is a random coincidence of unpredictable events and chain reactions. This can lead to an accidental nuclear attack.

Compared to other large-scale technical systems, there is another difficulty with early warning systems: there are "opponents", whose actions are directed against the control of such a system. Similar to any competition, the actions of an opponent are difficult to predict and cannot be controlled. As in any competition, for early warning systems too, it is uncertain whether every side will always remain in control. Here, however, if one side loses control, everyone loses, everyone is affected.

9 [Per92], page 33-55

10 https://de.wikipedia.org/wiki/Katastrophe_von_Bhopal

11 https://de.wikipedia.org/wiki/Nuklearkatastrophe_von_Tschernobyl

4 Evaluation of alarm messages

4.1 Incomplete information - false assumptions

In case of an alarm, the available information has to be evaluated and the documented false alarms show that the data displayed in early warning systems are uncertain, i.e., they may be wrong. In particular, the available information is usually not a complete description of a given situation, but important information can be missing, i.e., for the evaluation of a threat situation assumptions have to be made, which are also uncertain, i.e., can also be wrong.

The dangers that can arise from incomplete information and incorrect assumptions are described in [TSB20], and Section 2.2.3 of this article also discusses such a critical situation during the Cuban Missile Crisis in 1962, in which the Russian officer Vasily Archipov refused to consent to the launch of a nuclear weapon, possibly preventing a nuclear war.[12]

4.2 Unusual Errors

Unclear sensor signals or reports of unknown objects based on sensor data occur very frequently and are usually handled correctly by operators. Due to the frequency of such events, there is sufficient experience on which the personnel can rely.

Much more difficult are situations that occur rarely or have never occurred in this way before. For example, the false alarm of 3 June 1980 concerning the mass missile attack on the USA led to the second of three alarm levels, although the operators were able to verify very quickly that there was no real threat, because

- there were no missile sensor signals,
- the indications on the screens did not conform to any logical pattern and did not correspond to a sequence of events that would be expected in the event of an attack,
- different command posts received different indications of a threat.

Thus, even if personnel are well-trained and can reasonably handle cases that occur frequently, the risks of incorrect assessment increase for situations that occur infrequently or have never occurred before.

[12] [Teg17], page 168 - 169 and https://de.wikipedia.org/wiki/Wassili_Alexandrowitsch_Archipow

The same is true for technical improvements. Methods for automatically classifying and assessing data will improve over time, possibly including machine learning approaches. However, if the number of alarm messages is significantly reduced in this way, this does not increase safety, because false alarm messages will still occur, albeit less frequently. However, this makes evaluation by operators more difficult, because the rare errors are then unusual or perhaps have never occurred before, making evaluation more difficult. This means that there is even a greater risk that such an alarm message will be classified as serious.

.

4.3 Crisis situations and coincidence of events

In times of peace and relative relaxation, a review of alerts tends to be aimed at identifying them as false alarms. This can change significantly in crisis and conflict situations, as a potential threat is now the primary assumption. Furthermore, in such situations, military-related air traffic will increase, and the flow of information based on sensor data will also increase significantly. Accurate verification of events and alerts may thus become more difficult, and the threshold at which alerts are believed to be genuine will drop significantly.

A study from 2014 shows that, especially since the Ukraine crisis, there has been an increase in dangerous situations in European airspace with near-misses between Russian and NATO aircraft. There was another update to this study in March 2015 in which 67 near-misses were documented.[13] If such a collision coincides with an alert from a FWES, very dangerous situations can arise.

More military activity also increases the likelihood that multiple adverse events will coincide, and causal relationships are often assumed that do not exist.

The danger posed by a coincidental coincidence of several independent events in a political crisis will be explained with an example:[14]

On November 5, 1956, there was the following situation:

- In the dispute over the Suez Canal, England and France intervened militarily against Egypt.
- Hungary was occupied by Soviet troops.
- The Soviet news agency TASS generated fear of a worldwide nuclear war.
- Moscow, which saw itself as Egypt's protective power, sent messages to London and Paris with hints that attacks against those cities would be considered if the Egyptian attack did not cease.

[13] https://www.europeanleadershipnetwork.org/commentary/russia-west-dangerous-brinkmanship-continues/

[14] [Bra83], page 65

- Late in the afternoon of Nov. 5, the White House in Washington receives the message that Moscow is proposing a joint U.S.-Soviet military action in Suez.

Against this background, the following events and news converge the next night:

- Unidentified jet fighters fly over Turkey, and the Turkish Air Force is put on alert.
- 100 Soviet MIG-15s fly over Syria.
- A British Canberra bomber has been shot down over Syria.
- The Russian fleet sails through the Dardanelles into the Mediterranean. This was seen as a sign of hostility, since in times of crisis the Soviet Union must bring its fleet out of the Black Sea, where it was trapped in the two world wars.

The White House reaction is not fully known, but it is reported that General Goodpaster feared that NATO deployment plans might be triggered, which at the time envisioned an all-out nuclear retaliatory strike against the Soviet Union ([Fin64]).

An analysis later revealed the following causes for the four events:

- The jet fighters over Turkey were a flock of swans detected by radar and misinterpreted.
- The 100 Soviet MIGs were a much smaller routine escort for the Syrian president returning from a state visit from Moscow.
- The British Canberra crashed because of technical errors.
- The Russian fleet was on its way to the Mediterranean for a long-planned manoeuvre.

The individual events were relatively harmless when viewed in isolation, but the coincidence in a serious world political crisis led to a very threatening situation. If, in such a situation, nuclear missiles had been reported by an early warning system instead of MIGs over Turkey, the risk of a worldwide catastrophe would have been much higher.

4.4 Alarm chains

According to some historians, World War I was actually unintentional, and the Sarajevo assassination was not the sole reason for the outbreak of war, because states felt threatened by each other's highly equipped armies. There was an international treaty system between the various states, but this was so confusing that the decisions to mobilize caused the creation of a chain reaction of ever-increasing levels of alert. The war systems terrified each other and political leaders finally lost control.

The danger posed by an alert has often led to decision-making conflicts in crisis situations and cautious action to prevent escalation. For example, during the Soviet invasion of Czechoslovakia, NATO cancelled all routine reconnaissance flights over West Germany so as

not to give the impression that NATO was increasing military activity or moving to a state of alert.

Early warning and decision-making systems also run the risk of creating alert chains. In the false alarm of 3 June 1980, which was caused by a hardware failure, the second alert level was set, bomber crews had to get on the planes and start the engines, and the air command post in Hawaii was launched. Such activities are recognized by the enemy and can lead to increased alertness in conflict situations there as well, and this again has repercussions on the own assessment of the situation. In crisis situations with mutual threats and events that are classified as hostile, a false alarm regarding attacking nuclear missiles can thus set off a chain reaction with ever higher alert levels within minutes, which gets out of control.

The enemy early warning systems themselves are also monitored, and the systems can then interfere with each other. The nuclear forces with the warning and information systems must then be viewed as a mutually influencing complex system that can be described by chaos-theoretic methods but with uncertain behaviour in times of crisis and conflict. It is questionable whether such a system as a whole, in which all relevant processes occur within a few minutes, can be controlled and mastered.

4.5 Trust

In the first issue of “Die Zeit” after the election of the American president in November 2016, an article appeared with the headline "Countdown to hell - How does a president decide on nuclear war?".[15] In this, it is made clear that in the event of an attack notification by an early warning system, the president has only a few minutes to decide on a response. What attitude would the then elected American president Donald Trump have in such a situation? How would he react?

A serious decision in such situations may depend on one individual, including his current state of mind or character traits and attitudes. For example, the commander of a Russian submarine wanted to launch a nuclear weapon during the Cuban Missile Crisis, but another officer prevented this with his objection (see Section 2.2.3 of [TSB20]). Richard Nixon was mentally unstable and alcoholic during his tenure as U.S. president, and at the end of his term, the then Minister of Defence Schlesinger told the military commanders urgently to ignore instructions from Nixon regarding the use of nuclear weapons.[16]

An important feature of responsible political action is also to consider what consequences one's own activities may cause to potential adversaries and what assumptions adversaries

[15] Die Zeit, No. 47, 10.11.2016, Page 4

[16] https://www.independent.co.uk/news/world/americas/us-military-was-told-to-ignore-drugged-nixon-711339.html

may infer from them. Bob Woodward describes in [Woo18] that the former American president Donald Trump lacks awareness of this. As an example, he cites that Trump was just prevented from sending a Twitter message announcing the withdrawal of U.S. troop members from South Korea. "Taking the U.S. civilians to safety" would have been interpreted by North Korea as preparation for an attack.[17]

If there is a person of unstable character among the heads of state of the nuclear powers who is trusted to make a decision to launch a nuclear strike, then there is a danger of a fatal decision on all sides. For the adversary, when announcing an attack, must also consider whether he trusts the other, whose character traits he knows, to make such an attack in the current situation. So, for example, if there is a missile attack warning in the Russian early warning system, then the Russian president must also ask himself whether he trusts the American president to issue such an attack order. If the answer is "yes," that makes an immediate counter-reaction, i.e., a "launch on warning," more likely.

Lahl and Varwick emphasize in [LV19] that rational behaviour in political decision-making must be an indispensable principle for the idea of deterrence, but that it is difficult to ensure this from all sides all the time.[18]

4.6 Expectation

On January 3, 2020, the Iranian General Soleimani was killed by an American drone strike. In response, Iranian missile strikes on U.S. positions in Iraq occurred on January 7. Just hours later, in the early morning of January 8, Iranian air Defences shot down a Ukrainian airliner shortly after take off from Tehran.

Thus, expectation also plays a large role in human assessment of an alert, as the accidental shooting down of the Ukrainian airliner in Iran demonstrated what can happen in a crisis situation. Because of the attacks on U.S. positions in Iraq, a backlash or even war was expected, and it seemed plausible that the radar signal was an attack with a cruise missile. Before issuing the launch order, the commander should have obtained permission from his superior, but no communication was established.[19]

Even in early warning systems for nuclear missiles, the assessment of an alert may depend on whether an attack is expected or at least seems plausible based on the current political situation.

---

17 [Woo18], page 388 - 391 and „die Zeit“ No. 41, 4.10.2018, page 7

18 [LV19], page 120

19 Süddeutsche Zeitung from 13.1.2020, page 2

5 Cyberattacks - AI applications

5.1 Cyberattacks

Cyberattacks will also have an impact on early warning and decision support systems (EWDS), as cyberattacks can target them, crippling subcomponents, disrupting communications, tapping information, or sending specific signals. For example, allegations from the U.S. that Russia influenced the 2016 U.S. election campaign prompted a backlash of threats that U.S. entities were capable of attacking Russian command and control systems with cyberattacks.[20]

The following scenarios are conceivable due to cyberattacks:

1. coincidence of an attack message in an EWDS with a cyberattack,
2. transmission of false data to an EWDS,
3. manipulate components of an EWDS,
4. weakening an adversary's command and control,
5. disabling an adversary's nuclear missiles,
6. gaining control of adversary nuclear missiles.

The first point relates to the arguments of Section 4.3. The assessment of an alert of a possible attack by adversary nuclear missiles in an EWDS depends to a large extent on the context. In a crisis situation, if an alert coincides with other threatening events, an alert is more likely to be taken seriously and accepted as true. Such an event could be a cyberattack on the country's infrastructure.

The coincidence in time of a cyberattack with a missile alert can be quite dangerous, because the new U.S. military strategy states that a serious cyberattack can also be met with a nuclear counterstrike (see Section 8.4). In case of a cyberattack, it is usually very difficult to determine the originator and, together with a missile warning, the same attacker would probably be inferred.

The other points mentioned above are discussed in detail in [AS16] and [Sha18]. The authors describe the importance of developing cyberweapons for nuclear forces, and that the U.S. in particular has been working intensively on developing such weapons for several years.

In cyberspace, offensive tools are more readily available than purely defensive weapons, and this could favour the offensive and encourage preventive measures. For example, senior U.S. military officers have considered using cyberattacks to disable or destroy enemy nuclear missiles[21] and such measures have apparently been implemented against North Korea.

[20] [AS16], page 692

[21] [AS16], page 691

Under former President Obama, hackers reportedly manipulated missile launches that may have contributed to the failure of a few missile tests by North Korea.[22]

In 2015, a commission released a report urging the U.S. and Russia to put their nuclear missiles on lower alert, since otherwise launch-ready missiles waiting only for a specific signal to launch could be mistakenly launched by cyberattacks.[23] U.S. General James Cartwright, who was project leader in the development of the Stuxnet computer worm and commander of the U.S. nuclear forces from 2004 to 2007[24], warned that cyberattacks could lead to false alarms.[25] Such attacks do not have to originate with states, but can have other perpetrators that usually cannot be detected. Terrorist organizations such as Al Qaeda could also conduct cyberattacks against early warning systems or nuclear forces. For example, in 2015, the IS had declared cyber war on the U.S. and captured highly sensitive information in an attack on the Pentagon.[26]

In [AS16] and [Sha18], the authors see the danger that the previous nuclear balance of power, which is based on deterrence, i.e. assured mutual destruction, can be significantly disrupted by cyberattacks. If the enemy's nuclear missiles can be rendered harmless by cyberattacks, the principle of second-strike capability no longer applies. The authors fear that this could significantly reduce the threshold for the use of nuclear weapons, for example on the basis of false data sent in a cyberattack by a terrorist organization. The authors therefore call for urgent agreements between the major powers to avoid dangerous cyberattacks that could lead to a nuclear backlash.

Also, [And20] and [SW19] warn against a destabilizing effect of cyber warfare capabilities as well as advanced AI solutions. Capabilities not known to the adversary, for example for surveillance and reconnaissance, could be interpreted as superiority over the adversary and thus undermine the principle of deterrence.

Cyberwarfare capabilities can also be effectively combined with electronic warfare. In September 2007, Israel attacked a North Korean-backed nuclear weapons facility in Syria and used an airborne electronic attack platform to support the attack. Using a combination of cyber and electronic warfare, Israel has taken control of Syria's air and missile defence system to protect its own aircraft.[27]

---

22 Zeit Online, 5.3.2017 and [AS16], page 695

23 [AS16], page 695

24 https://de.wikipedia.org/wiki/James_E._Cartwright

25 https://futureoflife.org/background/nuclear-close-calls-a-timeline/?cn-reloaded=1, Description of the alarm message from 19.6.2016

26 FIfF-Kommunikation, No. 4, 2016, page 72

27 [SB20], page 114

5.2 Fake news - deepfake

In times of war, propaganda and fake news play a major role. In the future, fake news may also have incalculable effects on early warning systems and influence the assessment of alerts. In December 2016, the former Israeli Defence minister was quoted in a fake online article as saying that Israel would nuclear destroy Pakistan if Pakistan sent troops to Syria against the IS. The Pakistani Defence minister had failed to recognize the forgery and in turn threatened to use nuclear weapons.[28]

If hackers manage to intervene in a conference to assess an alert and connect with a "fake" president in the process, they can make him speak whatever they want. For example, Adobe's Voco program could be used for this, which allows a specific person's pronunciation to be used to speak any text. Or the hackers could use a system like Face2Face to have the president say whatever they want in a video. Anything can be falsified with these "deepfake" technical capabilities.[29] Exploitation of such capabilities by hackers (e.g., terrorist organizations) can make political action in crisis situations very difficult, because the very fact that operating teams know at some point that everything (e.g., sound and video recordings) may be faked can lead to great uncertainty in assessing crisis situations.

A Sipri report in 2019 describes the risk that, in the context of an information war, fake naturalistic mock orders in the form of audio or video sequences could mislead nuclear weapon operators into launching a nuclear weapon or not responding to an attack.[30]

5.3 AI-based decisions

With new technical capabilities, the variety of sensor data used to detect a missile attack will grow and the variety of object types to detect will also grow. The end of the Intermediate Range Nuclear Forces (INF) treaty led to a new arms race, including hypersonic missiles that significantly reduce warning time. As a result, there is so little time for human analysis that artificial intelligence (AI) systems will increasingly be used for this purpose. The importance of AI for military applications, as well as potential and possible dangers, are currently described by various authors (see e.g. [Bou19], [SW19], [SB20]). For example, the U.S. is building a nuclear-capable bomber that will be optionally manned but can also autonomously deliver nuclear weapons to a target.[31]

---

[28] Süddeutsche Zeitung from 27.12.2016, page 7

[29] https://de.wikipedia.org/wiki/Deepfake

[30] [Bou19], page 61

[31] [Bou19], page 58

Sharikov describes in [Sha18] the dangers posed by AI developments, especially in the context of nuclear forces. He emphasizes that the U.S., Russia, and China, in particular, are strongly pushing the development of AI techniques for military applications, and he fears that in crisis situations, when decisions must be made in very short periods of time, they may be shifted to AI systems and lead to unpredictable escalation.

The Russian Military Encyclopaedia contains a description of tasks for AI applications: Expert systems for diagnose are to be developed for the missile forces with the goal of automated information systems and decision support systems.[32]

In addition to decision support, intelligent data analysis in reconnaissance and automatic threat detection are mentioned as possible fields of application for AI systems (see [Kre19]). However, automatically generated detection results are always uncertain; they are only valid with a certain probability and may be wrong.

The use of artificial intelligence systems and the associated problems are discussed in more detail in [TSB20].

5.4 AI-based predictions of crises and wars

In March 2018, the German Armed Forces launched a project called "Preview" with the goal of using AI methods to predict crises and wars. For this purpose, large amounts of data are to be analysed automatically (see also Section 2.4 in [TSB20]). Although there is currently no evidence of a connection with early warning systems and the project has other objectives, such a connection may come up in 5 or 10 years. If an early warning system reports a missile attack that needs to be assessed, it is quite possible that the assessment team will also have access to such a system for war prediction. If this AI system predicts a war in such a situation, this can have a considerable influence on the assessment of the alert. In such a situation, an AI system will also be more likely to predict war, and the already critical situation can thus be intensified. The members of an evaluation commission may find it difficult to resist such predictions, as decision makers would rather aspire to share their existential responsibility with an AI system that has the nimbus of omniscience and infallibility.

Thus, one may ask, how would Stanislav Petrov have acted in 1983 if he had access to an AI system that predicted war? Perhaps things would have turned out differently.

[32] [Sha18}, page 372

6 Launch on warning

The "deterrence doctrine" states that the outbreak of nuclear war is prevented by having a second-strike capability. Whoever is attacked can wait for the impact of nuclear weapons and still has enough time and potential to launch a devastating counterstrike afterwards. In the catchphrase: “Whoever shoots first dies second”. This presupposes, among other things, that the military infra- and communication structure remains functional in essential parts. As long as there is consensus on a second-strike capability, a "launch on impact" strategy could be pursued, and the risk that an error in an early warning system could lead to an accidental nuclear war is much lower. However, there may be erroneous hit reports, as in the false alarm on Oct. 3, 1979 (see Section 3.2). False hit reports could also be triggered by communication errors, cyberattacks, or in situations comparable to that of 9/11/1979 (see Section 3.2).

6.1 Second-strike capability at risk

The retrofit of the military carried out in the 1980s endangered the second-strike capability because the Pershing II and Cruise missile medium-range missiles had automatic targeting based on cameras and automatic image recognition. This made it possible to achieve a hit accuracy of 10 to 50 meters, and this targeting accuracy meant that missile silos and command centres could be hit and taken out with a much higher probability.

Subsequently, there were indications from both sides that a "launch on warning" strategy may also be employed if necessary. When questioned by senators, the U.S. Secretary of Defence left this question open and refused to testify when asked. [33] The Soviets viewed the medium-range missile threat as so threatening that a transition to a "launch on warning" strategy was announced and that the launch of nuclear missiles would be accomplished largely fully automatically by computers. Any possibility of human intervention would be eliminated.[34] Also, in a July 12, 1982, Pravda article, the Russian defence minister had threatened a transition to the "launch on warning" strategy. In the months that followed, there were conflicting reports as to whether a "launch on warning" or "launch on impact" strategy was in effect.

[33] [BS87], page 36 and Halloran: Shift of Strategy on Missile Attack Hinted by Weinberger and Vessey, New York Times, 6. Mai 1983

[34] Washington Post, 11. April 1982

In any case, Russia has a system of nuclear weapons in deep underground bunkers in the Urals that could deliver a semi-automatic nuclear counterstrike if the political and military leadership in Moscow is eliminated.[35]

Meanwhile, China is discussing putting its nuclear missiles on alert mode, so that they can be launched if the early warning system detects an attack.[36]

Most recently, there have been growing fears [Sha18] that new pinpoint U.S. nuclear missiles combined with an effective missile defence system could enable the United States to destroy Russian or Chinese nuclear forces in a first strike without fear of their second strike capability. Even advanced hypersonic weapons that are not necessarily nuclear-armed could decisively weaken an adversary's nuclear forces and threaten their second-strike capability. A lack of second-strike capability, on the other hand, would significantly increase the risk of a transition to a "launch on warning" strategy.[37]

6.2 Situational aspects

It cannot be said exactly which of these strategies currently applies, because this information is subject to secrecy and corresponding threats can also serve propaganda purposes. In any case, when a missile attack is reported by an early warning system, an evaluation process is started in which there will probably be neither a strict "launch on warning" nor a strict "launch on impact." Instead, the decision will depend on the given situation. The deciding factor will be,

- how strong the threat is perceived to be,
- what the current political world situation is,
- whether there is a crisis situation,
- whether there are already other hostile incidents, and
- what is the state of the participants of the conference.

For many subtasks of an early warning system (usually detection tasks), there are already AI-based solutions that provide results with some probability, and as the available data (sensor data) will increase and the available time will decrease, more and more such subtasks will need to be solved automatically. In the short time available, no assessment by humans is possible and if there is a missile attack notification in times of crisis with mutual threats and "confirming" events (e.g., airplane crash or shootdown, cyberattack) the risk of a fatal wrong decision is high. Even if humans have the final decision, similar to other AI-dominated

[35] [Sha18], page 370

[36] [Kul16]

[37] [Ste17] and https://www.imi-online.de/2016/06/20/atomare-muskelspiele-die-nukleare-offensive-der-nato/

applications (e.g., financial transactions), it will be difficult to decide against the machine's recommendations. It may then no longer be a question of whether a "launch on warning" strategy applies or not.

7 Consequences of a nuclear attack

If the misinterpretation of an early warning and decision support system leads to a nuclear war, this has global consequences and can even threaten mankind as a whole. The direct consequences of nuclear missions will not be discussed here, other sources can be consulted for this purpose (e.g. wikipedia[38]). Only individual specific effects that are relevant in the context of this article will be briefly discussed.

7.1 EMP

An electromagnetic pulse (EMP) is a short duration broadband electromagnetic radiation that can cause electronic components to malfunction or be destroyed. A nuclear weapon explosion at an altitude of 100 km can trigger a "nuclear electromagnetic pulse" and lead to the destruction of electronic components, thus destroying or at least severely limiting the communications infrastructure. The nuclear weapons test on 9/7/1962 over the Pacific Ocean caused damage and partial destruction of supply networks and ships in the affected areas.[39] However, the main military communication lines are "hardened," meaning partially immune to the EMP.

It is often speculated that in a nuclear conflict, the first thing that is attempted is to trigger an EMP by a high-altitude nuclear explosion and damage and partially destroy the enemy's electronics. This can disrupt the operation of early warning and decision support systems and non-hardened communication networks and result in the loss of critical military and civilian infrastructure systems such as power supply.

7.2 Nuclear Winter, Ozone Layer

A large number of nuclear explosions can cause darkness and a cooling of the Earth's atmosphere, leading to a collapse of food production. This effect was first published by Paul Crutzen and John Birks in 1982, and in another study by a group of scientists in 1983, who called it nuclear winter. In the years that followed, there were other studies, each with similar results. However, new model calculations show that these effects were rather underestimated in the 1980s and that the cooling starts already with a use of nuclear weapons to the tune of 100 megatons. The use of several thousand megatons will result in

[38] https://de.wikipedia.org/wiki/Kernwaffe

[39] https://de.wikipedia.org/wiki/Elektromagnetischer_Impuls

severe global cooling over a long period of time and the collapse of global food production.[40] By comparison, the Hiroshima bomb had a yield of 13 kilotons, the largest hydrogen bomb detonated to date had a yield of 57 megatons.

A major nuclear exchange in distant regions (e.g., East Asia) can thus have serious consequences worldwide that affect other parts of the world and ourselves. The German weekly newspaper "Die Zeit" reported in February 2018 that a limited nuclear war, e.g., between India and Pakistan, would result in a prolonged nuclear winter that would cover the entire planet and ruin agriculture worldwide, according to the latest climate research.[41] A new study involving the Potsdam Institute for Climate Impact Research, among others, also confirms these findings.[42]

However, nuclear explosions not only result in global temperature changes, but also cause chemical processes in the atmosphere that lead to a weakening of the ozone layer, which protects against UV rays.[43]

[40] https://de.wikipedia.org/wiki/Nuklearer_Winter

[41] Die Zeit No. 8, 15.2.2018, page 16

[42] https://www.pik-potsdam.de/de/aktuelles/nachrichten/regionaler-atomkrieg-waere-ein-risiko-fuer-die-globale-ernaehrungssicherheit and https://www.pnas.org/content/117/13/7071

[43] https://sciencev1.orf.at/news/151238.html and https://www.pnas.org/content/105/14/5307

8 Current situation

8.1 Doomsday Clock

After the end of World War II, nuclear scientists established the Doomsday Clock to draw attention to the danger of impending nuclear war,[44] and the clock hand is reset once a year in January by nuclear scientists and Nobel laureates. The hand position and the reasons for its setting are published in the Bulletin of the Atomic Scientists. The clock was set at a few minutes to 12, meaning the closer to 12, the greater the current risk is considered to be. The first setting in 1947 was at 7 minutes to 12.

Here are some of the previous settings:

Year	Minutes	Reasons
1947	7	First setting of the clock
1953	2	Development and test of hydrogen bombs
1963	12	Nuclear Test Stop
1984	3	Accelerated arms race
1991	17	Disarmament agreement
1998	9	Nuclear weapons tests by India and Pakistan
2007	5	North Korea tests nuclear weapons, climate change
2015	3	Climate change, nuclear weapons modernization
2018	2	Trump, arms increase, threats to INF treaty
2020	1,66	Worsening political situation, climate change

In 2020, the nuclear war clock was set at 100 seconds to 12, meaning that nuclear scientists and Nobel laureates judged that the risk of nuclear war is currently higher than ever before. The reasons for this are that some nuclear powers are currently modernizing or further expanding their nuclear weapons, that essential treaties on limitation have been cancelled, and that climate change and the consequent deterioration of living conditions in many regions may lead to conflict. In 2021, the hand position was not changed and remained at 100 seconds to twelve.

[44] https://de.wikipedia.org/wiki/Atomkriegsuhr

8.2 Ban on nuclear weapons, Nobel Peace Prize

On 7 July 2017, the UN adopted a ban on nuclear weapons to which 122 states agreed. The treaty prohibits the production, possession and use of nuclear weapons and on 24 October 2020 the 50th state ratified the treaty. Thus, the Treaty on the Prohibition of Nuclear Weapons entered into force on January the 22nd, 2021.

In 2017, the International Campaign for Nuclear Disarmament ICAN received the Nobel Peace Prize, with which the jury rewarded ICAN's efforts to ban nuclear weapons.

However, all nuclear powers boycotted the negotiations and did not sign the nuclear weapons ban. Instead, a new arms race is beginning.

8.3 Termination of treaties - lack of confidence

The most important outcome of the disarmament agreements in the 1980s was the INF Treaty, however, in recent years there have been repeated mutual accusations of violations of this treaty, which ultimately led to its termination by the former U.S. President Donald Trump. On August 2, 2019, the termination took effect.

The U.S. has accused Russia of deploying new missiles in Kaliningrad that are attributable to the INF treaty and, conversely, Russia has accused the U.S. of violating the treaty with a missile defence system in Romania. They say that a system that can launch defensive missiles can also launch nuclear-tipped cruise missiles. Donald Trump's denunciation was also justified by the fact that China also possesses medium-range missiles and must be included in the new treaty negotiations.

In 1992, an "open skies treaty" was signed between 27 countries of NATO and the former Warsaw Pact. This treaty serves to monitor arms control agreements and conflict prevention and management and was an important confidence-building measure. The former U.S. President Trump also terminated the open skies treaty, and the U.S. withdrew from the treaty on Nov. 22, 2020.[45]

In September 2018, for the first time in many years, there was a major exercise with the Bundeswehr and NATO partners on NBC defence (NBC weapons are nuclear, biological, chemical weapons), which was justified by a changed security situation.[46] And in November, the largest NATO manoeuvre since the days of the Cold War followed. In October 2020, the German Armed Forces conducted a secret NATO exercise called "Steadfast Noon," which

---

[45] https://www.auswaertiges-amt.de/de/aussenpolitik/themen/abruestung-ruestungskontrolle/open-skies/203010 and https://www.n-tv.de/politik/USA-haben-Open-Skies-Abkommen-verlassen-article22185141.html

[46] https://www.welt.de/regionales/niedersachsen/article181601456/1300-Soldaten-ueben-ABC-Abwehr.html

included training in the use of nuclear weapons. This exercise also involved the Büchel airbase in Germany, where nuclear weapons are believed to be stored.[47]

The relationship of trust between the nuclear powers is currently worse than it has been for a long time, according to Michael Staack and Gunther Hauser in [SH20]: "Relations between Russia and the Western states are currently worse than they have been since the early 1980s - the time before Mikhail Gorbachev took office in the then Soviet Union (1985). In terms of security policy, the analysis is even more critical. The Cold War was relatively orderly at the time, and both sides were particularly concerned with avoiding the risks of accidental military clashes. Such well-rehearsed mechanisms and self-controls are currently lacking, and the network of confidence and security-building measures and crisis prevention built up within the OSCE framework is not respected or used. Therefore, accidental military escalation has become more likely than it was in the 1980s. New weapons systems with shortened warning times also contribute to this."

In [Sch20], Reiner Schwalb also emphasizes the importance of mutual trust and appropriate means of communication between conflicting parties to prevent uncontrolled escalation in times of crisis, and he suggests ways in which relations between nuclear powers could be improved. Currently, however, the nuclear powers are focusing primarily on improving their own strength with the aim of gaining supremacy over potential adversaries, and agreements on arms control are falling by the wayside. These interrelationships and the resulting dangers are discussed in [Ric20] and [Sta19].

An urgent appeal to improve NATO-Russia relations and de-escalate military risks was signed by 16 former foreign and defence ministers, 27 former generals and admirals, 24 ambassadors and 55 experts from universities and think tanks, among others, and finally released on December 6, 2020.[48]

Security problems have also intensified in East Asia in recent years. Conflicts and threats are recurring, especially between China and the United States. In addition, there are territorial disputes, for example, between China and Japan or between Japan and Russia. There is an enormous potential for escalation in these regions, but no suitable security structures.[49]

According to a November 2019 report by the U.S. National Security Commission on Artificial Intelligence, there is a risk that global strategic stability and nuclear deterrence will be undermined by AI-enabled systems, which can track and attack previously invulnerable military positions. States could thus be tempted to behave more aggressively, which could increase incentives for a first strike.[50] The report also proposes agreements among the U.S.,

---

47 https://www.bundeswehr-journal.de/2019/geheime-atomwaffenuebung-steadfast-noon/ and https://www.friedenskooperative.de/aktuelles/atomkriegsuebung-steadfast-noon-umgehend-stoppen

48 https://www.europeanleadershipnetwork.org/group-statement/nato-russia-military-risk-reduction-in-europe/

49 [Sta20], page 9, 11-13

50 [SW19], page 11

Russia, China, and other nations to seek a ban on the launch of nuclear weapons authorized or triggered by AI systems.[51]

The SIPRI report on the impact of AI on strategic stability and nuclear risks also warns against an increasing use of autonomous or AI-based decision support systems that only appear to provide an exact picture within the short warning time. To maintain some level of stability, it says, there needs to be a mutual exchange between the military about their AI-based capabilities.[52]

8.4 New Military Strategies, New Arms Race

In recent years, the press has repeatedly emphasized that the danger of accidental nuclear war is greater than it was during the Cold War in the 1980s. At that time, the peace movement was very popular and there were large mass demonstrations against further armament. Today, the population seems relatively indifferent to it. Two quotes on this:

- *Die Zeit*, 15.2.2018, page 15-17: „With the end of the Cold War, the fear of nuclear war also faded. But now the fear has returned. The bad thing is: it is justified. ... The missile crisis is here. Only it is not yet perceived by the public."
- *Süddeutsche Zeitung*, 12.6.2018, page 11: „… And yet today there is no longer a public outcry, little indignation, no mass demonstrations. William Perry is one of those who seek an explanation for this indifference. ... Perry says that the governments are no longer getting enough pressure from their populations because the population does not realize how great the danger is. There is a widespread feeling, he says, that the nuclear danger largely disappeared with the end of the Cold War. During the Cold War, Perry said, the bomb at least provided some stability. Today, he said, it is only dangerous." (Perry is a former U.S. Defence Minister.)

Since early 2018, a new military strategy applies to the USA that no longer rules out a first strike with nuclear weapons. This strategy provides that in the event of significant non-nuclear strategic attacks, which may include cyberattacks, the U.S. may retaliate with nuclear weapons.[53] Russian military strategy also does not rule out the use of nuclear weapons at an early stage in the event of war.[54] In October 2018, Putin reiterated in very drastic terms that

---

[51] [SW19], page 46

[52] [Bou19], page 50-51

[53] https://www.handelsblatt.com/politik/international/neue-us-nuklear-doktrin-atomarer-erstschlag-ja-aber-seite-2/3405564-2.html?ticket=ST-2254642-nozcXaSvCEKSTumxR6WW-ap1,

[54] Die Zeit, No. 42, 6.10.2016, page 5, No. 8, 16.2.2017, page 3, and [Ste17]

his country will launch a devastating nuclear counterattack if an enemy attack is detected with reasonable certainty.[55]

In recent years, there have been increasing reports that work is being done in various countries on the expansion and modernisation of nuclear weapons. In connection with early warning systems and nuclear forces, the following aspects are relevant:

- The modernisation and development of new weapon systems, such as hypersonic missiles,
- the incipient space armament and
- the further development of cyber warfare capabilities

The major nuclear powers, such as the United States, Russia, and China, are currently modernizing their nuclear weapons and developing new weapon systems that use hypersonic missiles. These weapon systems are steerable and difficult to detect by early warning systems and due to their high speeds (up to 20 times the speed of sound), they significantly shorten warning times. In addition to the aspects of higher accuracy and shorter warning times, there is also evidence of plans for smaller nuclear weapons that are more likely to be deployed. However, an assumed lower deployment threshold also increases the risk that an alert will be assumed to be valid, since the use of nuclear weapons becomes more likely.[56] Even small nuclear powers continue to rearm; North Korea, for example, probably also has missiles with intercontinental range and is now believed to have nuclear weapons-capable material for 30 to 60 nuclear weapons.[57]

Our societies now depend heavily on space technology, especially satellites to support navigation and communications. Completely incalculable, therefore, are the implications of the planned weaponization of space because even military systems are highly dependent on the functioning of satellite communications. As a consequence, several nations have announced plans to expand their armed forces to include the dimension of space.[58] Already in 2007, China demonstrated such capabilities by shooting down a retired weather satellite with a rocket.[59]

---

55 https://www.welt.de/politik/ausland/article182331422/Wladimir-Putin-Wir-kommen-als-Maertyrer-in-den-Himmel-die-Angreifer-werden-verrecken.html

56 https://www.tagesspiegel.de/politik/hyperschallwaffen-ein-neues-globales-wettruesten-startet/25935958.html, https://www.deutschlandfunk.de/das-neue-atomare-wettruesten-2-6-mini-nukes.676.de.html?dram:article_id=480420 , https://www.faz.net/aktuell/politik/von-trump-zu-biden/mini-nukes-amerika-will-mehr-kleine-atombomben-15430483.html, Süddeutsche Zeitung from 21.3.2020, page 32-33 and [Ric20]

57 [Neu20], page 31

58 https://deutsche-wirtschafts-nachrichten.de/507448/Krieg-der-Sterne-Die-grossen-Maechte-ringen-um-den-Weltraum and https://deutsche-wirtschafts-nachrichten.de/507728/Krieg-der-Sterne-Tei

59 https://www.faz.net/aktuell/politik/china-schiesst-satellit-ab-erfolgreicher-raketentest-im-weltall-1407673.html

Cyber warfare capabilities are also being expanded by many nations, and conflicts such as the one between Iran and the U.S. have recently been regularly accompanied by cyberattacks. The opportunities for disinformation campaigns and information warfare are also increasing, so techniques such as deepfake will be able to lead to a crisis of confidence and any information transmitted to an early warning system could be false. In many cases, this will be undetectable.

The Cold War era was characterized by bipolarity. Two military blocs faced each other, and an assured second-strike capability was the basis of nuclear deterrence theory: any nuclear attack would lead to certain mutual annihilation. Even though there were many dangerous situations that only by luck did not escalate to nuclear war, the deterrence theory prevented military confrontations in Europe. The fact that there were only two nuclear power blocs had facilitated disarmament agreements. Nuclear technology today is characterised by multipolarity, there are now several nuclear powers and agreements and effective control are becoming much more difficult. In addition, access to nuclear technology and weapons-grade material is becoming increasingly easy for states and non-state actors (terrorist organizations).[60] Kersten Lahl and Johannes Varwick write about this in [LV19] (page 121): "The more nuclear actors 'play along', the more sophisticated the technical developments become and the more complex the strategic decision-making field around nuclear missions and threats of use thus becomes, the higher the risk of a lack of international controllability of the category of nuclear weapons becomes."

8.5 Crises due to climate change

Since 2007, when setting the doomsday clock (see Section 8.1) the climate change and progress on international agreements to limit global warming are taken into account. Climate change will cause regions of the world to become uninhabitable, and rising sea levels threaten many regions in Asia in particular the large river deltas where more than 200 million people live.[61]

Extreme heat waves are also causing parts of North Africa and the Middle East to become uninhabitable due to the onset of drought, according to a report released by the Max Planck Society on April 29, 2016. More than 500 million people live there and are already severely affected by climate change.[62]

---

60 [LV19], page 117 - 121

61 http://wiki.bildungsserver.de/klimawandel/index.php/Meeresspiegelanstieg_in_Asien

62 https://www.mpg.de/10479763/klimafluechtlinge-naher-osten-nordafrika-klimawandel

According to a May 2017 report of the "Die Zeit", climate change is already forcing more people to flee their homes than in all wars combined; in 2015 alone, nearly 20 million people had to leave their homes because of the climate.[63]

If people have to leave their homes on a large scale, this will inevitably lead to more political crises, tensions and perhaps even armed conflicts between states. The same applies to the struggle for increasingly scarce resources such as water or raw materials, which are needed by industrialized nations.

[63] Die Zeit No. 22, 24.5.2017, page 29

9 Perspectives

9.1 Early warning systems are complex, dynamic systems - increasing risk

In early warning systems, extensive information has to be processed that is always changing. This concerns both the objects to be detected but also world-political contextual knowledge, including knowledge about technical possibilities and presumed intentions of potential adversaries. The number of adversaries with nuclear weapons is significantly higher today than during the "Cold War" in the 1980s and in addition, the desired space weaponization causes feedback with early warning systems in a variety of ways. If a satellite of an early warning system that is used to detect attacking nuclear missiles fails, this can have various causes, such as:

- technical failure,
- a collision with space debris,
- a cyberattack, or
- by the launch of space weapons.

These aspects must be included in early warning systems, because the last two points can also be the preparation for an attack.

It can therefore be expected that the volume and complexity of information to be processed in early warning systems will increase significantly in the coming years. This will enormously increase the demands on the recognition performance of the technical systems on the one hand and on the competencies of the human assessment personnel on the other.

This means that because of the short time available, more and more artificial intelligence components will have to be used. Because of the uncertain and incomplete data basis, such systems are unreliable, as we have discussed above, and their results cannot be verified by the personal in the very short time available either (see [TSB20]).

9.2 No chance to correct a wrong decision

Often, after multiple uses of a dangerous weapon type, a consensus may emerge that such weapons should be banned. For example, the Chemical Weapons Convention came into force on April 29, 1997, prohibiting the development, production, stockpiling and use of chemical weapons.

A ban on autonomous weapons and killer robots is currently under discussion. Even if such a ban has not yet been achieved and autonomous weapons continue to be produced and

used, an agreement to ban such weapons may still be possible after some time and a certain "experience of use". If, on the other hand, a false alarm occurs in an early warning system in a crisis situation today, and possibly further events reinforce this or alarm chains are set in motion, decisions can be made within a few minutes that lead to a massive nuclear strike. A subsequent realization that this was not actually intended and should have been prevented would come too late.

In the case of weapons such as chemical weapons or autonomous weapons, a subsequent reversal after a deployment is still possible, but not in the case of a global nuclear exchange.

Summary

Nuclear arsenals have become an ever greater risk and de facto they are unmanageable today, which means that confidence-building measures and treaties for de-escalation would be urgently needed. The most important decision would be for the nuclear weapon states to scrap their nuclear weapons and join the Treaty on the Prohibition of Nuclear Weapons (TPNW).

Worldwide organizations such as ICAN[64] and the UN[65] have been calling for this for many years, and Russia, under Gorbachev, has also repeatedly spoken out in this regard. He says in [Gor17], "I still see the danger of nuclear war as long as the last atomic bomb is not abolished. Such a war would be the last in the history of mankind."

Translated with www.DeepL.com/Translator and manually (slightly) corrected.

[64] The **Nobel Peace Prize** 2017 was awarded to the International Campaign to Abolish Nuclear Weapons (**ICAN**) "for its work to draw attention to the catastrophic humanitarian consequences of any use of nuclear weapons and for its ground-breaking efforts to achieve a treaty-based prohibition of such weapons."

[65] The **Treaty on the Prohibition of Nuclear Weapons** (TPNW), or the **Nuclear Weapon Ban Treaty**, is the first legally binding international agreement to comprehensively prohibit nuclear weapons with the ultimate goal being their total elimination. It was adopted on 7 July 2017, opened for signature on 20 September 2017, and has entered into force on 22 January 2021

Literature

Note: All internet links, including those in the notes on the individual pages, were accessed and checked on 22.01.2021.

[And20] Ross Anderson: Security Engineering – A Guide to Building Dependable Distributed Systems, Wiley, 2020

[AS16] Greg Austin & Pavel Sharikov: Pre-emption is victory - aggravated nuclear instability of the information age, The Nonproliferation Review, 23:5-6, 691-704, https://doi.org/10.1080/10736700.2017.1346834, 2016

[BS85] Karl Hans Bläsius, Jörg Siekmann: Computergestützte Frühwarn- und Entscheidungssysteme. in: Bähren, Tatz (Hrsg.): Wissenschaft und Rüstung, S. 163-199, 1985

[BS87] Karl Hans Bläsius, Jörg Siekmann: Computergestützte Frühwarn- und Entscheidungssysteme. Informatik-Spektrum, Band 10, Heft 1, 24-39, 1987

[Bou19] Vincent Boulanin (ed.): The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk. Sipri Report, https://www.sipri.org/sites/default/files/2019-05/sipri1905-ai-strategic-stability-nuclear-risk.pdf, 2019

[Bra83] P. Bracken: The Command and Control of Nuclear Forces. Yale University Press, 1983

[Dum80] L.J. Dumas: Human Fallibility and Weapons. Bulletin of the Atomic Scientists 39, 9, S. 15 - 20, 1980

[Fin64] H. Finer: Dulles over Suez, Chicago Quadrouple, S. 418, 1964

[GAO81] US General Accounting Office: NORAD's Missile Warning System: What went wrong? MASAD-81-30, 1981

[Gor17] Michail Gorbatschow: Kommt endlich zur Vernunft - Nie wieder Krieg! Benevento Publishing, 2017

[HG80] Gary Hart, Barry Goldwater: Recent False Alerts from the Nation's Missile Attack Warning System. United States Senate, Committee on Armed Service, Washington D.C., 1980

[Hik18] Uwe Hiksch: Konflikte werden durch Klimawandel weiter zunehmen. in: FriedensForum Nr. 1, Seite 3-4, 2018

[Kla19] Michael T. Klare: All Hell Breaking Loose - The Pentagon's Perspective on Climate Change, Henry Holt & Company Inc, 2019

[Kre19] Hans-Jörg Kreowski: Ein kurzer Einblick in die Arbeit der Enquete-Kommission Künstliche Intelligenz. In: FIfF-Kommunikation Nr. 2, Seite 7-9, 2019

[Kul16] Gregory Kulacki: China's Military Calls for Putting Its Nuclear Forces on Alert, https://www.ucsusa.org/sites/default/files/attach/2016/02/China-Hair-Trigger-full-report.pdf, 2016

[LV19] Kersten Lahl, Johannes Varwick: Sicherheitspolitik verstehen – Handlungsfelder, Kontroversen und Lösungsansätze, Wochenschau Verlag, 2019

[Neu20] Götz Neuneck: Begrenztes Wissen, alternative Einschätzungen, offene Fragen: Anmerkungen zum Nuklear- und Raketenprogramm Nordkoreas, in: [Sta20], Seite 21 – 40, 2020

[Per92] Charles Perrow: Normale Katastrophen - Die unvermeidbaren Risiken der Großtechnik, Campus Verlag, 1992

[Ric20] Wolfgang Richter: Nukleare Rüstungskontrolle in Gefahr. SWP-Aktuell A 34, 2020 https://www.swp-berlin.org/fileadmin/contents/products/aktuell/2020A34_ruestungskontrolle.pdf

[Sch11] Jürgen Scheffran: Climate Change, Nuclear Risks and Nuclear Disarmament – from Security Threats to Sustainable Peace. Hamburg: World Future Council, 2011, https://www.worldfuturecouncil.org/wp-content/uploads/2016/01/WFC_2009_Climate_Change_Nuclear_Risks_and_Nuclear_Disarmament.pdf

[Sch16] Jürgen Scheffran: Kettenreaktion außer Kontrolle – Vernetzte Technik und das Klima der Komplexität. Blätter für deutsche und internationale Politik, Nr. 3 (März), S. 101-110, 2016

[Sch13] Eric Schlosser: Command and Control, Verlag C.H.Beck, 2013

[SW19] Eric Schmidt, Robert O. Work, u.a.: National Security Commission on Artificial Intelligence – Interim Report, November 2019, https://www.epic.org/foia/epic-v-ai-commission/AI-Commission-Interim-Report-Nov-2019.pdf

[Sch20] Reiner Schwalb: Wege aus der Krise? In: [SH20], Seite 9 - 22

[SB20] Giuseppe Sgamba, Brad Bredenkamp, u.a. (ed.): Leveraging Emerging Technologies in Support of NATO Air & Space Power, Joint Air and Space Power Conference 2020, https://www.japcc.org/wp-content/uploads/Read_Ahead_2020_Screen.pdf

[Sha18] Pavel Sharikov: Artificial intelligence, cyberattack, and nuclear weapons—A dangerous combination. Bulletin of the Atomic Scientists, 74:6, 368-373, https://doi.org/10.1080/00963402.2018.1533185, 2018

[SH20] Michael Staack, Günther Hauser (Hrsg.): Russland und der Westen – Ist cooperative Sicherheit möglich? WIFIS-aktuell, Verlag Barbara Budrich, 2020

[Sta19] Michael Staack: „Rüstungskontrolle ist nicht mehr zeitgemäß." mit Kommentaren von Götz Neuneck und Alexander Gräf; in: die Friedens-Warte –

Journal of International Peace and Organization, Heft 3-4, 2019, Schwerpunkt „Mythen der etablierten Sicherheitspolitik“, Seite 167 – 181

[Sta20] Michael Staack (Hrsg.): Der Nordkorea-Konflikt – Interessenlagen, Konfliktdimensionen, Lösungswege, Verlag Barbara Budrich, 2020

[Ste17] Otmar Steinbicker: Rückkehr der „Flexible Response“? in: FriedensForum Nr. 1, 2017, Seite 13-14

[Teg17] Max Tegmark: Leben 3.0 - Mensch sein im Zeitalter Künstlicher Intelligenz. Ullstein Verlag, 2017

[TSB20] Ingo Timm, Jörg Siekmann, Karl Hans Bläsius: KI in militärischen Frühwarn- und Entscheidungssystemen, www.fwes.info/fwes-ki-20-1.pdf, 2020

[Woo18] Bob Woodward: Furcht - Trump im Weissen Haus. Rowohlt Verlag, 2018