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Sammanfattning

Under kriget i Ukraina har tekniska och taktiska innovationer bevittnats när det gäller användande av kommersiella drönare för IRS och bekämpningsuppdraguppdrag, och eldledning av artilleri. Syftet med studien är att bidra till bättre förståelse för utvecklingen av UAS-förmåga och att skapa ett användningsfall där UAS-förmåga om fem år beskrivs. Studien tillämpar empirisk data genom två fallstudier, i kombination med intervjuer som inkluderar perspektivet från fyra forskare och experter inom området. Det prognostiserade användningsfallet för UAS-förmåga beskriver en flerskiktsanvändning av flygplattformar av olika storlek, prestanda och specifikationer, vilket gör flyg- IRS och slagförmåga tillgänglig på lägre taktisk nivå. Andra aspekter i användningsfallet är artificiell intelligens som stödjer databehandling i ett nätverksövervaknings- och kommando- och kontrollsystem, samt autonom navigering. Implikationer för UAS-kapacitet i en elektronisk krigföringsmiljö och implikationer för utplacering av motåtgärder diskuteras. Resultaten presenterade i studien är generiska och bör kompletteras med ytterligare studier, som genom scenariobaseradforskning kan skapa tydligare rekommendationer till specifika aktörer kopplade till UAS-förmåga.

Nyckelord: UAS, UAV, UCAV, RPAS, Drönare, DJI, Ukraina, Israel, Ryssland, Förmåga, Prognos

Anton Dahlström, Thesis report

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Forecasting UAS capability with a five-year timeframe

Abstract

During the war in Ukraine, technical and tactical innovation in the deployment of commercial drones for IRS and strike missions, and artillery spotting have been witnessed. This study aims to create a better understanding of evolving UAS capability and create a use-case forecasting UAS capability in five years. The research uses a combination of empirical data through two case studies in combination with interviews, collecting the perspective of four researchers and experts in the fields. The forecasted UAS capability use-case describes a multilayer use of aerial platforms of different sizes, performances, and specifications, which makes aerial IRS and strike capability available at lower tactical levels. Other aspects in the use-case are artificial intelligence that supports data processing in networking surveillance, command and control system, and autonomous navigation. Implications for UAS capability in an electronic warfare environment and implications for countermeasure deployments are discussed. The results presented in the study are generic and should be complemented with further studies, which through scenario-based research can create clear recommendations to specific actors linked to UAS capability.

Keywords: UAS, UAV, UCAV, RPAS, Drone, DJI, Ukraine, Israel, Russia, Capability, Forecast

Innehåll

1. Introduction

Ever since World War I, when sensors and weapons were first employed on airborne platforms, the threat from the skies has grown into a multilayered network of platforms. In response, counter measures in the form of technology and tactics have been adopted for ground troops to be able to operate under this increased threat. However, over 100 years after World War I we can still witness the same basic tactic being utilized as protection from the skies, and trenches. With the development of advanced sensors straying undetected is becoming increasingly harder and therefor the most effective solution to survivability often remains to protect yourself from the warhead by simply digging a hole in the ground.

While trenches may be an effective countermeasure if the main purpose is survivability, it completely cripples mobility and is therefore only viable for defensive operations with low requirements on mobility. For offensive operations, where inherently mobility is one of the key factors to succeed, other counter measures must be implemented otherwise a stalemate will occur. Such counter measures must address the issue from a wide scope through both technical and doctrinal solutions and at different command levels.

The game of cat-and-mouse between measures and counter measures is inherent in military evolution. This could be observed during the last era of international operations in the Middle East and Africa, where measures and countermeasures duel between improvised explosive devices (IED) and counter improvised explosive device (C-IED) measures. Insurgents were using mobile signals as triggers for IEDs against troops moving on roads, as it allowed the observer to trigger the explosion from a far distance which quickly became a big issue for troops operating on the ground. The solution to this issue was radio signal jammers mounted on vehicles or carried by dismounted personnel disrupting any incoming signal to detonate the IED. The insurgent’s response to this countermeasure was to move the radio receiver outside the jamming radius, away from the explosive connecting it via wire, again causing problems for ground troops. The new solution was, so-called, satellites by using dismounted personnel searching outside the roads, ahead of the vehicles on the road, to find the wires connecting the radio receiver with the explosive before the vehicle reached the explosive. While this was not the end of the measure and countermeasure duel, it is a good example to highlight how technical and tactical aspects can interact to evolve capability.

Developments in the UAS field are sometimes referred to as a “game-changer” for how future wars will be fought (Ferguson, 2023). A so-called “game changer” would imply that the duel between measures and countermeasures spreads to the extent that it disrupts the general way of modern combat. Historical examples of such disruptive technologies are the introduction of machine guns, tanks, and aerial combat.

1.1 Purpose, aim, and research question

The purpose of the study is to contribute to the understanding of where UAS (unmanned aerial system) technology and deployment evolution is heading and how this affects the situation of ground troops. The knowledge outcomes of the study are meant to support the development and implementation of new UAS technologies but also support the development of countermeasures against these systems. The study aims to create a use case that describes future UAS capability and how it may affect or change the future battlefield.

The study has one primary research question.

- How will UAS capability look in five years?

But to highlight the fact that the outcome of the study is directed towards both developments of UAS and counter measures, the primary research question was divided into two separate questions, addressing both sides.

- How does UAS evolution affect future UAS capability?
- How does UAS evolution affect the survivability of ground troops?

1.2 Scope and delimitations

The scope of the study looks to forecast a use case five years into the future. Therefore, the study is delimited to technology already available or technology with a higher TRL (technology readiness level) for the study to not create a use case that is not plausible within the five-year timeframe. The study looks at the entire spectrum of UAS capability within the cases studied, but also supporting technologies, such as data processing, as UAS capability is reliant on other supporting functions and technologies. The study also looks at countering systems and technologies, such as air defense and electronic warfare systems.

1.3 Earlier research

Much of the research about the future of UAS and drone capability focuses on narrow and specific applications of the systems. Recently, many publications have focused on the impact of artificial intelligence and the deployment of drone swarms. The article “Artificial Intelligence, Drone Swarming and Escalation Risks in Future” (Johnson, 2020) discusses tactical possibilities of AI-Augmented swarming and concludes that the technology offers decisive military advantages, at the risk of uncontrolled conflict escalation due to unpredictable automated decision-making.

The Swedish Defence Research Agency published report series called “Technology overview autonomous and unmanned systems” (Rantakokko et al., 2019). The report does not exclusively discuss aerial systems but presents existing unmanned systems, international research, and development in the field, TRL and timeline estimations about the introduction of new capabilities, an analysis of developments in critical technology areas, and concludes by presenting different types of preliminary concepts of how unmanned systems may contribute to certain capability demands.

This study aims to contribute to the research surrounding UAS capability by using findings based on empirical data ranging from the first reported deployments of UAS to the most recent cases. Combined with a capability perspective, use input from experts with expertise from different areas connected to UAS. By using a smaller time scope the study aims to make predictions with a lower level of uncertainty, compared to other studies which take on a longer time scope.

1.4 Terminology

Terminology in the field of unmanned aerial systems is inconsistent as there is no set international standard. There are multiple designations, classifications, and groups based on the system's purpose, performance, and technical specifications (Classification of the Unmanned Aerial Systems, no date). Classifications are not mentioned in the study and therefore need no defining. However, multiple acronyms and designations are used and will briefly be explained in this section to clarify what they mean in the context of this study.

UAS (unmanned aerial system) is a general term used to describe any aerial system without a human pilot onboard.

UAV (unmanned aerial vehicle) is an aircraft without a human pilot onboard, primarily used for IRS (intelligence, reconnaissance, and surveillance) missions. UAVs are usually remotely operated by a pilot, but per definition can also operate autonomously.

UCAV (unmanned combat aerial vehicle) is a UAV additionally fitted with aircraft ordnance, such as missiles or bombs. UCAVs are therefore able to conduct ISR and strike missions.

Loitering munition, also known as suicide drones or kamikaze drones, are aerial systems capable of loitering over an area and striking the target by crashing into it. Loitering munition can be seen as a hybrid between a drone and a cruise missile.

Drone is often used as an umbrella term to describe unmanned aerial systems. However, in the context of this study, I have chosen to use the term exclusive related to commercial or civilian drones, most often seen in the form of quadcopters. The Swedish Defence Research Agency (FOI) formally refers to these systems as remotely piloted aerial systems (RPAS) (Svenmarck & Woltjer, 2014), however, I have chosen to not adopt this term as it explicitly states that the system is remotely piloted, and not operated autonomously. As autonomous navigation is discussed in this study, not using the term avoids the risk of confusion.

1.5 Theory

1.5.1 Capability

The study aims to learn about how new and improving technologies affect military capability. A systems perspective on capability is applied using two theoretical frameworks. The first framework is the *Warfighting functions* which are used to understand what functions are needed to achieve capability and how technology fits into these functions. The second framework is *DOTMLPFI* which is used to understand what aspects affect capability. Figure 1 illustrates the frameworks' relation to each other.

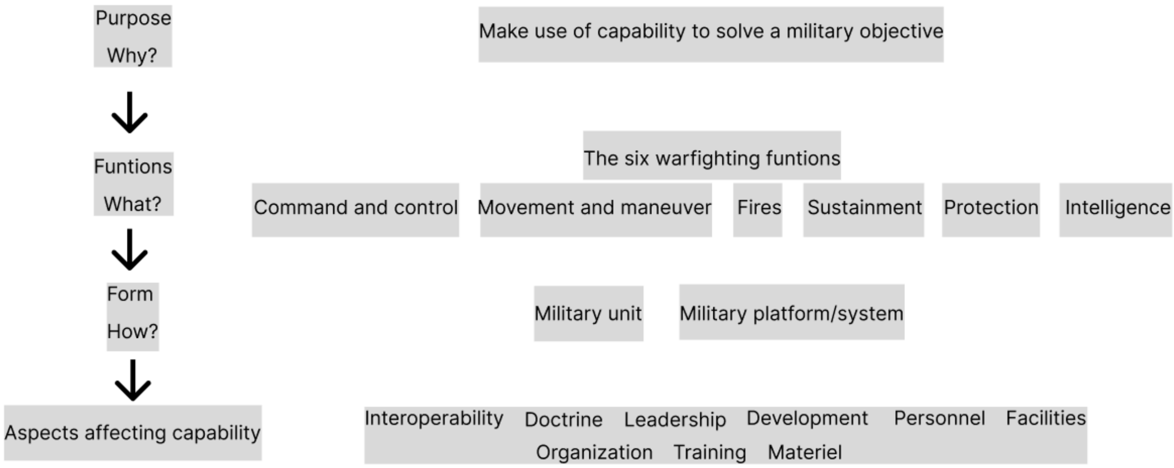

Figure 1, illustrates how the theoretical capability frameworks, Warfighting functions, Design logic, and DOTMLPFI, are used together.

1.5.2 Warfighting functions and design logic

The US Army's operations doctrine has a systems perspective on how combat power is achieved. "To execute combined arms operations, commanders conceptualize capabilities in terms of combat power." (2017, US Department of the Army). The eight elements to combat power are leadership, information, command and control, movement and maneuver, intelligence, fires, sustainment, and protection. The last six elements are the warfighting functions. Commanders apply combat power through the warfighting functions using leadership and information. Figure 2 illustrates the US Army's perspective on combat power and the eight elements.

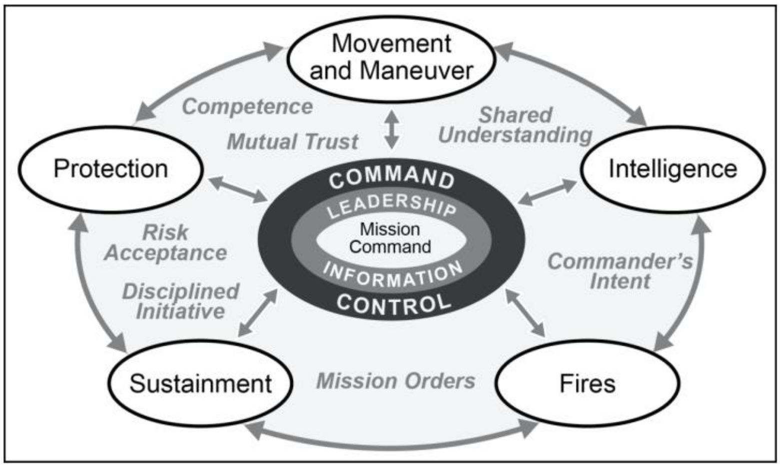

Figure 2 The US Army's perspective on combat power (2017, US Department of the Army).

To conceptualize the warfighting function's role in this study the design logic is applied. The design logic has three hierarchical levels: purpose, function, and form. The design logic says that a system has a purpose, which is fulfilled though functions, and the functions are realized in physical form. In the study, the military system's purpose is fulfilled using the warfighting functions, and the warfighting functions are realized in physical form through military subunits and the technology, platforms, or systems they deploy.

The Swedish military doctrine uses the corresponding six joint functions: intelligence, movement and maneuver, fires, command and control, sustainment, and protection (Försvarsmakten, 2016).

1.5.3 DOTMLPFI

The NATO definition of capability is “The ability to create an effect through employment of an integrated set of aspects categorized as doctrine, organization, training, materiel, leadership development, personnel, facilities, and interoperability” (NATO, 2021). These eight aspects form the second framework used to analyze and understand capability. It complements the prior warfighting functions and design logic framework as it is applied by analyzing the lowest form level in the design logic. In a forecast where the target of interest is centered around technological innovation, other non-materialistic factors may be overshadowed. By applying this framework, the scope of what is needed to achieve capability is broadened and highlights the concept that equipment and technology itself do not provide military effect.

1.5.4 Forecasting

To make credible predictions about how technology development may affect future capabilities, Robert M. Clark’s framework for military intelligence analysis was used. He claims that any target of interest, on any timescale, can be predicted using the framework. By examining past and present states of the target of interest, a predicted future state can be extrapolated, assuming the present forces acting on the target do not change. Projections assume forces acting on the target will change and therefore affect the outcome of its future state. Lastly, forecasts assume new forces will act on the target, further affecting its future state. Figure 3 illustrates the framework, the size of the circles around each estimation and prediction demonstrates the level of uncertainty in that state of the target. Clark claims there are six major forces to consider that must be assessed based on your specific problem. The forces are organization, programs, technology, capital, market, and regulations (Silfverskiöld et al., 2021).

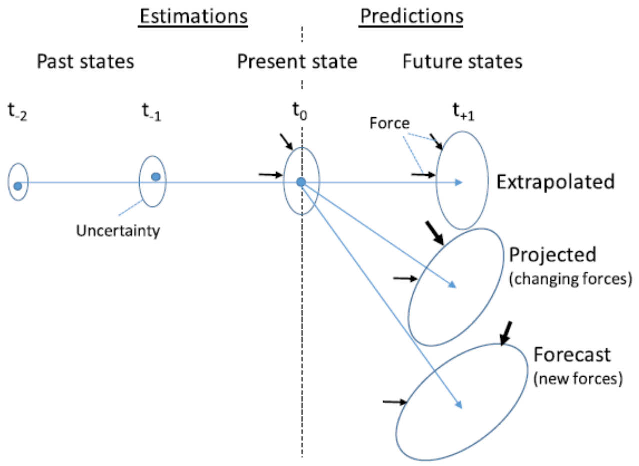

Figure 3, illustrates Clark's framework for predictions and forecasts (Silfverskiöld et al., 2021).

2. Method

2.1 Research design

To study a phenomenon and be able to make a forecast about how it may affect future capabilities a research design using Robert M. Clark's theory about forecasts and predictions was created. The subject of interest for the analysis and forecast is UAS capability. The research design comprises three steps:

1. Identify trends
2. Identify forces
3. Forecasted use case

A case study was conducted with the purpose to identify trends in the use of UAS in military conflicts. Using the identified trends, the continued expected evolution can be extrapolated assuming the evolution will remain linear. But as evolution is not always linear, Clark's framework concludes that forces affecting evolution must be identified and analyzed to understand how these forces will change future use cases. By identifying and analyzing these forces a second, forecasted future state can be created, which is the basis for attempting to predict future capabilities. Figure 4 illustrates an overview of the research design used in the study.

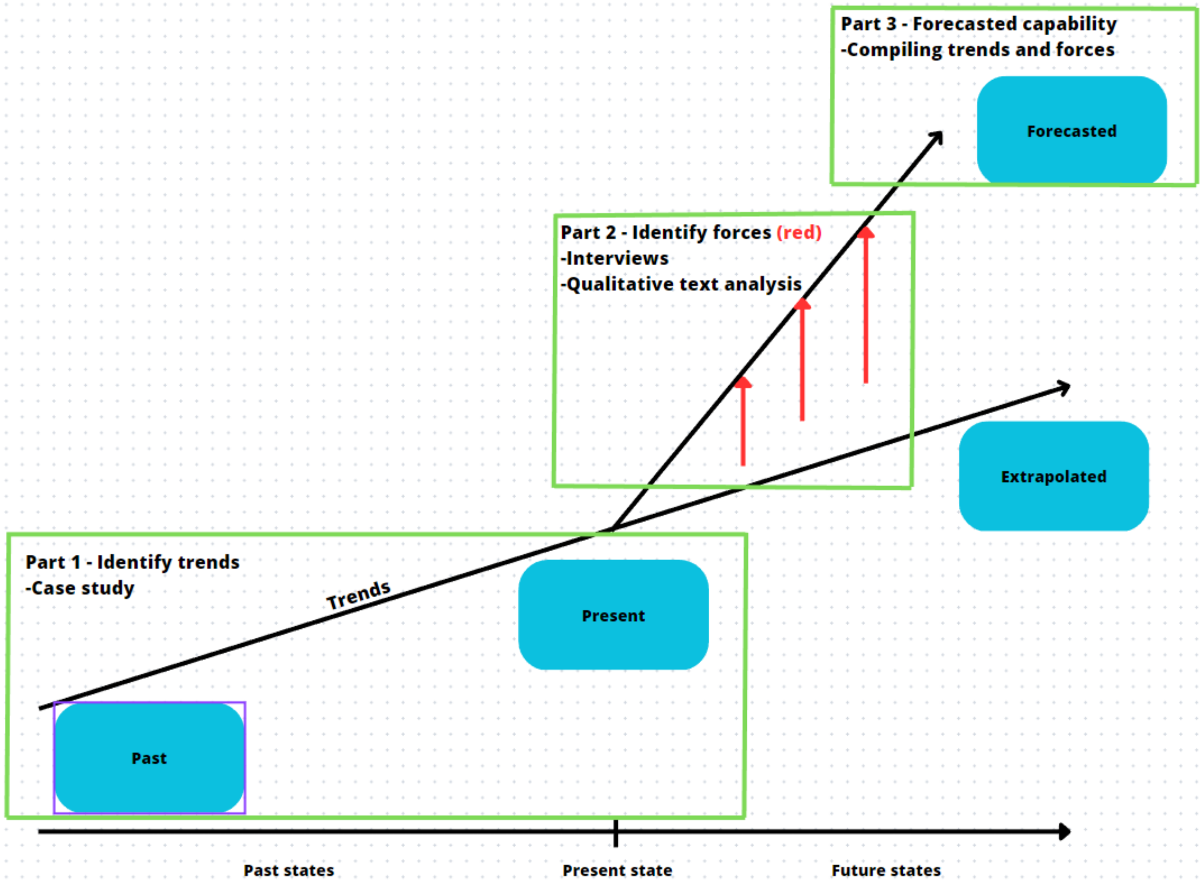

Figure 4, shows an illustration of the research design used for the study.

2.2 Part 1 - Case study

2.2.1 Case selection

The purpose of the case study was to identify trends in the deployment of commercial drones in military conflict. The first reported case of organized use of these systems in a military conflict was by the Islamic State in 2016 (2020, War on the Rocks). There are two problems related to using this case as the basis for the trend analysis, the first one is the limited timeframe. The timeline for the trend analysis would be eight years (2016-2023) and be used to make predictions five years from now. Clark does not suggest or specify a suitable timeframe for the past states, however, I find that the credibility of the prediction is lower when a trend analysis is based on a shorter timeline. Therefor the scope of the case selection was widened from exclusively commercial drones to UAVs in general which shifts the center of gravity of the analysis from specifically commercial drone platforms to UAVs and the warfighting functions they contribute to. The second problem with the case is that it represents a non-state actor’s deployment of drones. While many aspects of a non-state actor’s deployment of drones may be transferable to state actors, some may not be based on fundamental differences between the two, such as the lack of traditional military areal platforms assessable to the Islamic State. Therefore, I found mixing cases of state and non-state actors would have a negative effect on the validity of the study.

The first case selected as the basis for the trend analysis was the Israeli UAV program. Israel being the pioneer in UAV development and, ever since its first UAV deployment in the 1970s, has been involved in some kind of high or low-intensity military conflict, making it a suitable baseline for the UAS capability trends.

The second case was the Ukrainian War, subsequent to the Russian invasion in 2022. This case shows the first recorded cases of commercial drones widely deployed in a conflict between two state actors where both sides have an Air Force with a wide array of traditional aerial platforms and capabilities.

2.2.2 Data collection

Applying the theoretical farmwork to identify trends in UAS deployment meant understanding what warfighting functions UAS contribute to and how they are realized in form. The form can be further broken down using the DOTMLPFI framework as it highlights that the physical form is not only made up by materialistic aspects. Warfighting functions related to UAS deployment are primarily intelligence, fires, and command and control. The scope of the data collection was set to find information describing how UAS fulfills the functions over the entire timeframe of both selected cases.

For the Israeli UAS use case, data was collected using peer-reviewed studies. However, as the invasion of Ukraine is still only a little over one year old, there is very limited finalized research about the war, especially including the use of UAVs and commercial drones. Therefore, the main source of data for the Ukrainian case study was newspaper articles and think tanks. This had some implications on the data collection, compared to using peer-reviewed research papers as sources. Especially as Ukraine is deeply involved in information warfare with Russia, therefore information about Ukraine or Russia could not be assumed to be true when found in a news article, the credibility of every source of data was assessed. Before using data from a news article or a think tank the information was verified by finding a cross-reference to the same information from a different independent source. Some sources include videos of the observations, increasing its credibility.

The result of the data collection and the result of the analysis are presented separately.

2.3 Part 2 – Identifying forces

The trend analysis paints a picture describing where UAS deployment is heading based on historical data, this picture needs to be complemented with present and future aspects that may affect the extrapolated evolution. In the research design, these aspects are illustrated and referred to as forces. In the technology forecast framework applied for the study, Clark suggests the following forces to be considered and analyzed: Organization, Programs, Technology, Capital, Market, and Regulations.

2.3.1 Interviews

The starting point of the data collection for the force analysis was done using interviews with three researchers from the Swedish Defence Research Agency and one expert from the Swedish Defence Materiel Administration working with UAS acquisition. The three researchers were picked based on specific experiences or expertise working with sensor development, autonomy, and organizational implementation. The four interviews gave perspectives from both the researching agency and the customer or user side. While the expert from Swedish Defence Materiel Administration represents the user side perspective, the study does not include representation in the interviews from a military representative. This made the center of gravity of the study centered around technology, and less around doctrine and tactics.

The interviews were conducted in a semi-unstructured manner and could be described as a conversation about UAS development where the interviewee guided the conversation toward certain topics based on the findings in the trend analysis and topics of interest based on the research design and theoretical framework. But the interview respondents were also asked to speak freely on their views and opinions on UAS development to get their perspective based on their experiences and expertise. In an article assessing the utility of the method "Military Utility Assessment of Future Technologies (MUAFT)", a method to conduct assessments of future technologies based on the same theoretical framework as this study (Clark's framework), the article concludes that the method should be used by a group of experts with a wide representation of competences for the method to achieve validity (Silfverskiöld et al., 2021). While this comment is related specifically to the MUAFT method, this study shares the same framework, therefore the comment was seen as guidance in developing the method for this study. The role of the interviews in this study, therefore, was to act as "a group of experts with a wide representation of competencies" and get their perspectives represented in the study to improve the validity and quality of the findings.

The conversation during the interviews was guided toward topics related to the forces Clark presents in his forecast framework. Combining the forces with the elements in the DOTMLPFI framework allowed a higher detail in the analysis. The following elements: doctrine, organization, training, leadership, personnel, facilities, and interoperability, were used to further analyze the organizational forces in Clark's framework and make it more suitable for a military context, as the framework is not solely intended for forecasting military interests. The last element in the DOTMLPFI framework, material, overlaps with the technology force in Clark's framework.

Regulatory forces were delimited in the analysis. I found two different primary types of regulations relevant to the topic. Aviation and legal regulations. Aviation and flight safety regulations are different in other countries and militaries, findings about Ukraine or Sweden would therefore not be relevant to a generic use case. I suggest such an analysis to be conducted with a smaller scope. Secondly, legal regulation was delimited as well. Analyzing legal regulations would need a different set of theoretical frameworks than the ones used in this study. Furthermore, part of the purpose of the study is a threat assessment for ground troops. Looking at the state and non-state adversaries for Western militaries, they do not limit their use of arms regulated in international humanitarian law. Therefore, limiting the use case to potential legal regulations would risk underestimating the threat from future UAS capability.

The interview respondents are cited as "Interview respondents A, B, C, and D" in the report.

2.3.2 Analysis

The results from the interviews were analyzed using a SWOT analysis. My interpretation of the forces in the research design is that they do not necessarily have to point up and help the evolution forward (even though they are illustrated as pointing up in Figure 3), there may also be forces hindering evolution. Therefore, a SWOT analysis is suitable as forces acting positively on evolution are represented as strengths and opportunities, and negative forces are represented as weaknesses and threats.

Data collected during the interviews was validated, ensuring it was within the scope of the theoretical frameworks applied. The remaining data were categorized into two sets of categories: Strengths and Opportunities, and Weaknesses and Threats. The first category represents forces positively affecting evolution, and the second category represents forces hindering or regressing evolution. The data collected from interviews used in the SWOT analysis were complemented with other data and sources, such as observations in Ukraine to improve the detail and validity of the analysis.

2.4 Part 3 – Forecasting use case

Forecasting a future use case describing what effect UAS evolution will have on the future battlefield meant answering the research questions. This was done by compiling the findings of the trend analysis and SWOT analysis into one use case. Clark’s forecasting framework suggests two different future states, or use cases as I refer to it, a projected and a forecasted state. Determining the difference between the projected and forecasted future state was difficult in the context of this study, as the difference between the two requires identifying what is a changing force and what is a new force during the force analysis. Such differences in forces are more distinct in predictions with a larger scope than the five years of this study. The impact of this was that the projected future state was merged into the forecasted, as I could not foresee any influence on the result of the analysis by not making a distinction between changing and new forces.

3. Results

3.1 Data collection - Trends

3.1.1 Israel

Israel’s armed forces have historically had a strong reliance on UAVs in their arsenal and have been pioneers for drone surveillance and reconnaissance capability long before the platforms became a common part of American air operations (Lambeth, 2011).

When Egyptian and Syrian forces launched their assault in 1973 to start the Yom Kippur War, Israel was taken by surprise and had not yet deployed its servers to the frontlines. This meant Israel had to deploy the IAF to halt the surprise offensive. As the IAF had to focus its efforts against the Egyptian and Syrian assault forces, the IAF was vulnerable to Egyptian and Syrian air defense and suffered heavy losses (Rodman, 2010).

Despite heavy losses, the IAF was forced to continue its air operations in wait for IDF reserves to reinforce the frontlines. Meanwhile, efforts were made to cut the losses from anti-aircraft fire. Israel deployed American-manufactured UAVs as decoys to draw fire away from its aircrafts, and the effort seemed to have positive results as losses to ant-aircraft fire decreased substantially after deploying this tactic. This experience ensured Israel that UAVs are a useful tool in warfare (Rodman, 2010).

Following the Yom Kippur War Israel developed its first domestic UAVs, the Scout and Mastiff capable of carrying a limited payload of simple electronics, primarily visual cameras, possibly even infrared cameras. These UAVs were operational in the late 1970s. Before the 1982 Lebanon War IAF deployed these drones to monitor Syrian air defense systems in Lebanon and used similar tactics as during the Yom Kippur War by using expendable UAVs as decoys. With lessons learned from the Yom Kippur War, intelligence from these missions was used to form a battle plan to destroy Syrian air defense systems in the event of future confrontations (Rodman, 2010).

During the early phase of the 1982 Lebanon War, Israel made successful tactical employment of UAVs against Syrian air defense by using drones as fighter decoys to make Syrian surface-to-air missile (SAM) operators activate their radars which exposed them to strikes from Israeli fighter jets. This tactical use of drones resulted in the destruction of 17 of the 19 deployed SA-6 batteries, together with SA-2 and SA-3 sites. Simultaneously, IAI Scouts (a reconnaissance UAV) observed intercepting Syrian fighters preparing for take-off which allowed an E-2C surveillance aircraft to relay an intercept vector to airborne F-15s and F-16s. The Israeli fighter jets shot down 23 Syrian fighters with no losses of their own (Lambeth, 2011).

Realizing the utility of UAVs for the IDF following the success of the Lebanon War, Israel kept developing UAVs with a higher level of sophistication during the upcoming decades. The Searcher 1 and 2 were deployed during the 1990s, bigger and offering more advanced electronic systems than the earlier versions of Scout and Mastiff. As well as the Harpy attack drone, a loitering munition, also known as a "kamikaze" drone, was primarily developed to strike air defense radar systems by crashing into the target (Rodman, 2010).

During the 1980s and 1990s, Israel's main deployment of UAVs was in anti-Hezbollah operations in south Lebanon to locate Hezbollah training camps, arms depots, and rocket launchers. Drones provided real-time information on stationary and mobile targets, which were then engaged with precision fire by air and artillery units. UAVs may have used laser target designators for air-delivered precision-guided missiles to center on (Rodman, 2010).

After a 15-year conflict in South Lebanon Israel withdraw its troops from in 2000 Israel and transitioned into low-intensity warfare against Palestinians while still monitoring Hezbollah activities in Lebanon. For seven years the Israeli Air Force had around-the-clock air surveillance combat support for ground forces where UAV capability was essential for sustaining such surveillance tasks (Lambeth, 2011).

During the 2006 Lebanon War, Israel’s UAV squadron operated at maximum capacity and UAVs were deployed as their primary instrument for real-time ISR for air and ground commanders. However, the capability reached its peak during the war’s final offensive operation, Operation Change of Direction, where not a single troops-in-contact situation was not observed by at least one UAV overhead. Searcher and Heron UAVs were operating in stacks at high altitudes where they could neither be seen nor heard from the ground over numerous sectors of the battlefield to ensure maximum availability. Entering UAVs joined the stacks until it was needed, conduct its mission, and returned to base when reaching its minimum fuel state. The UAVs contributed to a common operational picture that was available to commanders at multiple command levels (Lambeth, 2011).

UAV missions often supported ground troop maneuvers or ensured safe passage for CSAR (combat search and rescue) and medevac operations by overflying Blackhawk helicopters entering hostile airspace. Other tasks were monitoring medium- and long-range rocket operating areas and searching for transported Zelzals and Fajrs missiles. As urban areas effectively hid vehicles transporting the missiles UAV operators had to fly closer to acquire a target. The lesson learned was that for these missions, smaller UAVs in high numbers were more effective. Such missions required a short sensor-to-shooter cycle time as the time frame for when the missiles were exposed and targetable was small. Targets would sometimes disappear in two to five minutes, according to a UAV supplier. Israeli Air Force achieved this by integrating UAV and attack helicopter operations. UAVs would relay electro-optical or infrared images to the AH-64s (attack helicopter) and jet fighter cockpits, allowing them to stay outside the lethal engagement range of infrared SAMs, antiaircraft artillery, and small-arms fire and still conduct precision strikes on geolocated and validated targets. UAVs used by the Israeli UAV squadron during the operation were Searcher, Hermes 450, Heron 1, and

Skylark. Only three UAVs were lost during the operation, two due to system malfunctions and one due to operator error (Lambeth, 2011).

Israel has not confirmed the use of armed drones during Operation Change of Direction, however, multiple sources have reported substantial use of armed UAVs fitted with Hellfire or Spike-ER anti-armor missiles. One report noted that Hermes 450 and the Searcher can be configured to carry two Spike missiles and that the Operation Change of Direction is the first evidence of Israel's use of UCAVs in order to further reduce the sensor-to-shooter cycle time (Lambeth, 2011).

Since the 2000s multiple UAV models such as Hermes 450, Hermes 900, and Heron. Some of the models can be mounted with warheads capable of attack missions. Israel has also deployed smaller hand-launched UAVs intended for short-range intelligence gathering by the infantry (Rodman, 2010).

3.1.2 Ukraine

In the initial stage of Russia's invasion of Ukraine in February 2022, Ukraine was able to make effective use of their Turkish-supplied Bayraktar TB2s UCAVs against the infamous 64-kilometer armored convoy heading for Kyiv, even though the convoy was protected by mobile anti-aircraft systems. According to the London-based RUSI think tank, the TB2s were used to destroy SAM missiles, artillery pieces, tanks, and trucks (Harding, 2022). In June 2022, attacks against two oil depots inside Russian territory may have been conducted using TB2s (Lowther & Siddiki, 2022). The use of the TB2s drones was possible due to Russia's inability to achieve air superiority (Kahn, 2022) and having their mobile air defense too scattered (Borsari, 2022).

The TB2s have a history of successful deployment, even in air defense contested air space. Most notably during the Nagorno-Karabakh War in 2020 where the TB2s were one deciding factor for Azerbaijan's victory over Armenia. Azerbaijan successfully used its TB2s against Armenian air defense by deploying cheap drones (modified old Soviet ere airplanes) used as decoys to bate Armenian air defense systems to engage their radars which allowed the TB2s to locate and destroy the systems (Kınık & Çelik, 2021).

Since then, Russia has shifted its strategy to focus its efforts on the eastern parts of Ukraine, allowing Russia to increase the concentration of its air defense systems. Increased concentration, the combined presence of multirange air defense systems, and electronic warfare have denied Ukraine to deploy its TB2 systems (Borsari, 2022). Oryx, an analytics group documenting equipment lost during the war, have confirmed 17 destroyed TB2s (Mitzer & Janovsky, 2022), the total number of TB2s Ukraine is operating is unclear. Simultaneously, Ukrainian air defense has denied Russia access to the airspace above Ukraine (Gordon, 2023). This highlights the vulnerability of such systems when facing proper air defense deployment.

In the absence of traditional air combat and surveillance capabilities, Ukraine adopted the use of commercial drones with Russia quickly following, after losing many of its Soviet-era drones to Ukrainian air defense (Lee, 2023). One popular drone model used by both sides is the Chinese-made DJI Mavic costing approximately 2,000$ with a range of 30km and flying a maximum of 45 minutes (Bunyan, 2023). The applications of these types of drones are mainly reconnaissance and artillery correction. Drones have also been modified and fitted with fin-stabilized mortar grenades allowing the drone operator to hit targets with high precision. Videos released of such usage show drones dropping munition into trenches, foxholes (Phillips-Levine et al., 2023), and destroying tanks by hitting the open hatch (News & McGee, 2022).

Both Russia and Ukraine have deployed so-called “kamikaze” drones after Iran supplied Russia with the Shahed-136 and the US supplying Ukraine with the Switchblade (BBC News, 2023). These drones are loitering munition, able to loiter over a target area during a limited amount of time and attack by crashing into its target. The modification of commercial quadcopters has followed the trend of kamikaze drones as well. Ukraine has converted drones designed for drone-racing, so-called FPV (First Person View) into smaller kamikaze drones. These drones are controlled by the operator wearing video-googles to get a pilot’s eye view (The Economist, 2023a). This type of armed drone gives a better ability to hit moving targets as well as targets not assessable to other types of munitions, such as targets behind cover in open buildings (Nevsedoma, 2023).

These types of commercial drone platforms seem to often be used for lower tactical combat and reconnaissance objectives, however, the data their sensors gather can potentially be of value for higher-level objectives. Ukraine has used satellite imagery for intelligence gathering. During the Kherson offensive of autumn of 2022, synthetic-aperture radar satellites (satellites with the ability to see through clouds and at night) showed Russia preparing its retreat east over the Dnieper River and building new defensive positions, before escaping

Kherson (The Economist, 2023b). However, satellites lack the ability to give intelligence about smaller units dispersed over a wide area, especially when concealed in trenches or camouflage.

3.2 Trends analysis

3.2.1 From large and few platforms, to smaller in quantity, to swarming

From Israel's first operational deployment of UAVs in the 1970s, UAVs have over time been tasked with additional missions previously conducted by fighter jets. This has allowed Israel a more aggressive tactical approach to air campaigns, for example flying in air defense contested air space with unmanned systems, even using UAVs bate to detect air defense systems and launched munition from manned platforms at stand-off range with lower risk to personnel and more expensive systems.

Similar trends have been observed in Ukraine. Fighter jets and Bayraktar TB2 UCAVs, have been unable to fly due to highly concentrated air defense, instead, commercial drones have been deployed for aerial ISR missions to identify Russian positions and direct artillery fire, or being modified to carry and drop explosives. While these systems are also vulnerable to countermeasures, specifically electronic warfare, they are still being deployed in high numbers and used as consumables as they are cheap and easy to replace.

3.2.2 Surveillance, to combat, to loitering

As the types of missions UAVs have been tasked to conduct have increased over time, the arsenal of different types of UAVs and payloads has increased. Starting with fitting standard RGB cameras, to more sophisticated EO/IR (Electro-Optical/Infra-Red) sensors, and laser target designators. Over time UAVs have been fitted with munition for strike missions and also been developed as loitering munition, also referred to as suicide drones or kamikaze drones.

The same development can be observed for commercial quadcopter systems. Starting as platforms only able to capture imaging in the visible spectrum and over time being fitted with EO/IR sensors. Quadcopter drones fitted with laser target designators are now reaching the market as well (Saballa, 2022). Then these systems were also mounted with munitions, in the form of fin-guided explosives, additionally also turned into loitering, kamikaze drones.

3.2.3 Around-the-clock surveillance

Since adopting UAS capability in the 1970s Israel has over time increased its reliance on UAS for aerial surveillance. In the 2006 Lebanon War UAV tactics allowed constant UAV uptime and every reported troop in contact situation was monitored from a UAV. Israel's drone surveillance network created a common operational picture accessible to commanders at multiple levels. The adoption of commercial drones in the Ukrainian military gave commanders at lower tactical level access to aerial surveillance, similar to how Israel's common operational picture did.

3.2.4 Shorter sensor to shooter cycle

Israel's campaigns against Hezbollah made Israel understand the importance of a fast sensor-to-shooter cycle as many targets were mobile or deployed in urban areas and easily hid after being detected. Israel has equipped their UAVs with laser target designators to effectively support standoff air-delivered precision-guided missiles. They have designed their UAVs so they can be mounted with munition and developed loitering drones further decreasing the sensor-to-shooter cycle as UCAVs can directly engage the target on detection. The same trend is seen in Ukraine and commercial drones. Drones were initially used to direct artillery fire, then weaponizing the drones, and modifying them into loitering munition making them able to strike mobile targets.

3.3 SWOT-Analysis

3.3.1 Strengths and opportunities

Multilayering

The added capability from cheap, commercial, quadcopter drones into the toolkit of the commander of a military force adds effectiveness through the *combined arms theory*. The theory says that different arms, weapon systems, or services should be used combined to increase the effectiveness and survivability of others. The strength of one system may compensate for the weakness of another, to achieve synergy (Ångström & Widén, 2015).

Where traditional means of aerial surveillance have been rendered ineffective due to integrated air defense systems, commercial drones have allowed Ukraine to keep conducting aerial IRS missions.

The static frontline and heavy use of artillery from both sides have created trench warfare. While the modified drones dropping fin-guided explosives have lower firepower than artillery, their increased precision allows their explosives to hit immobile targets more easily inside the trenches. Additionally, FPV drones, modified into "kamikaze" drones allow operators to reach targets with aerial protection by hitting from other angles than above, sometimes even through smaller gaps such as windows of buildings. This causes a bigger dilemma for the enemy as the number of elements to protect yourself from increases.

While commercial drones may contribute to military capability through the same warfighting functions (mainly intelligence and fire) as traditional more sophisticated UAS, their weaknesses are not the same as such conventional systems, in terms of what countermeasures are most effective. This increases the required amount and types of countermeasures the adversary needs at its disposal, which in term increases the robustness of the intelligence and fire warfighting functions provided through UAS capability.

Sensor evolution

Interview respondent A was asked about where sensors development is heading. Her interpretation of development in the field is that improvements in visual image resolution are flattening out, however, that is assuming the same detection technology is used and quantum technology is around the corner with will enable a more advanced detection technology. Such technology may allow a combination of 2D imaging with 3D information, which in turn may allow the sensor to see better through bushes and perhaps even through some types of camouflage, as well as less vulnerable to atmospheric conditions.

When sensor and detection technology is improving, in combination with new platforms and reconnaissance tactics, staying undetected on the modern battlefield is expected to become harder, if not impossible to some extent. However, conclusions about next-generation sensors and how they may contribute to UAS capability are somewhat rigged when tested in a controlled (experiment) environment according to interview respondent A. "When testing sensors detection probability, they are told to look for an object or person within a restricted area, knowing something is there. This is not a perfect reconstruction of a realistic scenario in warfare where reconnaissance is often more like finding a needle in a haystack."

Networking surveillance

With increased sensor coverage on the battlefield through increased deployment of cheap commercial drones equipped with sensors of different levels of sophistication, an opportunity to find the needle in the haystack more easily is presented. However, one challenge to the intelligence function when the number of sensors increases is the amount of data collected that needs to be processed. Step one in the conventional Intelligence cycle is Planning and Direction (Intelligence Resource Program, no date), this step may plan and direct intelligence-gathering activities in a way that limits the amount of data gathered to the amount the function can handle, therefore the number of sensors may not be the limiting factor in improving the intelligence function. However, this type of sensor coverage is more reminiscent of passive satellite surveillance, but with higher detailed imagery. Gathering data from undirected surveillance, using platforms deployed primarily for lower-level tasks (fire or reconnaissance) would produce a large amount of data that needs to be analyzed and processed before being produced into useful intelligence.

By applying AI tools to the intelligence function human intelligence analytics can be supported in analyzing and processing gathered data. Such tools are already operational in Ukraine’s intelligence organization and have proven useful. The American company Palantir Technologies specializing in big data analytics is supplying Ukraine with software that combines data from multiple sources such as commercial satellites, heat sensors, reconnaissance drones, open-source data, and human intelligence. The software then uses AI to transform the data into a map displaying probable positions of Russian artillery, tanks, and troops, (Grylls, 2022) then suggesting different means to strike the suggested target, such as artillery or armed drone (Ignatius, 2022).

Confirming to what extent this software is doing what Palantir and Ukraine say it does is hard, as all reports about its applications in Ukraine are coming from Palantir themselves who lets Ukraine use its software for free, advertising the software. Or from Ukrainian officers and operators who are deeply involved in the information warfare between Russia and Ukraine.

One factor contradicting claims that commercial drones would be directly linked to this type of data-gathering network is data security. Most of the commercial drones used by the Ukrainian military are produced by the Chinese drone maker DJI with a close connection to the Chinese government. Their systems use AeroScope which broadcast a signal with information about the drone, including the position of the pilot, which can be picked up, up to 50km away (Hollister, 2022). DJI has been accused of leaking this data on Ukrainian military positions to Russia (Baptista, 2022), while DJI denies these claims, it is unlikely that Ukraine would allow such systems to be directly linked to its intelligence network.

Traditional, non-automated intelligence gathering puts a higher emphasis on adopting mission command tactics for low-level commanders to supply high-level commanders with the right, detailed intelligence. This requires soldiers and low levels commanders to understand the purpose of their actions in relation to higher-level objectives. Otherwise, the intelligence cycle risk to be flooded with too much irrelevant data or relevant data risks being filtered out at lower levels. Automating this process allows more data to be processed and therefore reduces the risk of important intelligence being lost in the cycle.

Such AI tools may support decision-making as well. Which can increase the speed of the OODA loop within the command and control function at different tactical levels. The OODA loop is a mental model which describes a four-step decision-making process. The steps are: Observe, Orient, Decide, and Act (Farnam Street, no date). AI-supported decision-making could support commanders by conducting the first three steps in the loop providing a suggested course of action to the commander, the human in the loop, who decides and acts. Potential effective applications for this could be to reduce the sensor-to-shooter cycle further. One limiting factor for a faster sensor-to-shooter cycle is the human decision-making to, for example, chose which unit or weapon platform to strike the identified target with. A partly autonomous OODA loop could speed this process up and is potentially already happening in Ukraine according to reports (Ignatius, 2022). This may also be applied in maneuver warfare to increase the mobility and maneuverability of attacking units through faster decision-making.

While AI-supported networking surveillance may be a technical possibility, effectively adopting such technology into an organization is challenging. Interview respondent A has identified such challenges in the Swedish Armed Forces and thinks there needs to be an increased maturity in having automated processes running in the background. The details of Palantir's software in place in Ukraine are unknown, but previous research addresses organizational challenges with human-machine collaboration when implementing AI-power software (Hagos & Rawat, 2022). Such challenges are establishing trust in the underlying AI system and understanding the human–machine teaming as humans and computers have different strengths and weaknesses. Assigning appropriate tasks to humans and computer is crucial.

Autonomy and automatization – A force multiplier

With technical improvements in artificial intelligence, supporting autonomy and automatization can act as a force multiplier on the battlefield. The force multiplier opportunity within the intelligence processing function has already been covered in the sections above, but there are other similar opportunities for these systems. According to interview respondent B, one challenge for ground troops in adopting these systems is the need for drone operators. As an example, for an eight-man squad deploying a drone, one person would be occupied piloting the drone and at least one protecting the pilot, which occupies 25% of the squad to deploy one drone. Drone flights can be automated by setting up waypoints and paths to follow, however, this makes them particularly vulnerable as they are not able to react and adapt based on threats.

Potential applications for artificial intelligence in automating drone fights would be autonomous route planning, reconnaissance gathering, and threat detection. The development of autonomous obstacle avoidance is also moving rapidly, and drones fitted with sensors such as LiDAR (Light Detecting and Ranging) can autonomously navigate terrain with obstacles (Aldao et al., 2022). This suggests drones will be able to autonomously plan the route for a reconnaissance mission and adjust the route based on perceived or detected threats and navigate in the cover of the forest. However, the need for additional sensors for navigation is a limitation of this development as these systems generally have a limited payload.

Increased autonomy would also increase the robustness of the system in EW environments (Rantakokko et al., 2019). As the communication signal between the drone and pilot is vulnerable to jamming, a drone capable of full or partial autonomous navigation and routing would not rely on the communication signal to a pilot to continue its mission. However, Russia’s EW capabilities in Ukraine have shown how vulnerable GNSS signals are to jamming a spoofing (Thomas, 2022) and that other means of navigation must be adopted. Other, more robust PNT systems (Position, Navigation, Time) are available (Rantakokko et al., 2020), however, similar to autonomous obstacle avoidance, this also requires additional sensors fitted to the drones which already have a limited payload.

Deploying an autonomous reconnaissance drone in an EW environment is comparable to tasking a fireteam with a reconnaissance mission who then reports back what they saw. As the drone will not broadcast real-time reconnaissance.

3.3.2 Weaknesses and threats

Countermeasures

Traditional air defense systems struggle to detect commercial quadcopter drones due to their small size and plastic construction (Vick et al., 2020). Additionally, deploying multi-million-dollar air defense against commercial, mass-produced drones costing less than 10 000$ per unit is hardly justifiable from a recourse perspective. However, commercial drones are particularly woundable to electronic warfare systems as they rely on radio or satellite communication and GNSS for navigation. Russia has deployed Krasukha-2/4, R-330Zh Zhitel, and 301B Borisoglebsk-2 ground-based electronic systems, allowing them to use a combination of jamming and spoofing (Lowther & Siddiki, 2022).

Reports suggest that Russia has achieved higher success with its electronic warfare systems against drones ever since its retreat north of Kyiv and concentrating its forces in east Ukraine (Axe, 2022). Similar to the increased effectiveness of air defense systems in east Ukraine following the retreat, the static frontline has favored the electronic warfare units to have had time to set up and coordinate their different functions. This report suggests that the life expectancy of a quadcopter drone has dropped to three fights and fix-winged UAVs to six.

According to interview respondent C, Ukrainian forces are modifying their drones by removing GPS chips and using designated navigators, relying on maps instead of GNSS to navigate, primarily to protect themselves from AeroScope revealing their position to Russian forces. But by removing the reliance on GNSS for navigation, the systems should also be more reliable in an EW environment.

The cited report is from December 2022, and six months later drone usage is still high in east Ukraine for ISR and strike missions. This suggests two plausible explanations. First, Ukraine has found additional means, technical and tactical, like relying on map navigation, to counter the increased EW and still effectively fly their drones. Second, the fact that drones are cheap and available in mass numbers means they can be used as consumables and still be used to gain desired effect even when they are being neutralized in large numbers.

Military specifications, built for purpose, drive cost.

While cost and resource management is not a part of the theoretical framework used for this study, as it is not directly related to capability, low cost, high availability, and replacement allow for high-risk tactics and deployment in an environment where, as cited before, the average life expectancy is three fights.

As these systems are manufactured for commercial use, they are not specified for military requirements. Therefore the systems have multiple vulnerabilities, such as resilience to arctic climate (and low temperatures in general), battery limitation, data security, weather-sensitive (affecting sensors and maneuverability), and EW resilience. According to interview respondent C, the military industry is starting to specify these requirements when developing similar systems, designed for military purposes. Specifying and building these systems against military requirements will inevitably drive the cost per unit up. How much can only be speculated on, but it can potentially be a threat to the capability these systems contribute to, if not carefully considered what the effect of increased cost per system will mean when deploying them in high-risk environments, in relation to the improved specifications contribute to.

In Ukraine commercial drones are used with high flexibility at low tactical and technical command levels, a form of mission command being adopted in drone tactics. If the price of these systems increases, individual soldiers and low levels commanders are less likely to be able to deploy these systems in the same flexible way and take the same amount of risk. The deployment of these systems suggests that they are used as disposable equipment, like other disposable munition and systems (such as shoulder-fired anti-tank weapons). Increased risk appetite has historically been one of the key attributes driving UAV (tactical and technical) development as cheaper UAVs and UCAVs replaced fighter jets for surveillance, fire control, and strike missions. Increasing the price and sophistication of quadcopter drones would be a clear detour from this trend. While military-specified quadcopter drones may have a useful asset to complement less sophisticated ones, completely abandoning the cheapest systems may be harmful to their effectiveness.

3.4 Part 3 – Future use case

The trend analysis identified the following trends:

- From large and few platforms, to smaller in quantity, to swarming
- Surveillance, to combat, to loitering
- Around-the-clock surveillance
- Shorter sensor to shooter cycle

The SWOT analysis identified the following forces affecting UAS capability:

- Multilayering
- Sensor evolution
- Networking surveillance
- Autonomy and automatization – A force multiplier
- Countermeasures
- Military specifications, built for purpose, drive cost.

Using these findings, how will UAS capability look in five years?

The UAS capability will provide sensors with a higher level of sophistication, mounted on a wide range of platforms of different sizes, performances, and costs. Platforms in all categories include systems exclusively equipped with sensors for ISR and artillery spotting missions, and weaponized systems with a wide range of munition types mounted. Aerial ISR and strike capability are available at lower tactical and technical levels. The UAS capability provides data to a connected surveillance, and command and control network, able to process the high amount of data gathered through partially automated functions using AI tools. The network provides an operational picture with wide coverage and high detail, provided by sources ranging from the entire aerial spectrum of satellites to smaller drones, supporting decision-making at multiple hierarchical levels.

Systems are capable of autonomous navigation, planning, and threat perception, as a force multiplier by reliving the otherwise required number of operators. Autonomous navigation increases the robustness and resilience of the system against countermeasures as the system may continue the mission or safely return in the event of losing connection with the operator in an EW environment.

Aerial capabilities available at lower tactical and technical levels mean lower priority targets are subject to aerial strikes, artillery, and bombardment. A bigger toolkit of strike packages provides alternatives between smaller impact strikes with higher precision and higher impact with less precision in a cost-efficient, fit-for-purpose manner. In combination with the multilayered sensor platforms, the number and effectiveness of aerial threats are increased for any type of ground unit. This increases the need for multilayered countermeasures aimed at addressing the entire spectrum of weaknesses of the different UAS platforms.

4. Discussion

The purpose of the study was to contribute to the understanding of where UAS technology and deployment evolution are heading and how this affects the situation of ground troops. The research question asked was “How will UAS capability look in five years?” This was done by creating a use case that describes how potential future UAS capability may look and how this affects the situation for ground troops.

The findings of Part 1 in the study resulted in four trends identified in the trend analysis: From large and few platforms, to smaller in quantity, to swarming; Surveillance, to combat, to loitering; Around-the-clock surveillance; Shorter sensor to shooter cycle. Part 2’s results from the force analysis identified the following strengths and opportunities: Multilayering; Sensor evolution; Networking surveillance; Autonomy and automatization – A force multiplier, and the following weaknesses and threats: Countermeasures; Military specifications, built for purpose, drive cost. Part 3 compiles the findings of the trend and force analysis into a use case describing future UAS capability and its effect on ground troops.

The findings are generic and describe challenges and opportunities for UAS capability at a higher level, meaning they are meant to apply to multiple types of actors. As the introduction stated, the main research question was split into two questions to highlight the fact that the study is aimed to support knowledge in UAS evolution, but also the impact this has on ground troops. This is one of the main limitations of the study as the broader scope of the findings means they are not directly applicable to a specific military unit, or other actors, and cannot be phrased as specific recommendations but need to be interpreted by each actor for them to be useful.

During the interviews, when discussing UAS evolution one of the respondents said, “I think commanders at all units at different tactical levels need to ask themselves 'How does this affect me and my unit?'”. The impact this will have on ground troops will be different for a reconnaissance unit operating behind enemy lines, compared to a command-and-control unit, to use two extremes as examples. Both in terms of having access to this capability, and having this capability used against them. The utility of the study is by creating a generic picture describing UAS capability in five years, it allows different actors to get a general understanding of the potential future use case presented in the study and interpret that use case in trying to understand how this specifically affect them.

The study is conducted from the main perspective of UAS evolution, in the race between measures and countermeasures, referred to as the “game of cat-and-mouse”. Therefore, only the UAS development is represented in the duel between measures and countermeasures. Claims about future UAS capability are therefore based on the assumption that countermeasures are relatively unchanged in five years. This will not be the case as developments in countermeasures are ongoing at a similar pace as UAS developments.

Secondly, the finding in this study is predictions. As described in the theory section, forecasting future states and in this case, future capability, a certain amount of uncertainty is always present. The confident phrasing of the results presented in “Part 3 – Forecasting use case” should not be misinterpreted as certainly. The amount of uncertainty cannot be measured, all one can say is that the further into the future and the larger scope used, the higher the uncertainty. However, the aim is always to limit uncertainty as much as possible through good research methodology. But tomorrow there is more information available, and the finding of the study must always be revised and questioned based on the latest available information. In five years when the timeline of this forecasted use case hits its mark, the forecast itself is obsolete, as we then have the answer about future UAS capability. However, then we may evaluate the method of this study to learn about forecasting and how we may make better predictions with less uncertainty in future research.

The finding is based on empirical data, with the center of gravity of the data collection from Ukraine. This impact the validity of the findings as some results may be specific to a Ukrainian use case and therefore have implications on the generalizability.

An example of such implications is in how the war in Ukraine is fought which is connected to the geography of the battlefield, the defense and offensive doctrine of the two fighting sides, and the type of technology and materiel available to the fighting counterparts. Ever since Russia withdraw from northern Ukraine in its effort to seize Kyiv, the frontlines have remained relatively stationary and reminiscent of trench warfare. One factor contributing to the war turning into trench warfare is the open agricultural land in the area. This has arguably been favorable for the use of commercial drones in ISR and strike missions, with open land and stationary troops. How this capability would translate into a scenario where, for example, Sweden is defending from an aggressor may be very different as the Swedish defense doctrine differs from a Ukrainian doctrine, a majority of Sweden's surface is covered by forest, and a scenario where the Swedish Armed Forces try to deny a landing operating on Gotland is also vastly different in how effective UAS deployment may be.

Another example of such implications is the threat to data security posed by using civilian systems equipped with AeroScope. This threat is very specific to the use of DJI drones, manufactured in a country partnering with your adversary, and will be obsolete when military-specified equivalents to these systems are operational. However, the threat to data security does not disappear because AeroScope or similar systems are not equipped. With a more connected and networking surveillance, and command and control system data security become a higher priority. Even the most advanced UAS are woundable to electronic warfare shown by the downing of a US RQ-170 Sentinel in Iran, claimed by the Iranian side to have been achieved through jamming and spoofing (Rubin, 2020). Security of the data must be ensured, both the data transmitted and the data stored inside the platform, as the small and cheap systems to an extent are deployed with high-risk tactics where systems are expected to be lost during missions.

The study complements earlier research that focuses on specific technical innovations related to UAS capability by applying a systems perspective on capability and using empirical data for trend analysis, combined with expert knowledge about technical and tactical innovations to create a future use case compiling multiple aspects affecting future capability. The study has also made scientific contributions by applying Robert M. Clark's forecasting framework in creating a research design attempting to forecast future capability.

To complement the generic findings of this study, and to address the limitations related to generalizability, I suggest future research about UAS capability to apply a scenario-based approach which can result in findings giving specific recommendations to different actors affected by evolving UAS capability. For example, studying the role of UAS capability in the defense of Sweden or Gotland, or how the capability will affect combat scenarios for specific unit types.

5. Conclusion

The research design used in this study, combining a case study with input from experts and researchers contributes to understanding where UAS evolution is heading. The result shows trends and forces which were combined into a use case describing future UAS capability. The purpose of the study was to increase knowledge about the future UAS capability to support the ongoing race between measures and countermeasures. The findings are generic and anyone part of this so-called race must interpret these results in a way that they become applicable to their situation or dilemma. More studies, complementing the generic results of the study are needed to give concrete advice to different actors affected by UAS evolution.

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