Technology Wargaming: Experiencing Future Technologies Combining Multiple Approaches

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ABSTRACT

The authors describe their experience of various wargaming-related methodologies applied in the Technology Foresight research program at armasuisse Science and Technology, also known as DEFTECH (DEfence Future TECHnologies), in order to identify disruptive technology trends, to assess their implications within a military context and to inform the Swiss Armed Forces of possible opportunities and threats.

This includes an iterative process, started in 2017 and still ongoing, in which not only an open platform has been created but also several international workshops have been conducted. The applied methodologies ranged from matrix-style wargames on higher aggregated levels, red teaming efforts inspired by the "Idea of System Cards" of NATO's Disruptive Technology Assessment Game (DTAG), up to storytelling approaches.

The special focus on technologies lead finally to the development of a tactical tabletop wargame entitled "New Techno War" that is commercially available. Built as a platform, an internet component allows interaction between interested stakeholders who would like to simulate additional technologies or scenarios and make them available to the community. A digitization of the game integrating multi-agent simulation, decision support, artificial intelligence, and video gaming is in development.

The authors present the conclusions of the past research including different design ideas, identified pros and cons, best practices, current developments and vision.

1.0 INTRODUCTION & BACKGROUND

What you normally expect from a research program about Technology Foresight are certainly reports and analysis about technologies that might come to life at a given time horizon. That horizon can be close or far, according to what you consider. This seems a logical and straightforward answer, and it is. However, just pause for a moment and ask yourself: are you interested in the technologies themselves or in what they will offer; how will they affect the way you operate and which opportunities and threats could they represent? At this stage, even go one step further and ask yourself if what you are really interested in are the opportunities, the threats, and what they represent, or is it what they represent FOR YOU? This difference is not anecdotal as it means moving from a deliverable that is more descriptive to something that **resonates with you individually**. The best way of accomplishing this is to generate a unique experience, interacting with your senses, such that you can refer to it when needed.

We are in the defence environment and the normal expected deliverable would be a report dedicated to a technology area. Working on the narrative including some story telling might therefore be a way of delivering experience to the reader. Unfortunately, the experience might only stay at the emotional level. Allowing people to play with what the technology would enable and to experience the consequences of their decisions in a given scenario would definitely bring more insights.

However, there is an additional challenge ahead: the elements we would like to experiment with do not yet exist. Therefore, instead of simply testing them, we will have to simulate them. Turning to the simulation world with ideas and feelings rather than values to feed the necessary mathematical models present is not that obvious. It is at this moment that "gaming" came to mind. But how? With what? With whom? At which level? How long? Without really knowing it, we opened the Pandora Box of possibilities and alternatives we will have to consider to build our gaming environment.

What is reported here is an original tentative attempt to present not only the work done, but also the motivation of the different stakeholders involved in one way or the other in this journey. Past, present, future; everybody played an important role in where we are today and where we will be tomorrow. Elements that could appear obvious now were not such at the beginning; and what will be achievable in the future requires for sure the struggles of today.

2.0 CONTEXT

This project is part of the Technology Foresight research program at armasuisse Science + Technology, also known as Deftech - DEfence Future TECHnologies. The mission of the program is to identify disruptive technology trends, assess their implications within a military context, and inform the Swiss Armed Forces of its possible opportunities and threats.

Started in 2013, the program is coordinated centrally and supported by a yearly budget to execute the different projects. Given its specificity, the vision of Deftech is to anticipate via synergies. Over the years different focuses took place with respect to foresight methodologies, representation and visualization of the information, leveraging of Open Source Intelligence (OSINT), use of science-fiction and more recently, the use of wargaming with focus on technology as well as of the understanding of acceptance (or not) of dual-use technological applications in the society.

Given the collaborative nature of the program, most of the activities and their outcomes are available on the dedicated Internet platform (https://deftech.ch).

One of the main challenges of new technologies consists in evaluating their future impact and creating insights, which are both tangible for military operators and commanders and feasible for the military planner and systems developer. As wargames are exercises based on human interaction it can, when applied to a technology context, be useful to materialize emerging technologies in a dynamic and contested operational setting defined by potential military users. This allows exploring potential technology implementations and their effects. Therefore, technology analysis is one of the main applications of wargaming within the defence environment.

This formed the cognitive interest as well as the application and starting point of our chosen methodological way ahead, which is described in the following sections.

3.0 TECHNOLOGY WARGAMING – FIRST ITERATION

In 2017, we started by conducting a technology wargame for Switzerland in the year 2035. In this framework, we focused on three separate sub-scenarios, which described potential, but most typical security challenges. Preselected future technologies, described according to armasuisse's "DEFTECH Radar" (https://deftech.ch/visualise), were made available to the players in the wargame in such a way that they could flexibly be used as required during their course of action.

The game design was inspired by the idea of matrix games according to Engle due to its explorative approach and its flexibility during design and execution. In our case, we developed a two-sided tabletop seminar game with planning cycles for each turn, after which either side carried out their actions alternatingly. In every turn, both sides, with four participants each, discussed the desired effects of their actions and described the technologies applied for that matter, moderated by facilitators. Based upon that discussion, the facilitators assigned a success probability to the action. The actual outcome was determined subsequently by rolling the dice to integrate random effects to the interaction and keep the game going.

According to our design, the game created a continuous narrative based upon the players' decisions, technology applications, discussed arguments, and the determined outcomes. Analytical insights resulted from the narrative itself, observations by analysts and the inputs by the players while discussing and striving to create effects under constant antagonism and counter-measures by the opposing party. Furthermore, the documented narrative, the analysts' notes and the most controversially discussed topics provided various vignettes and hypotheses for subsequent research.

Besides these results, we identified some challenges and drawbacks of our design: First and generally speaking, wargames provide exploratory insights at the cost of eluding replicability due to the open human interaction. Even more, the materialization of applied technology and the integration into systems posed a main challenge, especially the high level of aggregation. In order to mitigate deficits we adapted elements from NATO's Disruptive Technology Assessment Game (DTAG), i.e. the so-called "Idea of Systems" (IoS).

To create IoS, relevant future technologies are determined first. In a second step, IoS Cards are fabricated during a workshop in a given card format, i.e. the combination of one or several selected technologies with specific equipment, in order to operationalize new potential systems. Such IoS Cards can be used as stand-alone (i.e. documenting insights and ideas how to apply relevant technologies to future military systems) or as input for further technology wargames as described above. We executed this step in a workshop at armasuisse in 2018 that featured several working groups of up to eight persons who had to come up first with one or two IoS Cards vis-à-vis a specific scenario and objectives to achieve. Afterwards, the groups paired by two and challenged their IoS Cards mutually in a Red Teaming effort with sequentially structured discussions. A third step, consisting of a technology-focused wargame playing with the IoS Cards and its related analysis can be executed as described for the wargame above. As alternative to classic wargaming, the IoS Cards could also be used as a modelling input for games and computer simulation to analyze the underlying technologies in an assumed future operating environment, as described later.

Figure 3-1: Gaming input and execution of the initial wargame

4.0 THE BIG SHIFT: TOWARDS TABLETOP WARGAMING

Analyzing the situation, we came to the now obvious idea that in order to understand the impact of a new product, enabled by the integration of new technologies, we need to simulate it at the level it is used. In our case, this meant moving from the strategic level to the tactical level where values for parameters such as protection, lethality, mobility, have to be defined for every system. As the focus is on understanding, the potential disruption offered by these systems, we must have the flexibility to change those values easily to see which combination will allow a tactical disruption or a simple advantage.

Let us consider the example of the exoskeleton. The vision would be to equip some foot soldiers so that they can move quicker, carry more weight (protection? ammunition?), be less subject to physical fatigue and injuries, etc. The big question for each of these parameters is "how much?". Enabling the soldier to carry 80 kg instead of 50 kg may provide an advantage as it could mean more protection or more ammunition given the circumstances, but is it significant enough to focus on the development of such a system? What if you could carry 800 kg instead of 80 kg?

To stimulate exchange and discussions, the game must therefore make it easy to simulate these changes and stimulate the discussions around them. **The goal is not about winning, but about understanding the strengths and weaknesses presented by these future systems** in given tactical scenarios. With all that in mind, the option of a tabletop game came as a solution.

However, with the intention of integrating the "gaming" part within a half-a-day process allowing the presentation of the new system before its simulation, we came out with the following pre-requisite:

(1) The game will be created around "blue against red" scenarios.

(2) The User Manual should be simple enough so that within 15 minutes, beginners are able to start playing.

(3) The duration of a game must last maximum 60 min in order to allow the testing of different options

during a half-day period.

(4) The game must be modular enough to allow the introduction of new future technologies / systems as well as new scenarios in order to adapt to the interests and focus of different stakeholders.

In the development process, we directly involved the Swiss armed forces, i.e. the military doctrine and future planning teams, in the definition of the scenarios as well as in the selection of the future technologies. Together we made sure that everything we simulate from the blue side respecting the Geneva war conventions. We validated the various technological parameters with experts to ensure that at least for the first iteration, we will play with values that can be assumed as achievable in the coming years.

Considering these requirements, we started the journey towards what will become the “New Techno War” (NTW) wargaming platform.

4.2 The challenge to make it simple

Most of the tabletop wargames, among which the most commercially successful, aim at a most extensive realism. You normally achieve this due to precise game mechanics and exaggerated details, at the expense of simplicity. It is rare to see a rules manual of less than 30 or 40 pages minimum. For our development, we had to inverse the paradigm to come out with a 4-page manual to *simulate as accurately as possible* but to *keep it as simple as possible*.

We therefore started from the principle that we needed to develop a game that would take up the current Swiss doctrine in a simple and very flexible way. Flexible, because we must be able to refine the parameters of the game to see clearly the effect of a new technology that has an impact on those parameters, and those parameters only.

Figure 4-1: Representation of the tabletop game "New Techno War" with focus on new technologies and systems (The title "Challenge today tactics with the systems of tomorrow" summarizes what we tried to emphasize by playing that serious game)

At this stage, all the players around the table should start to understand better what a new system could bring in a specific tactical situation. Much better than by simply reading a report about it. However, there is still an open question we have not really addressed: Being the defender or the attacker, is there a specific way to use this new system to fulfil the assigned mission?

Answering that question requires that you consider *all* the possible ways to use the new system in that given scenario. To do that, you need to move into the digital world.

5.0 FROM TABLETOP TO DIGITAL

We decided to move with the wargame to the digital world not to have it played on a screen, but to get additional insights on how the new systems could be used optimally and to challenge the current tactical procedures. In order to reach that vision, we started investigating the following three topics:

(1) What can we learn from generating all the possible outcomes of a blue vs red scenario?

(2) What can a human learn from playing the wargame against an Artificial Intelligence (AI)? How can we do it?

(3) What type of information can we present to the human player so that the tandem human plus AI is better than the AI alone? How do you present the information to the player?

5.1 Simulating all possible outcomes

The number of plausible outcomes in any nontrivial wargame are so vast that humans cannot conceivably explore and analyze them all. This inability to explore an entire space of outcomes might not matter in a training wargame focused on creating a learning effect, but it is of paramount significance if you are using it for the development of a new doctrine, for testing concepts of operation and assessing tactical decisions. In these cases, you need to differentiate between what is possible, plausible, or probable.

How can this challenge be overcome? Thanks to so-called multi-agent simulations. Because computers play faster than humans do, multi-agent simulations can explore the entire space of game outcomes systematically and identify optimal courses of action, which lead to plausible game outcomes.

5.1.1 Multi-agent simulations

Rule-based systems like tabletop games can be straightforwardly translated into simulations: game rules and game environments like terrain and time are encoded as computer models, spun forward gradually while the outcomes of player interactions are recorded as the new state of the simulated world.

Multi-agent simulations are digital twins of real-world systems such as cities, financial trading or military operations. To build a multi-agent simulation, a synthetic population is first generated. This is a static snapshot of the system of interest, including individuals' sociodemographic properties and behaviours along with the sociotechnical environment. The synthetic population is then animated based on the behavioral rules and environmental constraints using simulation technology. The simulation is then calibrated to produce outputs statistically indistinguishable as much as possible from real-world variables of interest. This type of validated simulation is not only helpful for exploring the spectrum of game outcomes, but also for diagnostics, predictions, and foresight.

5.1.2 Simulating the wargame

Building and running of a multi-agent simulation of our NTW involved the following steps:

(1) Familiarization with NTW: several rounds of NTW were played to learn the game and understand the rules.

(2) Building the model of NTW, including players, equipment, rules, and topography based on the rulebook, other materials and the subjective understanding of NTW.

(3) Encoding the model as a multi-agent simulation: writing software to approximate game "physics" such as a digitized version of the game board; description of force packages comprised of systems, effectors, and platforms for each scenario; defining mission objectives for agents, and equipping agents with reinforcement learning behaviors.

(4) Verification and validation of the simulation: game outcomes of manually played rounds were sketched by hand (see Figure 5-1, left). Blue and red dashed lines represent how human players moved BLUE and RED military units during the game. Blue and red dots indicate firing positions. Blue and red solid lines show lines of fire. Hand drawn sketches were then digitized (Figure 5-1, right); 1,000 simulations of NTW were run and outcomes were automatically sketched in a format similar to the hand drawn sketches (Figure 5-2). Finally, manual game outcomes were compared with simulated game outcomes by machine learning algorithms developed for image recognition.

(5) Creation of an infrastructure to run experiments to explore the space of game outcomes and identify optimal courses of action. This includes producing 10,000 simulation runs.

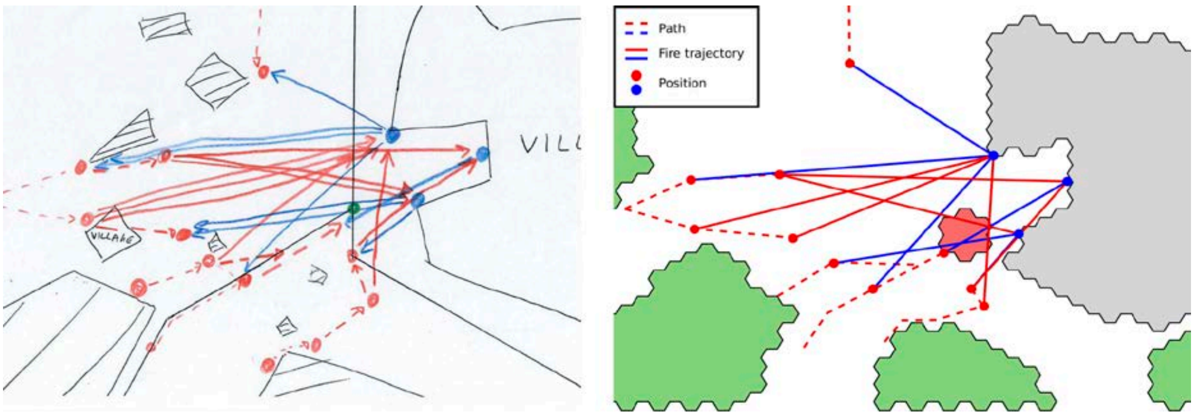

Figure 5-1: Manually sketched outcome of a game played by two humans vs. digitised version

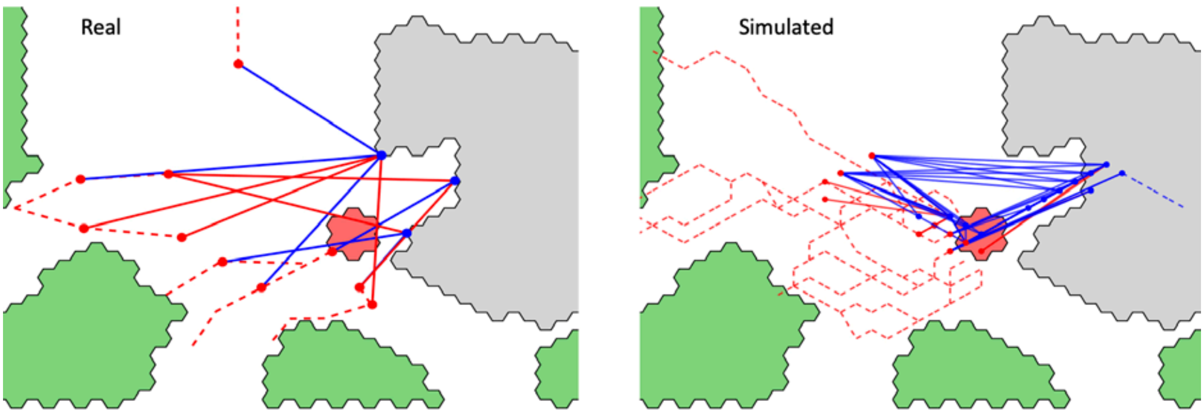

Figure 5-2: Visual representation of the outcome of a simulated game.

5.1.3 Analysis of the results

As posited at the beginning, simulations can explore the entire space of plausible game outcomes. We did not intend to reproduce specific game outcomes, but to know if the artificial intelligence powering the multi-agent simulation has the properties needed to produce plausible outcomes that transcend human imagination and play. First, we find that the simulation does produce outcomes as the games that humans played. These are shown as red crosses in the brown cluster in Figure 5-3. The point cloud represents 1,000 simulated games. Second, three distinct groups emerge from clustering game outcomes by machine learning. The significance of this graphic then becomes evident: *The simulation plays games and produces reasonable outcomes that human players did not envision.* These are all the games represented in the blue and green clusters.

Figure 5-3: 1,000 simulated game outcomes represented as a point cloud (Games are clustered into three distinct groups. Real world games, depicted as red crosses on the left of the point cloud, resemble only the brown cluster of games. Games represented in the blue and green clusters are games that the simulation played, yet were not envisioned by the human players. The distance between the dots represents the difference between two digital representations of games as presented in Figure 5-2)

5.1.4 What else can we learn?

Games played by humans suggest that BLUE can win NTW about 40% of times. The simulation suggested instead that BLUE has a much lower chance of winning, around 3%, considering the complete set of outcomes and not only the ones played until now by humans. After fine-tuning BLUE's reinforcement learning parameters, BLUE's win ratio did not exceed 10%. The simulation thus indicates that humans are probably overconfident to win. This can be explained by initially not being aware of the other possibilities to play the game. Humans lock into narrow, familiar patterns; simulations do not. Simulations help identify optimal courses of action without falling prey to our own cognitive deficits.

Eliminate the cognitive biases by playing against a digital champion is the ambition for developing two artificial intelligences (one playing RED, the other playing BLUE) for NTW.

5.2 Enhancing warfare tactics using Artificial Intelligence

Modern AI-based agents outperform humans not only in the capability to provide information but also to make decisions in controlled situations. What this means: in a miniature world with given rules and actions an IT system not only provides the background for decision-making but is capable of deciding by itself. If a decision task can be cast into such a simplified world (commonly in terms of a game), then very often a tailor-made AI can assist in the choice of the right actions. The described setup includes virtually all strategic games, such as Chess, Go, Shogi, Hex, etc. for which AI players effortlessly beat human world champions.

At the core of this technological breakthrough lies the idea of training AI by playing through billions of simulations. Each win or loss is recorded and the AI is improved with every step. Not only one simulation is provided to the decision maker but also an AI runs through as many as possible reasonable cases and selects the actions that most likely yield the best results. After enough iterations, this procedure gives rise to the marvelous moves that surpass the ability of human masters at essentially all strategic games.

5.2.1 Simulating Warfare in the New Techno War setup

The NTW game has been designed in close collaboration with military experts. It serves as a simplified but realistic model for decision-making in various real-world scenarios of warfare. The player faces a typical situation of military conflict and has to decide upon strategy and tactics to reach his military objectives. Of course, the player can run through a limited number of scenarios (simulations) in his/her imagination and take the best action based on experience, available data and simulation. However, methods for training AI agents have been established for many other games to reach super-human performance. An AI-based approach is implemented for NTW with the goal to learn military tactics and strategy. Once it reaches satisfactory performance within the rules of the game, the structure of the game might be extended to capture the reality of warfare more accurately. Examples include adding future weapons, specification of their properties in detail, incorporation of additional agents with separate goals, etc.

5.2.2 AI architecture for strategic games

In terms of the development of AI players for strategic games two methods of search for the best decisions can be viewed as standard. We describe these approaches in some detail below.

First, there is the classical search in which an AI player attempts to simulate as large a number of game states as possible and then chooses the best of the simulations. This approach can be described as brute force in the sense that its ultimate goal is to try all possible game states and follow the decisions that lead to victory. In practice, exhaustive search is usually not possible as even simple games quickly breach the capacity of the strongest computers. The number of reasonable game states in Chess is estimated to be around 10^{40}, a number far beyond the reach of computer simulation. Consequently, not all the states are analyzed but the AI restrains to a sufficient number of reasonable outcomes. The search is quantified by two key parameters. The branching factor measures the number of reasonable actions the opponent player can take, given the current decision. The search depth defines how many consequent actions are simulated. For Chess a typical branching factor is around three, i.e. for each move three replies are usually considered, and a depth of maximally 80 moves. Once the maximal search width (given by the branching factor) and depth are reached, a customized evaluation measures the quality of the outcome. A common AI algorithm that implements this approach is the so-called AlphaBeta search. It should be mentioned that publicly available Chess programs that implement AlphaBeta (such as StockFish) running on a commercially available smartphone play far stronger than the human world Chess champion.

While AlphaBeta is extremely successful in a situation where the branching factor and the search depth are not too large, it quickly fails when these metrics increase. It is due to the exponential nature of the search exercise that even one unit of additional depth multiplies the required capacity of the computer by the branching factor. Consequently, this issue cannot be addressed by simply choosing better computation infrastructures.

The second and more modern method to make decisions in games addresses explicitly the weaknesses of AlphaBeta search and can be described as directed search. Various architectures have been proposed but the basic setup is as follows. Two deep neural networks (DNN) are used for decision-making. The first is evaluative in the sense that it measures the quality of positions. The second DNN directs the search by estimating the probabilities of reasonable actions. As compared to AlphaBeta this method focuses more on the likely and relevant consequences of a decision rather than checking as many as possible. The search algorithms of this type are summarized under the acronym MCTS (Monte Carlo Tree Search). In recent years MCTS search algorithms have outperformed AlphaBeta search for many games including Chess, Go, Chogi, Hex and constitute the current state of the art.

5.2.3 AI for New Techno War

As compared to Chess the NTW is characterized by a significantly larger branching factor but at the same time smaller search depth. The branching factor roughly reflects the number of reasonable actions. In the case of NTW multiple types of actions are possible, including moves, attacks, and response actions. Furthermore, in each round of NTW all figures of a player can act, as compared to Chess, where exactly one figure moves. This result is a branching factor of typically from 50 to 100. On the other hand, NTW has a limited depth for each scenario, the standard depth being 12, which is much smaller than for Chess.

Because of the large branching factor ready-made AI in AlphaBeta or MCTS frameworks cannot access the NTW but a customized approach has to be developed. A particular peculiarity of the game lies in the possibility of response actions, which break the standard move orders of the strategic games described above. In summary NTW requires an AI, which is tailored to the particular structure of the game and has to be developed in a custom effort. Our team currently implements an experimental AI within the PyTorch open source AI framework (by Facebook). The experiments are undertaken with multiple agents to measure their performance on NTW. The artificial agent can play against humans through a web interface (see Figure 5-4).

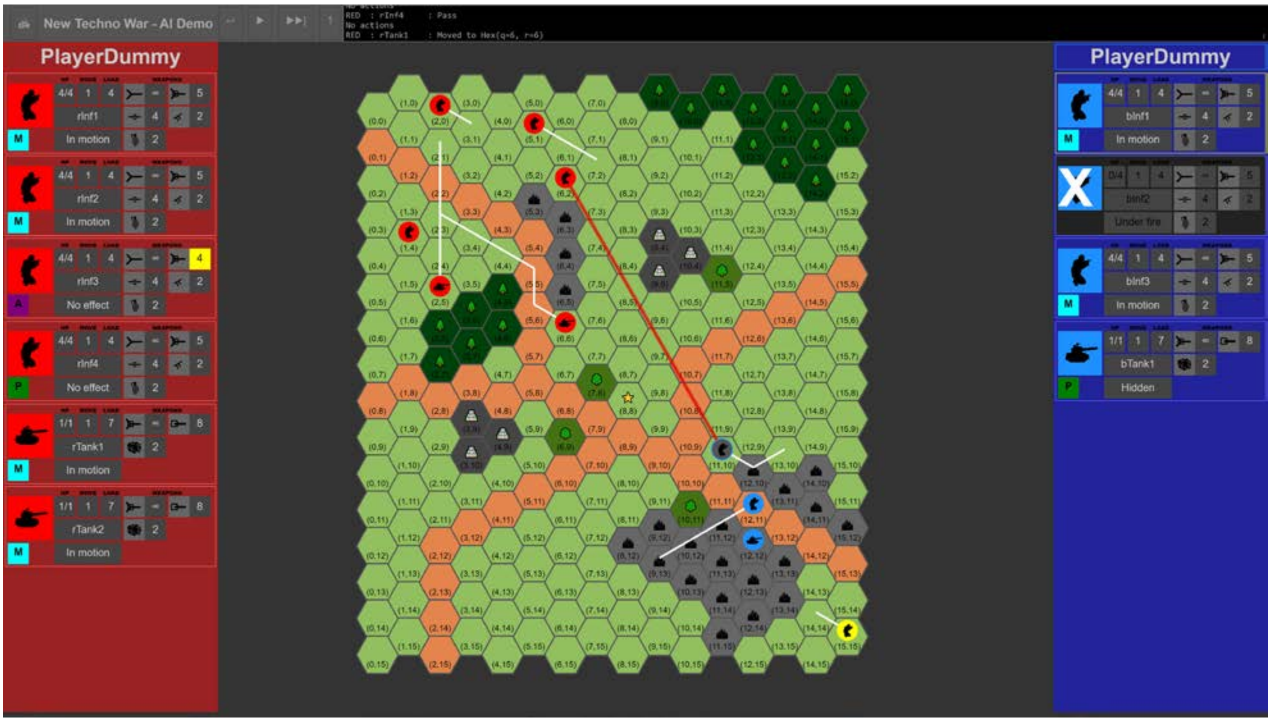

Figure 5-4: Interface Web of the digitized New Techno War game allowing human players to challenge the Aritificial Intelligences trained for that game.

5.3 Simulating the Soldier Digital Companion

Having at this time the data about all the possible outcomes of the game and Artificial Intelligences able to play it, we should be in a position to help the player to take the best decision independently of the situation. We know that in real life it would be different, but still we would be interested to simulate what a "digital companion" could be and to better understand how the cognitive bias of the player appear when playing. To that purpose, we have developed a simple video game of NTW.

The player will embody a soldier in the field. The challenge is to take up some of the initial situations created for the board game and transforming their resolution into a pedagogical narrative. We aim to deliver an additional perspective to the questions raised by the use of new technologies.

These narratives will always ask the player to find the optimal use of the new systems present in NTW i.e. unmanned aerial systems, exoskeletons, armed delivery robots, and medical evacuation robots. The game interface, represented as the soldier's companion, will support and evaluate the player's performance.

As smartphones can be considered already as our daily companions, the game is developed for Android and Apple devices.

5.3.1 Mission creative process

While the board game missions define the initial situations, we will use the data provided by the multi-agent simulations to define a limited number of game progressions (e.g. *complete success* path, *mixed success* path, *failed* path). These data will form a narrative tree composed of different branches. These branch points will constitute the choice of actions presented to the player during a mission.

5.3.2 General Gameplay

Upon selecting a mission, its situation is described, accompanied by a narrative illustration. A choice is then offered to the player (e.g. move forward / activate the exoskeleton / wait). Depending on the selected choice, the next situation is presented, followed again by another choice. After repeating this sequence a few times (see branch points), a mission result is displayed. The player will first be asked to select (from a limited choice) the reasons behind his decision-making. This data will be sent to an analytics service in order to be interpreted afterwards.

Finally, the player's choices will be represented graphically, accompanied by a critical commentary based on the ideal path. The goal is to allow the player to understand his mistakes. Once the mission is successfully completed, a new mission will unlock and become playable.

5.3.3 Companion specific gameplay

During the first missions, the players/soldiers will have to make decisions based on their judgment alone. The companion will only be present to comment on the situations described in the game, to give global information on events in progress and to provide an after-action review.

It is only after a few missions that the companion will begin to suggest the optimal path. The aim of this gameplay mechanic is to accustom the player slowly to receive help in his decision-making process.

However, for the last missions, the companion will begin to suggest bad options, leading to mission failure if followed by the player. The narrative approach will justify this by the hacking of the companion by the enemy.

With the help of the game data retrieved via a data analysis service, this gameplay mechanic will measure the percentage of players who, once accustomed to relevant advices, tend to follow blindly the indications given by the companion, even if this information is obviously wrong. This illustrates that even your loyal digital companion can be subject to cyber threats!

Figure 5-5-: Screenshots from The Soldier's Digital Companion

6.0 CONCLUSION AND VISION

The initially chosen methodology, the IoS Card workshop as well as the wargaming itself, stood out for their interactivity and the participants' engagement level. One main reason for this might be their exploratory character combined with antagonistic elements in order to challenge opinions, decisions, and solutions by an opposing party. In addition to the research itself, these activities provided a platform for socializing within the community and imparting knowledge on new technologies.

- Wargaming can help to demonstrate technological impact based on scenarios as an operational framework. It can demonstrate how humans, both friendly and opposing ones, might apply technology in the future.
- Wargaming enables exploration. Although it is nearly impossible to reproduce the course of an executed wargame, it can help to define the starting points for further analysis and break up mainstream or premature opinions due to its adversarial character.
- Nevertheless, wargaming takes time for its execution and is not the right methodology for every purpose. This applies especially to technology research topics that do not include human decisions and choices but focus on physical effects and possibilities, for which technical experiments, computer simulation, etc. might be suited better.

At this point, our approach incorporating tabletop games and computer-based analysis (as presented above) completes the efforts for future analysis. Game-based analysis helps to gain insight on human behavior, be it as a potential user of future technologies or be it as an individual, challenged by adversaries' innovative use of technology.

Multi-agent simulations with several thousands of runs close the gap of time restrictions caused by human interaction and of human bias by optimizing courses of action according to the underlying game mechanics. Admittedly, this emphasizes the urgency for validity and verification throughout the modelling & simulation process.

As a conclusion, it seems that a mix of methodologies and tools will generate the most reliable and useful results. A well-structured programmatic approach combined with a mixed tool kit ensures to exploit the strengths of different methodologies and to mitigate or even eliminate weaknesses. Additionally, a methodological mix and iterative process provides for the essential triangulation needed in the context of far-reaching decisions in the field of military capability management.

We are still at the beginning of this adventure and efforts are still needed in many directions before we can generalize conclusions and validate certain intuitions. It will be an exciting journey towards what appears to be the construction of mixed physical and digital ecosystem. Its interactions will allow us to better understand and anticipate the roles new technologies might play in one future or the other.

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