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МАГІСТЕРСЬКА ДИПЛОМНА РОБОТА

на тему: Розробка та впровадження внутрішніх
інновацій у великій державній організації

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Intro

Economics literature has paid much attention to the government's role as a major funder of R&D, nevertheless there is much less study of how the public sector should design innovation procurement. A key decision is whether to take a centralised approach where the desired innovation is tightly specified or to take a more open, decentralised approach where applicants are given leeway to suggest solutions. [1]

Currently Ukraine has an opposite problem compared to more mature US procurement policy. The innovations are mostly driven by private investments, commonly by public fundraising programs. We have a few accelerators and other programs that are investing in military innovations and hundreds of small to medium manufacturers who are developing new military capabilities. Often innovations are driven from the bottom by frontline soldiers trying to invent new ways of protection, damage, intelligence gathering, optimising logistics or HR processes etc. And a few companies working forever with the MOD that can navigate the bureaucracy and are selling through well-established, often corruption-prone, procedures.

Modern innovations state is similar to the startup-based approach, you can find different teams trying to develop competing solutions, sometimes due to the lack of awareness, sometimes due to their belief that their project is solving problems in a better way than the competitors. But the battlefield, just like any other market, is selecting the right products with the most capable teams, ideas get blended together, developers are merging their efforts, some products are getting good funding, some are getting closed even after showing a promising traction.

There's no shortage of information about innovations, but most of those works were written with a focus on commercial sector and consumer markets, much less is known about public sector innovations and even less on a specific topic of defence innovations.

I have experience of creating one of the successful IT products for radio-electronic intelligence support. In this work I'd like to reflect on what were the success factors for my project, research how military innovations are managed in other successful countries, find the common ground and develop recommendations for driving military innovations in Ukraine during the russian-Ukrainian war.

Research

The goal

The innovations of the Ukrainian military are just happening, sometimes they are successful and mind-blowing, sometimes people with bright ideas are struggling to bring them to the battlefield. In the reality of the war, even the delay of half a year means that hundreds of people died due to the inefficiency of the system.

But the innovations and R&D management are well-studied disciplines that are used both in the industry and in policy-building. The goal of the research is to analyse the literature to build a framework that will help develop a model for the Ukrainian defence innovations sector. I will research the state of the defence industries in both developed and developing, big and small countries, analyse the success factors, mistakes and main innovation drivers and how they can be relevant to Ukraine. To better understand innovations in defence industries I will review the best practices of innovation and R&D management in private industry (where the efficiency and the speed of innovation determine the success of the enterprise) and the innovations policy-making on governmental level in non-defence fields.

US military innovations

General state

The US Department of Defence is the largest investor in R&D in the world and comprises about 60% of total U.S. federal government R&D (CRS 2018). It has been an important financier and early customer for technology, both transformational and incremental. Its investments often have dual-use properties, generating opportunities for large private sector spillovers.[1] Nevertheless, here are concerns that the US military R&D declining in recent decades, compared to the private sector, accompanied by the significant sector consolidation (out of 226 defence contractors in 1976 only 6 survived by 2019). The “virtuous cycle” in which American defence R&D investment yields powerful commercial applications and enables unrivalled military supremacy is failing. There are at least four challenges. [1, Appendix A2.Economic Context for U.S. Defense R&D]

- procurement regulations have become more complex and onerous, raising barriers to entry for new firms and contributing to the dominance of the prime contractors (Cox et al. 2014).
- relevant frontier technologies do not seem to be marketed to DoD
- the national innovation ecosystem has shifted away from areas most relevant to defence (Sargent and Gallo 2018)
- prime defence contractors have consolidated, often serve only the defence market, and are perceived as increasingly less innovative.

SBIR

SBIR (Small Business Innovation Research) is among the world’s largest and most influential small business R&D grant programs, spending $3.11 billion across 11 Federal agencies in 2018. The Department of Defense (DoD) accounted for $1.32 billion, and the Air Force had the largest program among the military services. The Air Force holds multiple competitions in which firms apply to develop military technologies, first through a White Paper (Phase 1) and then a prototype (Phase 2). After 2018, the Air Force started a reform that included an Open innovation competition that ran alongside the Conventional model. In this Open program the firms could propose what they thought the Air Force might need instead of getting specific descriptions of what is desired by the AF. [1] It is worth mentioning that the SBIR program is a peace-time initiative to drive 'dual-use' technologies to ensure the innovations will reach private markets, not just drive military R&D and to reach new firms the can enter the Defence market.

SBIR's main goal is to bring new firms and innovation to the government sector (Defence industry in our case). They are focused on the R&D stage, not basic research (TRL 3-6, not 1-2). But it also created another problem - most of those enterprises started to specialise on the R&D and were seeking next SBIR competitions instead of commercialization or scaling the winning innovation which manifested in steady innovation decline since 1990s [1].

The conventional and open programs have similar administrative processes: the AF publishes several 'topics' once in four months, each topic representing a discrete competition. Once applications are received, the evaluation phase begins which consists of three stages: first, disqualification of ineligible competitors; second, multiple governmental evaluators with an expertise in a relevant field evaluate competitors by Technology, Team, and Commercialization criteria (cost is not a factor, unlike an auction, in SBIR competition it doesn't matter who produces cheaper solution), three scores are summed and the winners are those whose overall scores are greater than a threshold determined by the funding available; three, awarding the contracts, administer the award, winning firms are made public (the innovations in SBIR are not classified, the grant programs are 50K$ for Open topic winner and 150$ for Conventional one), non-winner identities and the scores are never public.

The deliverable of Phase 1 of SBIR is a white paper describing the outcomes of research, if the research is successful - the innovation can become a part of a bigger acquisition program. The only difference is the competition goals: in conventional competitions the topics are very specific like ‘Develop Capability to Measure the Health of High Impedance Resistive Materials’, in open competition it’s up to the firm to identify military applications for their technology. Phase 2 has higher awards (300K$-2M$) and is intended to last 12-24 months, with a goal to deliver a prototype of the technology; the government is also encouraging firms to seek additional outside investments to fund the prototype.

The ultimate goal of SBIR is to facilitate innovation adoption and commercialization (TRL 7-9), this means that after the prototype is demonstrated the technology should be converted into a scalable innovation. At this stage the Venture Capital funds, the bigger industry players and non-SBIR defence contracting programs are entering the stage.

SBIR reform analisis

The research [1] shows that Open program competition has measurable positive and significant effects in three domains: the chance of military adoption measured by subsequent non-SBIR DoD contracts, the probability of subsequent VC funding, patenting and patent originality. The only Conventional effect is the chances of winning a future SBIR award, while there is no effect on this outcome in the Open program. This feature of the Conventional program is undesirable from a policymaker perspective, as it creates lock-in and insularity. After some experimentation period the AF is settled to prefer the Open program with a budgetary split of 80% to 20%.

The authors [1] are also pointing to a series of studies where follow-on contracts were compared to money prizes as an incentive for competitions like SBIR. The studies show that follow-on contracts are ideal for unsolicited proposals for settings like SBIR. The same logic is applicable for some Ukrainian activities like MoD hackathons. We should be aware of the key difference highlighted in the research: unlike Ukraine, the US DoD represents a highly risktolerant customer with almost unlimited buying power, which drastically contrasts with limited Ukrainian budgets and zero failure tolerance.

Another two reforms launched at the same time are the Air Force Pitch Day and National Security Innovation Network (NSIN) topics, which represent a balance between highly specific and open topics. The AF Pitch Days were held offline with a goal to bring together senior officers with large procurement programs and startups. The process is similar to SBIR but the topics are more wide, like ‘Battlefield Air Operations Family of Systems Technologies’, the feedback is instant and the winners are supposed to sign the contracts on that same day. NSIN topics come from a central DoD office, rather than one of the services and are focusing on dual-use technologies identifying commercial technologies that can provide immediate solutions in the field for the Air Force. Both reforms showed the results that are similar to Open topics.

Open topics and was a successful but radical reform, but there are more incremental means:

- The DoD can use more Requests For Information (RFI) in advance of Requests For Procurement (RFPs) to improve the information flow.
- Bring other branches other than the AF to the evaluations process and increase diversity, as the final technologies are commonly diffused to other military branches as well.
- Set aside last SBIR-winners or subsidise startups to mitigate the core problem: consolidation and lock-ins, and to encourage more new entrants.

General innovation factors

As we saw before, the US experienced a decline in defence sector innovations due to some factors: increased regulations and the consolidation of the defence market, decreased attention and budget after the end of the Cold War, no sense of existential threat or some other catalytic factors. But the US defence industry still arguably the most successful one, so it worth mentioning the factors that led it to that state. It can be attributed to a combination of factors that span organisational, technological, strategic, and cultural aspects.

Technological Superiority and R&D Investment: The U.S. military's focus on maintaining technological superiority has been a crucial factor. Significant investments in research and development (R&D), both within the Department of Defense (DoD) and through collaboration with private sector and academic institutions, have spurred innovations in areas such as stealth technology, precision-guided munitions, and cyber warfare.

Advanced Training and Professional Development: The emphasis on advanced training programs and continuous professional development for military personnel ensures that the force is capable of integrating and utilising new technologies and tactics effectively.

Inter-Service and Inter-Agency Collaboration: Successful innovations often stem from robust collaboration among the different branches of the military (Army, Navy, Air Force, Marines, Space Force) and between various government agencies. This collaborative approach facilitates the sharing of knowledge, resources, and best practices.

Private Sector and Defense Industry Partnerships: The strong partnership between the U.S. military and the defence industry is a key driver of innovation. The defence industry's competitive environment fosters innovation, with companies constantly researching and developing new technologies to meet the evolving needs of the military.

Adaptability and Flexibility in Doctrine and Strategy: The ability to adapt and revise military doctrine and strategy in response to changing geopolitical situations and emerging threats has enabled the U.S. military to effectively incorporate and leverage new innovations.

Cultural Emphasis on Innovation and Experimentation: A culture that encourages innovation, experimentation, and a willingness to take calculated risks has been fundamental. Programs like DARPA (Defense Advanced Research

Projects Agency) exemplify this approach by funding ambitious projects that have the potential to revolutionise military capabilities.

Legislative and Policy Support: Supportive legislation and policies that facilitate funding, experimentation, and procurement processes are critical. The U.S. government's legislative framework and policy-making bodies have historically backed military innovation through substantial budgets and initiatives that encourage technological advancement.

Global Intelligence and Reconnaissance: The integration of advanced intelligence, surveillance, and reconnaissance (ISR) capabilities has enabled the U.S. military to make informed decisions and maintain situational awareness, which is crucial for the effective use of innovative technologies and strategies.

Operational Experience and Feedback Loops: Operational experience, including lessons learned from conflicts and military engagements, informs the innovation process. Feedback mechanisms ensure that real-world experiences shape future innovations, from tactics and training to equipment and technology development.

Focus on Future Threats and Capabilities: Forward-looking assessments and a focus on anticipating future threats drive the development of new military technologies and doctrines. This proactive stance ensures that the U.S. military remains prepared to face emerging challenges with innovative solutions.

Israel military innovations

The context

Israel's defence strategy is founded on three key principles: deterrence (including nuclear), early warning (both strategic and tactical), and the capability for rapid military decision-making leading to decisive battlefield victories. Technological advancements are pursued to support these core strategies. Israel's security policy is influenced by a strategic culture of a strong siege mentality and a quest for absolute security. This has led Israel to prioritise achieving material technological superiority over its numerically superior adversaries.

The Israeli defence industry predates statehood, from the first days of the state establishments the strategy was to create a self-sustaining domestic arms industry. During 1950s-1980s domestic R&D and manufacturing was at its highest, marked by the development of a wide array of weaponry from the iconic Uzi submachine gun to main battle tanks (Merkava), missile boats (Sa’ar-4 and Sa’ar-4.5), many types of tactical missile systems and event its own combat aircraft (Kfir and Lavi).

By the late 1980s, Israel recognized that its strategy of seeking complete self-sufficiency in arms production was becoming increasingly unsustainable, primarily due to the rising costs of developing advanced weapons systems, such as the Lavi fighter jet. This realisation was compounded by the United States' decision to cease funding the Lavi project, which highlighted the limitations of Israel's reliance on foreign support for critical technologies.

Subsequently, Israel shifted towards a policy of "focused self-reliance," emphasising the development of unique "force multiplier" systems specifically designed for the Israel Defense Forces (IDF) and not available on the global market. This strategic pivot meant that Israel would import large military platforms like fighter aircraft and corvettes while concentrating its domestic arms production on critical technologies that ensure strategic sovereignty.

The Israeli arms industry, primarily represented by Israel Aerospace Industry (IAI), Rafael Advanced Defense Systems, and Elbit Systems Ltd., evolved into a sector specialising in niche areas where it holds core competencies. This transformation enabled the focus on developing and manufacturing advanced technologies such as drones and UAVs, air-to-air missiles, missile defence systems, counter-rocket systems (like the Iron Dome), anti-tank munitions, armoured vehicle protection systems, C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance), and targeting systems, as well as electronic and cyber warfare technologies.

With this shift, Israel's defence industry has become highly export-oriented, relying significantly on foreign arms sales for its sustainability. Between 2016 and 2020, Israel emerged as the world's eighth largest arms exporter, transferring approximately $4.14 billion worth of arms internationally. Its largest customers during this period were India, Azerbaijan, and Vietnam, which together accounted for a substantial portion of Israel's arms exports. This change underscores the critical role of overseas sales in the viability of Israel's defence industrial base [2].

Over the last three decades, Israel's arms industry has shifted significantly from primarily serving the domestic defence needs to relying on arms exports for its survival. This transition is pivotal not just for the economic viability of Israel's defence sector but also because the revenues generated from arms exports are crucial for funding military R&D programs that enhance Israel’s defence capabilities, including projects like the Iron Dome missile defence system.

The transformation of Israel's defence industry has been paralleled by the explosive growth of its commercial high-tech sector. Israel has emerged as a global leader in science and technology, with robust industries in information technology, computer engineering and cybersecurity, aerospace and space, renewable energy, and biotech and pharmaceuticals. The country invests about 4% of its GDP in civilian R&D, one of the highest rates worldwide, attracting significant foreign direct investment from tech giants like IBM and Intel. For instance, in 2011, Intel announced a $2.7 billion investment to develop a next-generation computer chip in its Israeli facility [2].

Israel's highly technology-literate population, fostered by education policies emphasising science and technology and by promoting public-private partnerships, has been critical to this success. The country consistently ranks high on various global innovation indexes, reflecting its strength in technological innovation.

Two main factors have been crucial to Israel's military-technological innovation: the strategic necessity of maintaining a qualitative edge in a challenging regional security environment and a national culture characterised by innovation, competitiveness, and improvisation. This unique combination has not only propelled Israel to the forefront of global arms markets but has also ensured that its defence and commercial high-tech sectors remain intricately linked and mutually reinforcing [2].

Another important factors are: informal culture non-hierarchical – even anti-hierarchical – society, Israelis are remarkably casual, informal, assertive, and flexible in their dealings with each other; young officer core, by design, IDF has a very limited number of high-ranking positions, much less than Ukrainian and NATO armies; and unity that favours innovation, Israel has a single-service structure for all the army including ground forces, air forces etc. and the army is conscription-based and mandatory to everyone without gender considerations [3].

Modern state

Israel's defense sector is deeply involved in the exploration and integration of Fourth Industrial Revolution (4IR) technologies. Key areas of focus include robotics, autonomous vehicles equipped with multiple sensors for various military branches, nanotechnology and nanomaterials, advanced sensor technology, the interconnectivity of individuals and objects, artificial intelligence (AI), enhancement of human capabilities through technology, electromagnetic pulse (EMP) weaponry, and the application of quantum technology for a wide range of purposes.

One such development started in 2006, the Israeli Defense Forces (IDF) began implementing the Digital Ground Army system (DGA), an advanced command and control framework. This system equips field and staff commanders with instantaneous access to visual and other vital data directly from the battlefield. It highlights the positions of allied and enemy units, evaluates potential threats to friendly forces, suggests methods of attack, and identifies and automatically rectifies communication issues within the ranks. The DGA system undergoes continuous enhancements to stay at the forefront of technological advancements. A notable update, set for rollout in 2019, was the Shaked Warfare system. This innovation integrates a customised Android smartphone and a digital watch, providing numerous strategic advantages. It enables field commanders and soldiers to navigate and manage combat scenarios through a digital map, indicating both enemy and ally positions in blue and red. Additionally, it delivers real-time alerts and updates about enemy movements and terrain conditions, advises on appropriate vehicle usage or the feasibility of reaching targets on foot, and facilitates the marking and monitoring of targets via smartphone. In general, starting from 2010, recognizing their transformative potential, the IDF has increasingly emphasised the integration of sensors, extensive databases, artificial intelligence (AI), the Internet of Things (IoT), advanced methods of energy conservation, and similar technologies, assigning these elements a more significant role in their operations.

By the late 2010s, Israel's dynamic and innovative technology sector boasted around 5,000 startups, with another 600 being established annually, marking the highest rate per capita globally. In 2017, Israel's research and development spending was 4.2% of its GDP, ranking it second worldwide. This sector benefits from a robust integration with the global market and technology landscape. In that same year, foreign investments made up 77% of all investments in the technology sector. This global connectivity enhances the access of the Fourth Industrial Revolution (4IR) technologies to the military, ensuring Israeli tech firms remain at the forefront of technological advances. Moreover, partnering with Israeli firms offers European companies a politically smoother avenue for collaboration, especially in cases involving dual-use or military-related technologies. As of 2018, about 230 start-ups in Israel were focused on 4IRrelated technologies, including AI, robotics, IoT, big data, energy, operation optimization, autonomous vehicles and drones, and nanotech [4].

Israel also has excellent conditions for know-how transfer between civilian R&D activities and military due to the central place of the defence industry in the country which resulted in the extensive growth of spin-offs and spin-on.

The primary mechanisms for transferring technology to Israel's defence sector include the personal networks of hi-tech leaders and employees with IDF units, the Ministry of Defence's Directorate of Defence Research and Development (DDR&D), the Israel Innovation Authority, and various cooperative initiatives linking the defence sector with academic institutions. The foremost among these (personal networks) is an informal system where IDF veterans, now in the hi-tech industry, maintain connections with the military units they previously served. The DDR&D serves as the Ministry of Defense's arm responsible for advancing technological developments for the IDF, often by integrating efforts from the private sector and academic institutions into military research and development. The Israel Innovation Authority, a civilian governmental entity, aims to bolster the nation's hi-tech and technological innovation ecosystem, including facilitating civilian enterprises' involvement in defence projects. Lastly, the reference to various collaborative models, both within and external to academic settings, highlights the pathways for transferring academic research and scientific knowledge directly into the defence domain. The DDR&D is responsible for drawing up the defence establish- ment's R&D policy, as part of their work, the DDR&D is involved in acquiring development projects for the IDF from various types of entities, including academia, hi-tech companies, and collaboration with other countries. It operates a scientific research organisation – the division for technological research and infrastructure – that works closely with Israel's academic institutes to assess the military potential of new S&T developments, it's responsible for locating, developing, and promoting advanced technologies that address Israel's current and future security needs [4].

The Innovation Authority is a governmental agency that is responsible for planning and executing the country's innovation policy. It fosters the advancement of cutting-edge technology initiatives, assists entrepreneurs and startups in refining their innovative tech ideas, encourages technological innovation within established companies, and supports academic teams in bringing their concepts to the market. Its main tools are programs that provide financial support, access to government-owned trial sites and facilities, and the opportunity to participate in national R&D programs [4].

Israel's MOD is fully aware how valuable the collaboration with the private sector is, its tenders are much less bureaucratic then the US ones, they are open for small companies and even to companies that are partially owned by non-israel citizens. But the downside is the management of classified information and sensitive technologies. In fact, the MOD's regulation is that any know-how developed or obtained with its support 'will remain under the sole ownership of the ministry (of defence) and the supplier will not be allowed to use it for any other purpose than this order', it also prohibits to produce or supply the product or any of its parts to anyone but the MOD (unless explicitly approved). Those limitations discourage companies from taking part in MOD-financed R&D projects [4].

Israel's defence export handbook lists more than 200 contractors, but most of them are comparatively small, with four main companies dominating the market: IAI, Rafael, Elbit Systems, IMI. All major defence industries in Israel started as government ventures, and (except in the case of Elbit) started their existence as departments in the Israel MOD, but later the MOD divested from those ventures because the capability of any regulatory bureaucracy to run industrial enterprises efficiently and profitably are severely limited (even though, some companies are still government-owned, but managed as for-profit LLC) [5].

UK military innovations

The UK defence innovation sector is trying to find its way in 21th century. It started to redesign in 2015 when the UK MOD realised that the traditional approach started to fail. The main challenge identified was that democratisation of information and technology and the use of disruptive innovations of adversary state and non-state actors increased the tempo of technology maturation, driving towards ever shorter timescales. On the other hand, the rising complexity of modern systems was leading to increasing time to deliver new military capability through the traditional acquisition system [6].

Those challenges were highlighted in the Strategic Defence and Security Review (SDSR) 2015. In response to this report the UK MOD launched the Defence Innovation Initiative (DII), which led to establishing the Defence Innovation Advisory Panel (DIAP), Innovation and Research InSights (IRIS) unit, the Defence and Security Accelerator (DASA), and the creation of an £800 M Defence Innovation Fund. In parallel, the Commands, DE&S and Dstl have launched their own innovation strategies [6].

The Future Force Concept was published in 2017 as a new innovation doctrine and withdrawn in 2023 with an updated doctrine due to the russian full scale invasion of Ukraine. It's worth noticing that innovations are becoming the main focus point: 'The value of adaptability at pace – agility – on the battlefield has become clear. We have learned that staying ahead of the threat and gaining strategic advantage can be achieved through novel and creative means, exploiting technology and adapting weapons systems, such as Uncrewed Air Systems, during contact, rather than relying entirely on an existing force package. This underscores the requirement for a more agile acquisition process and an even stronger partnership between government and industry, both primes and small- and medium-sized enterprises.' [7].

The UK is planning to invest significantly more than £6.6 billion in advanced Research and Development (R&D), supporting the National S&T

Council (NSTC) as well as collaborating within NATO's Defence Innovation Accelerator for the North Atlantic (DIANA). They identified 5 key technologies to invest: AI, Engineering Biology, Future Telecommunications, Semiconductors and Quantum Technologies and recognized the need to invest heavily into the industrial base as well as the university sector [7] (see Triple Helix Model).

Another noticeable step is the IP management: 'ambitious new approach to the exploitation of intellectual property (IP) generated by Defence S&T and other innovators, developing the Government's existing vehicle for spinning out IP, Ploughshare Innovations Limited, and promoting larger-scale commercialisation – to accelerate military capability delivery (the journey from prototype to mass produced and in the hands of troops) as well as tech sector growth and job creation' [7]. Basically, they established a corporation which has access to governmental IP with a purpose to commercialise those innovations. The UK MOD is working with the private equity and venture capital community through National Security Strategic Investment Fund (NSSIF) and nascent NATO Innovation Fund (NIF) to attract private investment and grow new national security and defence companies [7].

Learning from Ukrainian experience they decided to focus more on the pace of innovation, that it's not always the most advanced and expensive technology that wins, but rather the one that can adopt faster and are going to reform the acquisition paradigm from one focused on specifying exact requirements to one that acknowledges the importance of iterative development, calling this a 'spiral development' [7].

Brazil military innovations

Differentiating of the problem

Military technologies are characterised by high costs in development, production, and logistics throughout their lifecycle, alongside limited production scales for advanced systems and equipment. In addition they are facing trade barriers and legal restrictions in the countries that possess their property rights. The manufacturing process of these products exhibits a high degree of vertical integration, as their key components are typically developed and produced by the defence industry itself. Development occurs over extended periods, often making production reliant on customer demand and the costs they can bear. Only simpler products for regular use, such as small calibre ammunition, have a consistent production process and more predictable marketability, akin to the production of civilian consumer goods.

Brazil also experienced a significant defence industry and innovation growth from 1970s until mid 1990s, dominated by aviation (Embraer), armoured vehicles (Engesa) and missiles (Aviras). After the 1990s the Brazilian defence industry collapsed due to global industry decrease and domestic economic recession and renewed growth only with NDS in 2008.

All those problems were critical for the Brazilian military complex and are well known to the Ukrainian army that faced different kinds of restrictions on technologies that can be sold to the country in the state of active war or the limitations on how those technologies can be used in addition to high costs that smaller economies can't afford. That's why Brazilian case studies are important to this work.

National Defence Strategy

In 2008 Brazil launched the National Defence Strategy (NDS) policy to stimulate the advancement of science and technology, alongside innovation, specifically for national defence, by implementing a national strategy focused on high-tech products. It encourages the collaborative participation of civilian and military science and technology institutions, industries, and universities. Furthermore, it identifies key areas and technologies of interest, and establishes financial mechanisms to support research into materials, equipment, and defence systems.

NDS established partnerships involving private technology companies, universities and research centres in three strategic sectors: aerospace, cybernetics and nuclear energy. The technology provided by these players are involved in several fields of the national industry including fighter jets, smart weaponry, submarines, drones and communication technologies [8].

The Brazilian policy focused on seven Strategic Projects each developed in collaboration between several companies and dedicated academic institutions [8]:

- ASTROS 2020. To provide means capable of bringing long-range shooting support with high precision and lethality to land forces. Estimated 1.4bn R$ [8]
- Cyber Defense. To train and develop protection measures and to mitigate cyber-attacks. Estimated 0.4bn R$ [8]
- Anti-Aircraft Defence. To enable land forces to meet the defence needs of strategic land structures, protecting them from possible air space threats. Estimated 4.1bn R$ [8]
- PROTEGER. To protect strategic land structures to ensure social well-being. Estimated 11.9bn R$ [8].
- Guarani. To turn the infantry military organisations into modernised cavalry organisations. Estimated 17bn R$ [8].
- OCOP. To provide the army with military equipment and defence products, which are necessary for the operational use. Estimated 30.1bn R$ [8].
- SISFRON. To provide remote sensing, decision-making support and operational use in order to strengthen the presence of the government along the border. Estimated 11.9bn R$ [8].

NDS innovation stages analysis

The authors of [8] have analysed four stages of the innovation: idea creation, selection, development and diffusion based on semistructured interviews with the relevant serviceman and official documentation of those projects.

The key actions for **idea creation** happens by gathering the information obtained via exchange programs, during interaction between Brazilian and foreign servicemen and through operational reports (specifically defined documents that present lessons learned during different military activities, describing the main problems and needs of the army). These ideas are moving from the bottom to the Land Operation Command and are forwarded to the selection phase. According to all the interviews conducted by [8] ‘need to provide the army with new capabilities, seeking for a progress that can be used in the entire force.’. Those Strategic Projects are responsible for providing an institution to enable the planned transformation.

In each one of the seven Strategic Projects the creation of ideas occurred through a process known as ‘cross-pollination’ [9], i.e. through the collaboration between different military units.

The next stage is **selection**, in this case the seven ideas were selected by the military high command and forwarded to EPEx which improves and develops them to meet the demands required by the force. The criterias for the selection is technical viability (the board of science), financial feasibility (the finances board) and operational needs of the Brazil army (COTER, the institution responsible for the operational area of the force, identifying operational needs and categorising priorities).

Selected ideas move to the **development stage.** The biggest problem highlighted by the interviewed servicemen is a ‘lack of regularity of budgetary resources’, i.e. the lack of long-term planning [8], a well-known problem of the Ukrainian industry. One of the solutions is establishing public–private partnerships (PPP), Brazil has some success cases, but no consolidated experience. The main problem in establishing PPP is ‘a need to clarify some legal issues in order to enable initiatives with legal security because, usually, these are long-term initiatives’ [8].

The development stage is coordinated by EPEx but occurs in a decentralised way. In the case study of the seven strategic projects, each one of them was developed by the centre that could establish a PPP, had one project manager and one coordinator (mostly experienced colonels and generals) and were developed by dozens of companies involved.

The last stage is **diffusion**, after the development and initial tests and adjustments are done the next suite of the testing is performed with several other units or organisations to ensure the projects are fully integrated to the operations and are generating systemic capability. The diffusion is done in several stages: initial testing, safety and basic functionality verification, then a chosen group of servicemen is testing the product in real circumstances and a new evaluation and verification of strengths and improvement areas is performed, reports are analysed, adjustments are done and the product goes to distribution. The main problem of this stage is a challenge to keep up with the schedule due to the delay of financial support [8].

The NDS program is a relevant case for the Ukrainian defence sector and represents a practice of the triple-helix model [10].

General Principals

Collaboration

The common logic of our globalised and interconnected world is to build collaborations for innovative products. R&D costs are high and has to be paid up-front, so the investor has to maximise the production and sales for this R&D to pay off. Another upside of collaborative innovation process is the ability to build specialisations and diversify responsibility. So it’s no surprise European countries have a long-standing tradition of collaborative military programs. However, generally many of these collaborative programs are failing to deliver economic efficiency due to increasing coordination problems and the duplication of activities over countries. In 1990-x the biggest defence players consolidated in the US (forming Lockheed Martin) and Europe (forming EADS). But lately Europe has been trying to raise competition in the defence industry. Countries in general are struggling finding a balance between national security interests and global competition and collaboration [11, p. 55]. Huge wave of European consolidation meant that countries with large industrial defence bases will drive smaller countries out of the market, and it was unacceptable from their national security point of view. Different countries also had different opinions on government ownership in merged defence companies [11, p. 59].

The development of the NH90, standard NATO helicopter is an example of collaboration that involved too many stakeholders. The goal was clear: interoperability, lowering unit-cost, reduction of lifecycle costs. The result of the project was a success, but mentioned goals were not achieved: countries could not agree on many details and were including competing companies into the project due to those nations security and economics reasoning, but those companies were reluctant to share knowledge due to their private market competition. The project was delayed for more than seven years and developed 12 versions (instead of 2 anticipated types) in the process [11 p.63].

Similar problem occurred with the Joint Strike Fighter program. Initially 3 manufacturers competed to develop the F35. For the second phase Lockheed Martin and Boeing were selected, during this phase (Concept Demonstration Phase) they had to develop a flying demonstrator for possible production. Lockheed Martin won that phase and proceeded to the System Development and Demonstration Phase (SDD) securing a 19 billion $ contract. At this stage international allies where offered to join the program for participation fee. Countries were included into the design stage and their main goals wer to get involved in technology sharing and industrial development. But private companies of those countries were selected to participate on the ‘best-value wins’ approach, thar lead to minimal technology sharing and huge internal competition, and the allied governments were not satisfied with their return on investments and knowledge sharing. The project itself got delayed and the per-unit price were exceeded for at least 25% [11, p 64]. Both examples show how political concerns hinders market economy and harms the project. But the political interests and market-based approaches are too intertwined in the defence industry.

Organisational innovations matters

Technological innovations are important, they give the military new capabilities. But it's up to the organisation to fully utilise those capabilities. We saw a few examples of new capabilities utilised on a big scale, like Starlink that provided access to the high-bandwidth satellite Internet using the terminal that could be deployed anywhere by people with no specific education. This ubiquitous Internet access combined with organisational changes provided Ukraine with dozens of new emerging technologies and a revolutionary way to build a military C3 (Command, Control, Communications), ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance), etc.

On the other hand we pioneered a revolutionary technology like drones usage and had a huge advantage during the first months of the invasion, but with a lack of government support and mid-/top- level officers understanding, success stories of this technology innovation were limited to a few units and volunteer centres. That led to russians quickly catching up, scaling their domestic production, building specialised units etc. The question of who is using this capability better has no answer, but Ukraine definitely failed to capitalise on this technology even though it was the first one to realise its perspectives.

And we are not unique in this, Dima Adamsky in his book 'The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US, and Israel' makes a distinction between Revolution in Military Affairs (RMA) and Military-Technical Revolution (MTR), suggesting that sometimes the later doesn't guarantee the former. Moreover, it's common for the side that leads technical innovation to fail to recognize its potential for RMA and give the opponent to use the technology innovation to get the upper hand. As an extreme example, the US that developed a nuclear bomb failed to gain leadership, after they got back for competition in Europe it was too late, USSR nuclear potential led to assured mutual destruction. This not only neutralised the MTR advantage, but shifted focus to conventional warfare, where the US was significantly lacking behind [12].

Similar problems the US faced with their development of precision-guided weapons and over-horizon intelligence without reconceptualising the existing paradigm. Even Israel, which used those weapons on the battlefield in Lebanon's Bekaa Valley in 1982, only 10 years later, in the mid-1990s started to reform its doctrine to form a 'small and smart military', not just enhancing the existing capabilities [12].

In the particular case of our solution, it partially revolutionised the usage of radio-electronic warfare optimising the use of hardware and operators work. But the way we did it, as a bottom-top initiative, it didn't change the work itself, just optimised the processes already in place. To be truly transformational it had to break those processes and give a new perspective on how it could be done more effectively in network-based military organisation. It was a whole new level of technological and organisational challenge that was delegated to another team that used a top-down approach and tried to push processes changes from the top-level officers level. Unfortunately, by the time of writing this had no successful results, partially because of their failure to communicate the benefits to mid-level officers, partially because their distancing from the real battlefield and understanding of its needs.

Defence Innovation Framework

Useful tool to analyse defence innovation structure on governmental level proposed in [13]. The authors identify three components of defence innovation: technological, organisational and doctrinal. Technological component is a hardware of defence innovation, providing some particular products and capabilities. Organisational and doctrinal are like a software part that can change using the same technological base.

Based on an extensive body of literature they propose the framework for analysing country defence innovation strategy. It's based on seven categories of factors:

- **Catalytic**: Top-Level Leadership Support; External Threat Environment; Revolutionary Product or Process Breakthrough Opportunities. These factors are usually external to the defence innovation system, occurring on the highest and most influential levels of the ecosystem. Without them, the defence system remains tied to routine modes of incremental innovations.
- **Inputs**: Foreign Technology Transfers; Resource Inputs (State Budget Allocations, Capital Market Investments); Human Capital (Size and Quality of Workforce, Cultivation of Top Talent), Civil–Military Integration. Factors that determine resources that flow into the defence innovation system.
- **Institutions**: Plans and Strategies; Regulatory and Standards-Based Regime; Incentives (Intellectual Property Protection); Governance Norms; State-Market Relations; Technology Push Vs. Demand Pull Dynamics. Rules (formal and informal), norms, routines, established practices, laws and strategies that regulate the relations and interactions between actors.
- **Organisations**: Defence Corporations, State Agencies, Military Entities; Research and Development System. The principal actors within the defence innovation system and main units of analysis of the framework are organisations.
- **Networks and Subsystems**: Manufacturing Process; Acquisition (Research, Development, and Engineering) system; Social Networks; Diffusion. Networks are effective channels of sharing information, often more quickly and comprehensively than traditional institutional linkages, they can help to overcome barriers to innovation. Subsystems are issue or

process-specific networks that link organisations and other actors with each other to produce outputs and outcomes.

- **Contextual**: Historical Legacy; Domestic Political Environment; Development Level, Country and Market Size. The diverse set of factors that influence and shape the overall defence innovation environment.
- **Outputs**: Production Process; Maintenance; Sales and Distribution; End-User Demand; Commercialisation. Determine the nature of the products and processes that come out of the innovation system.

Based on patterns and relationships between those factors, authors differentiate 4 regimes of innovations:

- **incremental catch-up regimes**: absorption-oriented factors like technology transfer are the most important, main efforts are focused on engineering and production, no catalytic factors are prominent. Examples: Brazil and India.
- **Rapidly catching-up regimes**: most of the same absorption-oriented factors but reinforced by catalytic factors like top-leadership support and threat environment linked to resource allocation. Example: China.
- **Advanced developed regimes**: main drivers are the factors that promote original innovations, bottom-up institutions, IP protections and subsystems focused on the generation of original knowledge and products. Example: USA.
- **Emerging technological domains:** factors that emphasise new innovation approaches: a technological environment, social and professional networks that connect entrepreneurs and those entities focused on early stage, high-risk research, market-oriented organisational and institutional factors that encourage risk-taking, experimenta- tion, and new ways of collaboration. Example: Israel.

The types of innovation outcome in this framework extend from simple copying at one end to sophisticated disruptive innovation at the other:

- **Duplicative Imitation**: products are closely copied with little to no improvements, this is a starting point for latecomers. The process begins with acquisition of foreign technology which goes directly into production.
- **Creative Imitation:** generates imitative products with new performance features and component-changes. The work is mostly to integrate domestic components into the foreign technology.
- **Creative Adaptation:** products are inspired by foreign technology but can differ in significant way, one of the forms is reverse-engineering, need significantly more research than earlier stages.
- **Crossover Innovation**: products jointly developed with foreign partners with significant knowledge and technology transfer which results in creation of the domestic R&D base able to generate original innovations. However, there is still considerable reliance on foreign technological and managerial inputs.
- **Incremental Innovation:** limited updates and improvements to existing systems and processes. This can be a replacement of subsystems or tailoring product to specific markets and users rather than significant technology improvements through original R&D.
- **Architectural Innovation:** changing the way components are linked together without changing the core design concepts or redesign the production process. While this changes seem small, they have an opportunity to drastically optimise the product or the process.
- **Component or modular innovation:** Creation of a new component base that can be installed into the existing platform, requires hard innovation capabilities such as R&D centres and large-scale investments.

- **Radical or disruptive innovation:** result of breakthroughs in both new component technology and architecture. Requires broad-base R&D capabilities, deep financial resources, and readiness to take a risk.

Non-military innovations best practices

Open Innovations

Open innovation is a paradigm that asserts firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology. This concept contrasts with the traditional model of closed innovation, in which R&D activities are solely conducted within the boundaries of the organization, and all aspects of the innovation process—idea generation, development, and commercialization—are controlled internally.

The term "open innovation" was popularised by Henry Chesbrough in his 2003 book, "Open Innovation: The New Imperative for Creating and Profiting from Technology." Chesbrough identified the increasing availability and mobility of skilled workers, the growth of the venture capital market, external options for ideas sitting on the shelf, and the increasing capability of external suppliers as factors contributing to the rise of open innovation.

Key aspects of open innovation include:

- Inbound Open Innovation: This involves sourcing external knowledge, technologies, processes, or inventions to accelerate internal innovation. It can take the form of partnerships, acquisitions, licensing, and crowdsourcing.
- Outbound Open Innovation: Here, unused internal ideas and technologies are transferred outside the organisation through licensing, spin-offs, or sales to accelerate their development and commercialization by others.
- Coupled Process: A combination of inbound and outbound open innovation, where companies work in alliances, partnerships, or joint ventures to both give and take in the innovation process.

Benefits of Open Innovation:

- Accelerates the innovation process by incorporating a broader range of ideas and technologies.
- Reduces the cost of R&D by leveraging external research and development efforts.
- Increases diversity in innovation, potentially leading to breakthroughs and disruptive technologies.
- Provides new revenue streams by commercialising unused internal inventions.

Challenges:

- Managing intellectual property issues, including protecting proprietary information while engaging in collaboration.
- Integrating external innovations into existing products and systems.
- Cultivating an organisational culture that supports external collaboration and innovation.

Open innovation has become a fundamental strategy for many companies seeking to stay competitive in rapidly changing markets by leveraging the collective intelligence and resources available beyond their organisational boundaries.

Open innovations depend on individuals (who comes up with innovations), networks (open innovations are about collaboration between internal and external actors), governance (coordination and maintenance of those networks), national institutions and innovations systems (that influence innovation processes involving multiple actors). [14]

The key success factors are trust and people who can build relations internally and externally. Different people with different mindsets are important for different stages. Lindegaard distinguishes two main types: innovation leaders and intrapreneurs. The former are responsible for innovation activities like building networks and generating innovative opportunities, the latter are responsible for operational activities to make those innovations happen [15].

Innovation brokers

According to [16] and [17], there are two key roles essential to successful R&D, called innovation brokers: idea scouts and idea connectors. R&D managers should be aware of those roles, employ the right people and even more crucial - making the right connections between them. The flow of information is a blood stream of innovative companies [17]. Whereas it seems essential to manage the knowledge base, acquire any information possible and utilise it in the best way possible, the real world is adding its restrictions.

First of all, all this knowledge is acquired, assessed and utilised by people, those people don’t have simultaneous knowledge of all the information in the world, it takes time to acquire the knowledge, assess if some new technology useful for some particular case inside the organisation, find the best way to utilise this technology to solve selected problem and to push it through the organisational network. All those stages require time, resources and different kinds of people in place. Historically, professor Tom Allen, in a series of influential studies of MIT Sloan School of Management noticed that a small group of R&D professionals were also great networkers, both inside their organisations and outside of them, those people were the key points though witch the knowledge about new scientific and tech developments flowed through the R&D units into the organisation. He called those rare individuals ‘technology gatekeepers’.

Nowadays when the information is in abundance through the Internet, the concept of gatekeepers has undergone the division of labour and specialisation. Instead of one person who can be equally good at finding new ideas, selecting the correct ones and moving them through the organisation, it became much more common to select roles for researching the ideas in some specific area, but the next challenge that is often missed - the ability of those people to move their ideas through the R&D department. Hence the specialised roles of 'idea scouts' and 'idea connectors' - people who have strong internal networks, aware of what's going on inside the organisation, who are responsible for those developments etc. The role of the 'idea connector' is to connect the relevant development found by the idea scout and connect them to the relevant people inside the organisation who can benefit the most from it and have a power to 'sell' this idea internally and make sure those ideas are developed into a real product. There are a lot of evidences that without that role even the best ideas are buried in organisational routine and incorporating a small number of dedicated idea connectors can have an asymmetrical result on organisational performance [17].

Another great example for our innovation management we found in [17]. The company started to gather the ideas through a crowdsourcing process, they allowed their clients to post their ideas and rate other ideas. A marketing associate acted as an idea scout contacting the authors, interviewing them trying to identify recent trends and summarising them for the company to act upon. Initially this activity was seen as a great success based on the thousands of comments and what looked like a good job of the marketing associate. But the marketing associate had little to no connection to the key influencers and decision-makers inside the company. He was unaware of general strategic directions and visions, as a result often asked irrelevant questions or proposed recommendations that were unfeasible based on current companies operations and logistics or contacted people by their job title and not by their informal role, so the valuable information did not reach relevant decision makers. The company solved the problem by adding a connector (a product-strategy manager that worked with the company for years), that led to many real implementations of the crowdsourced ideas.

The last case is very noteworthy as by the time of writing one of our departments was going to launch the crowdsourcing project to gather relevant ideas and developments. This case study will help us to avoid the same mistake.

Internal barriers

Idea scouts are commonly newcomers with outside-directed connections, they lack the influence and political skills to push ideas. So we need to ensure some connector will be in place to have the power to launch projects between divisions.

Another common internal barrier for the adoption of innovation is Not Invented Here syndrome: business-units commonly have some kind of internal competition and are reluctant to use external solutions, seeing them as a part of someone else's achievement and trying to downplay its value. Again, the role of the connector is crucial here to move innovations between units and combine them into value-added products.[17] It's also a challenge to move the knowledge between the units, as it's a totally different task comparing to external knowledge sourcing, business units don't alway have incentives to advertise their developments internally.

There are 4 distinguished innovation phases with different roles instrumental, lacking some of them may lead to idea not reaching the result: Ideation (Scout gathering ideas from both external and internal sources), Selection (Connector helps Scout to select worthie ideas that aligned with the organisational strategy), Diffusion (Connector identify the relevant people who can use the idea to create a new product of process), Exploitation (where the innovative idea is developed and creates some value).

Innovation broker profiles

As discussed, there are different personal and professional traits necessary for idea scouts and idea connectors. Rarely there are people who possess both traits and can fit in both roles, it's a much better managerial practice to identify people that can fit in one of those roles. In order to do so the manager should understand those traits and use some helper tools like ONA (described in the next section).

The main job of the scout is to build an inflow of ideas either from the external networking or from the inside. It's a person that can identify useful ideas from the outside, possess a deep knowledge base of a particular tech space, strong analytical skills and high information-technology literacy. This is the person that has a broad network outside the company, most commonly it's a relative newcomer that still has that network from previous places. This person should have a genuine interest in keeping track of the cutting edge technologies in her domain expertise and most likely should have a higher-level education degree in that field.

To facilitate idea scouts the organisation should allocate the time and resources for them to scan the outside world, attend networking events, grow their social-media skills, build a growth path to ensure they are getting recognized for their work.

The connectors are internally focused people who have power inside the company and understand informal connections. This person should be able to connect different concepts in a meaningful way, possess a broad perspective of the company context, and where a new piece of information can fit in. She has to be able to translate external information to a form understandable by the relevant insider and be influential enough to put the idea to an action. Potential connector should have a well-established internal network, so in contrast with the Scout, it's someone who works in the organisation long enough. This person should enjoy helping others and have a reputation for technical expertise among her colleagues.

To boost connectors performance it's better to involve them in cross-functional projects and job rotation to build internal networking and organisation context understanding. It's also recommended to explicitly link them with the Scouts and for some organisations it's useful to make their social graphs publicly available.[17]

Organisational Network Analysis

To better understand organisational informal structure and the best people to fill in the roles, the authors [17] recommend to use the ONA (Organisational network analysis) tool, invented in social studies and recently adopted by business management. This tool helps managers to gain a bird’s eye view on their division informal connections, which often drastically differ from the formal hierarchy. This tool helps to identify the best suited people for the idea connector role.

The other potentially useful ONA application is to analyse the outward networks of the idea scouts and to analyse their effectiveness and potential growth drivers, often managers can recognize the networks that have little to no penetration of idea scouts connections. As an example the authors [17] researched the medical-devices company R&D division, the universities labs were important source of knowledge, but after performing ONA analysis, they discovered that company’s scouts where connected to only 3 out of at least 10 university labs globally that performed the researches important to the company. That was the three universities that scouts graduated from, most of the knowledge was not accessible for the company.

Open Strategy

The Open Strategy framework summarised in [18] and discussed in detail in [19], [20], consists of four stages: commons-based peer production (the ‘content’-branch), crowd-based input to decision making, collective buy-in and action and collective sense-making.

The key difference is that the strategy becomes not something secret, known only to the top-management team, but on the contrary, something that is build together and open to everybody. The idea of Open Strategy is to involve as many stakeholders and as early in the process as possible that should lead to better commitment and alignment throughout the organisation.

While the whole framework is not applicable to military industry, some parts are well-researched and can be utilised.

For instance, idea crowdsourcing is a tempting solution that has previously been discussed, and has new important challenges in managing crowd-based input to decision-making. The organisation has to design the process to avoid endless wrangling and self-promoting behaviour, the leadership has to adopt ideas from the crowd while maintaining strategic focus [18].

The general idea looks promising, but the more in-depth research of the [20] shows that the participation doesn't yield any significant benefits except for the Sense Of Virtual Community. Furthermore, the different types of participation yield different results, while commenting and evaluating other ideas yield positive results on SOVC, simple submission of ideas leads to negative effect on SOVC. Submitting ideas may serve as a means to unleash

ideas or to let off steam without commitment. While the isolated act of posting ideas may contribute creative thoughts, it might be counter-productive if it stimulates actors to this tool as an idea dump without generating interest toward understanding the other perspectives or grasping the big picture. Also the unmet expectations of engaged wider stakeholders may lead to frustration.

Nevertheless, research [19] argues that centralised and hierarchical structures can benefit from some forms of OS increasing participation and inclusive practices (participation is about increasing stakeholders input for decisions, inclusion is about creating and sustaining a community of interacting stakeholders engaged in an ongoing stream of issues in the strategy process [19]). Another key finding is that transfer of the information between stages is conducted by filtering ideas and passing them from one set of stakeholders to another in centralised organisations while working by championing of ideas and the carryover by participants in decentralised organisations. It's interesting to note that the Ukrainian military exhibits both centralised and decentralised patterns depending on the scale. The study [19] shows that participatory activities were not only useful to aggregate inputs and preferences on certain choice of policies or strategy, but they were also important for organisations to remain updated about changes in their environment.

Unsurprisingly, it also stresses that the quality of the decision-making is linked to the selection of the participants. The more diverse the selection, the better representation. It sounds like common sense but in our experience it's mostly overlooked, by gathering information from the most active and tech-savvy contributors or headquarters officers, as that's the easiest people to reach, even though they represent a small fraction of total headcount.

The [19] researchers also highlight the balance between participation and inclusion. Despite all the benefits of the inclusive practices, they are much more costly and hard to scale. Greater inclusion of individuals contributed somewhat to new idea generation but sharply increases the time and cost of reaching the agreements, those costs can inhibit the value of inclusion for centralised organisations.

Cross-pollination

One of the promising ways for innovation generation is cross-pollination. Well described in a series of papers, we'll focus on the research of how to better create new innovations with [9] and the research of diffusion and commercialisation of those ideas [21].

Cross-pollination is a recombination of previously separate concepts. For example, Biotechnology emerged at the intersection of biology and organic chemistry. The example of a successful discovery is a DNA as a double helix that was made by a collaboration of people in multiple disciplines.

Cross-pollination is a well-researched area, and there are hundreds of examples of how interdisciplinary teams produce more radical innovations. What's interesting, authors [21] noticed that even though the effects of adding different combinations of people to the team was widely studied, the study of the concepts itself is lacking. The implicit assumption of those studies were that tha concepts are cross-pollinated from those different fields of expertise. Another tip is that the researches were focused on producing the innovative ideas but to have an impact those ideas should move from knowledge to technology (like patents) and to commercialisation, and just a small fraction is going through these barriers.

The authors [21] researched the collaboration between industry and academia scientists, they argue that this can bring more science to commercialisation but goes with the risks of moving academia from basic researches to more applied ones, get more proprietary view on the knowledge, get some non-disclosure agreements and pressure to not publish the unflattering results. The academia vs industries have different stimulus in expiration vs exploitation, the academia is focused on creating novel discoveries where the industry is motivated to get sherterm results that are much more likely to be achieved from the existing knowledge. The findings show that companies are more likely to publish results mentioned in patents, illustrating that the notion of the industry scientists hindering the valuable results is not true. But the researches done with industrial partnership are less innovative. Cross-pollinated concepts are more likely to reach commercialisation but only by academia scientists, if industry scientists are included, the result is negative (however, that can be explained by the hypothesis that the industrial scientists are only allowed to publish if the results are not containing significant commercial value).

The article [9] is not focusing on ideas itself, it takes a more practical approach by researching how to manage risk-reward balance for the interdisciplinary teams. The authors found noticeable correlations between the value of the innovation produced by the team, the characteristics of the fields and the team members themselves.

The first noticed correlation is not surprising, the inverse relation between the alignment (similarity) of the disciplines and the value of the innovation. The more aligned the disciplines the more consistently moderate innovations are produced, you won’t see many failures but you won’t find any breakthroughs either. For example, you can team up Economics and Physics, you will innovate efficiently and produce many moderate-value innovations, because the fields share the same foundational tools of Math. The opposite part of the spectrum is more intriguing: the more divergent fields are combined, the average value is going down while the variation around average increases: the more failed innovations are produced, but the ones that are successful are more likely to become a significant breakthrough. As an example, economics and psychology share contradictory assumptions: the economics theory assumes people are making rational choices, psychology argues people are not rational. Most of the ideas from this combination will fail, but some will be significant like the Nobel prize winning behavioural economics.

The authors did not just stop there, they researched the way to control risks on that divergent side of the spectrum. First it doesn’t matter how misaligned or different the disciplines are, the combination of the more established and well-understood fields yields better results. Second, bringing together people with deep, rather than broad, expertise is much more likely to produce good results, even though they are much more reluctant to cooperate.

Frugal Innovation

Frugal innovation is an approach that emphasises creating high value through minimal use of resources, focusing on essential functionalities, and often targeting underserved markets. It's distinguished from conventional innovation by its driver (needs vs. wants), bottom-up process, core capabilities (functionality, ruggedness, adaptability), and its primary location in developing or emerging markets. This approach is not limited to product innovation but also encompasses service innovation and can be applied universally, not just in the context of emerging markets.

Frugal innovation has been explored in various contexts, including its role in addressing the COVID-19 pandemic, where it demonstrated that low cost does not necessarily mean low impact. The strategy is about using locally sourced ideas and materials to develop low-cost products and processes, a concept deeply rooted in practices like 'jugaad' in South Asia, which translates to a make-do approach. Modern frugal innovation insists on scaling ideas to benefit the maximum number of people, combining the need for open-access knowledge sharing with the protection of intellectual property rights.

Key principles underlying frugal innovation include robustness, portability, simplicity, and sustainability, with a focus on reducing total ownership costs and making products user-friendly. The concept is seen both as an outcome and a process, where 'frugal engineering' refers to the process, and the resulting products or services are the outcomes. This innovation strategy is increasingly recognized for its potential to contribute to sustainability and address global challenges effectively by doing more with less.

Design Thinking

The Design Thinking framework by d.school (The Hasso Plattner Institute of Design at Stanford) lies at the heart of our work and described in different sources, our favourite is [22]. It’s based on close collaboration with real users, the process starts with building empathy with the potential customers, the designer (innovation manager) should understand how people think, feel and behave, dive deep into their current processes, understand what real underlying problem is hiding behind those observed behaviours. After these observations the designer should formulate the hypothesis about the problems and possible solutions to those problems and test those hypotheses with the prototypes of the product.

The framework consists of 5 stages:

- **Empathize**: <u>observe</u> the people’s behaviours in the relevant context, try to find discrepancies between what people say and what they really do or some workarounds that look unnecessary. <u>Engage</u> with people, interview them, keep conversation loosely bound, try to understand Why they behave in this way. Watch and listen, ask them to show how they do and explain why they are doing this in that particular way.

- **Define**: the goal is to formulate a purposeful and practical problem statement. At this stage we're trying to bring clarity, find emerging patterns and the issues that stood up during the previous stage and to make sense of what's really happening, and dive deep into real problems.
- **Ideate**: this stage is about idea generation, the goal is to go wide and generate as many ideas as possible, we're not focusing on selecting the right one, this will be done later by testing on real users. Come up with 2-3 voting criterias and select a few ideas based on those criterias for prototyping.
- **Prototype**: depending on the stage of the process the prototypes may be as quick and cheap as possible, on later stages they may be more refined and accurate. The goal of those prototypes are not to deliver real value but to gather user feedback.
- **Test**: The goal of this stage is to solicit the feedback and better understand the user, get more insight into his behaviour, don't just observe, keep asking 'Why' question. Few concepts on how to test: show, don't tell, create experience, ask user to compare.

The core idea is multiple iterations that could be performed by cycling through a whole of 5 stages as well as iterating inside the same stage (for example, by building multiple prototypes).

The Innovation Value Chain Framework

To get a good understanding on how to better innovate in existing well-established organisation it helps to first diagnose what exactly is going wrong, one of good articles about this is [23].This article discusses the complexities of generating fresh ideas and achieving profitability from them, recognizing that different companies face unique challenges in this regard. Some organisations might excel in ideation but lack effective systems for commercialization, while others may have robust processes for launching new products or services but struggle to generate innovative ideas. The authors propose a framework for assessing innovation performance across three main phases: idea generation, conversion, and diffusion. This framework also identifies critical activities within these phases, such as internal and external idea sourcing, idea selection, funding, and company-wide promotion of ideas. By applying this framework, managers can gain a comprehensive view of their innovation efforts, identify weak links, and adapt best practices to strengthen these areas. The article highlights different scenarios where companies may be deficient in idea generation, conversion, or diffusion, and how addressing these specific weaknesses can lead to improved innovation outcomes.

This model helps organisations understand how innovation moves from inception to implementation and widespread adoption. Here's a brief overview of each stage:

- **Idea Generation**: This initial phase is all about coming up with new ideas. It involves creativity, brainstorming, and the collection of insights from various sources. The goal is to foster an environment where innovative thoughts are encouraged and captured.
- **Conversion**: In this stage, ideas are transformed into tangible outcomes. It involves evaluation, selection, development, and commercialization processes. The focus is on turning promising ideas into viable products, services, or processes through rigorous assessment and refinement.
- **Diffusion**: The final phase is about spreading the innovation within and beyond the organisation. This involves marketing, adoption, implementation, and scaling strategies to ensure the new products or services reach their intended audience and achieve widespread use.

Across this stages managers should perform 6 critical tasks: internal sourcing, cross-unit sourcing (cross-pollination), external sourcing, selection, development, and company wide spread of the idea

Birkinshaw's innovation value chain emphasises the interconnectedness of these stages and the importance of managing each phase effectively to enhance an organisation's overall innovation capability. It also highlights the potential barriers that can occur at any stage of the process and suggests that for innovation to be successful, companies need to excel not just in individual stages but in ensuring a smooth flow across the entire value chain. The organisational capacity to innovate is as strong as the weakest link in the chain. It doesn't matter how many ideas are generated if the selection stage is not working and it doesn't matter if the organisation has a state of the art development cycle if there are no ideas to start with. So the organisation should focus not on their strengths but rather on fixing the least productive links of the chain [23].

The authors propose three general groups of problems and ways to solve them:

- **Idea-poor companies**: build external and internal cross-unit networks. External networks can be solutions (like P&G, publishing product requirements to the network to find a solution to the product need) and discovery (like Siemens to find emerging discoveries and to match them to business opportunities), the key metric is diversity, not the number of contacts. Internal networks should be an ongoing dialog, occasional cross-function brainstorming won't work, people have to collaborate.
- **Conversion-poor companies**: most commonly companies do have official processes for managing ideas that grew-up to be risk-averse and bureaucratic. Two proposed ways are to build 'multichannel funding' and 'safe havens'. Multichannel funding can vary from small discretionary pots of seed money up to full-scale seed funds, the main goal is to move new ideas away from competing for main budgets that are utilised by existing programs. Safe havens is a way to protect new ideas from the corporate bureaucracy while still growing them in a cooperation, giving them corporate resources like sales channels or research facilities.

- **Diffusion-poor companies**: even when ideas are generated, developed and succeeded, in big organisations they are still facing internal resistance. Products may become a huge success in some markets but don't get traction from managers in the other divisions. To solve this top-management has to introduce idea-preachers and champion those ideas throughout the organisation by building networks of idea adopters, frequently contact local decision-makers and push this idea through the organisation.

R&D Management

Technology readiness assessments

The development of new system capabilities often depends on successful advanced technology research and development efforts. These developments face the major challenges of performance, schedule, and budget. The introduction of TRLs by NASA in the mid-1970s aimed to allow more effective assessment of and communication regarding the maturity of new technologies. Since its inception, TRLs have been embraced by various organisations, including the U.S. Congress' General Accountability Office (GAO) and the Department of Defense (DOD). This paper concludes with observations on prospective future directions for technology readiness assessments [24].

The formal TRLs system consists of 9 stages of technology maturation, each stage is characterised by different costs and associated risks that can drive managerial decisions. TRL-3 is a highly uncertain stage when some feasibility is established, but it's not clear if it will ever reach a production-ready state, where TRL-7 is the stage when most of the uncertainty is eliminated and more or less clear timing and budgets can be estimated to put the technology into real-world production.

- TRL-1, Basic principles observed and reported [24]
- TRL-2, Technology concept and/or application formulated [24]

- TRL-3, Analytical and experimental critical function and/or characteristic proof-of-concept [24]
- TRL-4, Component and/or breadboard validation in a laboratory environment [24]
- TRL-5, Component and/or breadboard validation in relevant environment [24]
- TRL-6, System/sub-system model or prototype demonstration in a relevant environment [24]
- TRL-7, System prototype demonstration in the expected operational environment [24]
- TRL-8, Actual system completed and "qualified" through test and demonstration [24]
- TRL-9, Actual system "flight proven" through successful mission operations [24]

Technology readiness assessments and TRLs have played a crucial role in managing the uncertainties related to performance, schedule, and budget in system developments. These assessments provide a structured way to communicate the maturity of new technologies, which is essential for effective project management and decision-making.

Knowledge management

One of the key points of R&D management is knowledge management, how institutional data converts first to the information and then to the knowledge. Without this flow any amount of data could be collected but it won't impact the bottomline. First of all it's crucial to distinguish these terms (some researchers distinguish more than three entities, but even this simpler categorization provides a good framework) and not use them interchangeably.

Data is a set of discrete objective facts about events [25]. It could be structured records of transactions, data tells nothing about why something happened or how likely it is to happen again. Data by itself has little relevance or purpose. It's most likely collected and stored in a specialised system that can vary depending on the amount and the pace of generation, the system that processes rare events will have different design and access patterns then the system that processes terabytes every hour. *Quantitatively*, data can be evaluated by the cost (How much does it cost to capture or retrieve a piece of data), speed (How quickly can we get it into the system or call it up) and capacity (How much will the system hold). *Qualitatively* it can be evaluated by timeliness (Do we have access to it when we need it), relevance (Is it what we need), and clarity (Can we make sense out of it) [25]. More data is not always better, companies tend to collect as much data as they can, but more data can make it harder to make sense of what really matters, data says nothing about its own importance or irrelevance.

Information is data shaped to have an added value ('inform' originally meant 'to give shape to'). Information is best described as a message (in the form of a document/audio/video/etc) that has a sender and a receiver and is meant to change the way the receiver perceives something. The goal of this message is to inform a recipient, this means that the recipient, not the sender, decides if this is really useful information or just a noise. Information moves around the organisation through hard (with definite infrastructure like wires, addresses, post offices etc.) and soft (informal, ad hoc) networks. Measuring information is a harder task, but those measures can include quantitative (connectivity, transactions) and qualitative (informativeness, usefulness) parameters as well. Unlike data, information has meaning. We transform data into information by adding value and shaping it in various ways, it can be: Contextualized, Categorised, Calculated, Corrected, Condensed [25]. It's also important not to confuse the information and the technology/medium that delivers it, having more information technologies will not improve the state of information by itself.

Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information [25]. It's often embedded in documents, repositories, routines, processes, practices, norms and exists within people. Knowledge is derived from information by such processes as: Comparison (how does information about this situation compare to other situations we have known), Consequences (what implications does the information have for decisions and actions), Connections (how does this bit of knowledge relate to others), Conversation (what do other people think about this information) [25]. The value of knowledge is that it's closer to action than data or information. The hard part of knowledge management is that it resides in people's heads unlike data records and information messages that could be stored somewhere. Information can move up the value chain to become knowledge (by adding a context, experience, comparison, consequences, etc.) and back (the most common case - too much knowledge that people are not able to make sense of).

Knowledge is a complex system and we should be aware of it, simple answers to complex solutions do not work, clarity often comes with a price of ignoring some of the essential factors. It works by building and recognizing patterns and allows reacting to similar situations quickly in a similar way. Accuracy can be created if people avoid comparison, but accuracy is short-lived, for example reliance on a single, uncontradicted data source can give people a feeling of omniscience but will lead to non-adaptive actions.

Unlike data and information, knowledge is subjective and contains judgement, people's values and beliefs have a powerful impact on organisational knowledge. Without reliable access to organisational knowledge, employees start to use what is most easily available. These available knowledge can be reasonably good, but in a competitive world it leads to lost competition, in the army it leads to extra death toll.

Military knowledge management challenges

Knowledge develops over time, through experience that includes what we absorb from courses, books, and mentors, etc. Experience changes ideas about what should happen into knowledge of what does happen. Effective knowledge transfer is a critical issue for the army, U.S. Army's Center for Army Lessons Learned (CALL) uses the term ‘ground truth’ to describe real situations experienced close up rather than one learned from theory [25]. Their experts are taking part in real military operations as learning observers and spreading the knowledge afterwards using photo, video, briefings and simulations. The key element of knowledge management is the "After Action Review" (AAR), even though it was first established as a tool to rebuild values of integrity and accountability that suffered during the Vietnam War. This exercise involves an examination of what was supposed to happen in a mission, what actually happened, why there was a difference between the plan and reality, and what can be learned from this experience [25]. It’s critical to establish the atmosphere of openness, collaboration, and trust between the soldiers and the officers involved and to quickly incorporate the results into the training programs and military procedures.

There are some barriers for knowledge management in the army that are unique to the military environment:

- **The scale of the organisation**. In Ukraine the defence forces alone are around 1M people, nevermind the defence industry and civil volunteers. In organisations of this scale, it’s hard even to know what you know and who possesses this knowledge. Researches show [25] that the maximum headcount that allows organisations to know one another well enough to have a reliable grasp of collective organisational knowledge varies between 200 and 300 people. The size alone is a huge challenge as a number of potential connections grows exponentially.
- **Secrecy** multiplies this challenge. The default mode of military and defence industry is operations security. The information flow is limited and restricted, sometimes governed by formal restrictions on classified information transfer, sometimes just the regular ‘don’t say too much’ mindset. Often, it’s hard to spread even the knowledge that bears no

secrets, due to the habit of military units not to share information when it’s not essential to their operation.

- **Lack of accountability.** Most of the military personal have no direct accountability for lack of knowledge sharing or acquisition. Even when some practices like trainings and operation reviews are formalized it’s easy to do it in a formal way that have no real value.
- **Lack of motivation**. Some elite units are eager to stay on top of their game, learn new tools and tactics, build internal knowledge sharing, train newcomers etc. But most of the Ukrainian army is conscripted and people who serves there has no interest investing their free time and resources in trainings even when this knowledge maximizes their chances to survive. This personal lack of motivation is multiplied by institutional hostility to initiative.
- **Lack of education.** Most of the soldiers has no higher education, significant proportion of them are conscribed from the rural areas and lack even basic education, even professional officers had substandard higher education in military universities. This makes it harder to acquire new knowledge and evaluate information value and credibility.

Summary

Acquiring and managing knowledge and technologies in R&D involves a strategic approach to harness internal and external resources, fostering an environment that encourages innovation and learning. Here are key strategies and practices for effective knowledge and technology management in R&D:

Establish a Knowledge Management Framework

- Create Knowledge Repositories: Develop centralised databases to store and organise knowledge. These can include documented research findings, patents, project reports, and lessons learned from past projects.

- Implement Knowledge Sharing Platforms: Use intranets, corporate social networks, and collaboration tools to facilitate the sharing of ideas and information across the organisation.

Foster a Culture of Continuous Learning and Innovation

- Encourage Cross-functional Collaboration: Promote teamwork across different departments to foster diverse perspectives in problem-solving and innovation.
- Recognize and Reward Contributions: Establish reward systems to acknowledge individuals and teams who contribute significantly to knowledge creation and sharing.

Leverage External Knowledge and Technologies

- Form Strategic Alliances and Partnerships: Collaborate with universities, research institutes, and other companies to gain access to new research, technologies, and expertise.
- Participate in Industry Consortia: Engage in industry groups and consortia to stay abreast of advancements and best practices in your field.

Invest in R&D Talent Development

- Hire and Develop Skilled R&D Personnel: Recruit individuals with a strong background in R&D and provide continuous training and development opportunities to keep them updated with the latest technologies and methodologies.
- Encourage Advanced Education and Training: Support staff in pursuing advanced degrees, certifications, and attendance at conferences and workshops related to their fields.

Utilise Intellectual Property (IP) Management

- Protect Key Technologies and Innovations: Use patents, trademarks, and copyrights to safeguard your organisation's innovations and gain a competitive edge.

- Monitor and Analyze IP Landscapes: Regularly review IP databases and industry trends to identify potential technology opportunities and threats.

Implement Advanced R&D Tools and Technologies

- Adopt Cutting-edge Research Tools: Utilise the latest research and development software, laboratory equipment, and simulation tools to enhance research capabilities.
- Leverage Big Data and Analytics: Use data analytics to mine large datasets for insights that can guide R&D decision-making and innovation.

Engage in Open Innovation

- Crowdsourcing Ideas and Solutions: Utilise open innovation platforms to source ideas, technologies, and solutions from external contributors, including researchers, startups, and the general public.
- Participate in Hackathons and Innovation Challenges: Organise or participate in events that encourage the rapid development of new technologies and applications.

Continuous Monitoring and Evaluation

- Establish R&D Performance Metrics: Define clear metrics to evaluate the success of R&D projects, including time to market, ROI, patent filings, and publication citations.
- Review and Adjust R&D Strategies Regularly: Periodically assess the effectiveness of your R&D strategies and make necessary adjustments to align with evolving industry trends and organisational goals.

Governmental level

Triple Helix Model

The original paper [10] introduces the Triple Helix model, emphasising the intertwined relationships between universities, industries, and governments in fostering innovation. The Triple Helix model serves as a methodological tool to understand innovation processes by focusing on the recursive overlay of communications among these three institutional spheres.

Etzkowitz argues that for contemporary innovation processes to be effectively captured, a Triple Helix of overlapping yet relatively independent institutional spheres is required. This model facilitates the organisation of research questions in relation to various models and metaphors of R&D and innovation. By focusing both on national contexts and on a variety of systems of reference for assessing R&D and innovation, the paper aims to inform policymakers and analysts about the potential of the Triple Helix model as a means of comprehending innovation processes.

The Triple Helix model is positioned as an essential framework for understanding how collaborative interactions between universities, industry, and government can lead to innovative outcomes and drive economic development. Through this introduction, Etzkowitz sets the stage for further exploration of the model's applications and implications in various contexts, highlighting its significance as a means to enhance our understanding of the dynamics of innovation ecosystems.

The paper and the model has a significant value for our research as it’s focusing on a larger picture on a governmental and intergovernmental scale, researching policies in science and technology and their impact on research and development. It also underlines the fundamental differences of those interactions during the wartime and how they are changing in the postwar period. The Triple Helix Model framework describes the reciprocal interactions between industry, universities and government in the creation of a modern knowledge-economy.

To better understand the model, it’s useful to take a look at three basic evolution types described in [26], two opposing and the balanced one:

- **Statist Society:** the government controls both universities and industry, the government is expected to take the lead in developing projects and providing the resources. The statist model is characterised by specialised basic and applied research institutes, including sectoral units for industries. Universities are largely teaching institutions, distinct from industry. Often the model has an objective for country to develop the tech industry independently of the rest of the world

- **Laissez-Faire Society:** Universities provide basic research and trained personnel, its role is to provide knowledge. The industry is supposed to find this knowledge with little to no assistance. The collaborations are forbidden, and the intense competition is expected and government interactions are limited to the cases of ‘market-failure’.
- **Balanced Model:** a prominent role for the university in innovation, on a par with industry and government in a knowledge-based society. A movement towards collaborative relationships, innovation policy is an outcome of their interactions rather than a prescription from the government. In addition to fulfilling their traditional functions, each institutional sphere also "takes the role of the other" [26].

Military Innovation schools

There are four main schools of thoughts that are helpful to analyse weather the organisation succeeds in military innovation [27].

- **The Civil-Military Model of Military Innovation:** developed by Barry Posen in the 1980s, concludes that innovation will only occur if civil statesmen intervene in military service doctrinal development, preferably with the assistance of maverick officers from within the service. Left on their own, military organisations will gradually stagnate. Civil top-ranks have to push military vision, conservative militaries are more likely to fail in innovations. Our experience showed that the injection of experienced civil managers and tech personnel into the Ukrainian army led to a spike in innovations.
- **The Interservice Model of Military Innovation:** states that the main driver for innovations is an interservice rivalry for the limited resources. It

should be most relevant when new operations or technologies are born that are not essential for the existing branches of the military, the rivalry emerges between those different branches and drives innovations. Like Ukrainian rivalry between SBU and GUR in naval drone usages in the Black Sea.

- **The Intraservice Model of Military Innovation:** focuses on the competition inside the same military branch, argues that military services should not be treated as unitary actors. Successful innovation requires a very specific alignment of service leaders, mid-level officers, and institutional arrangements to protect the longevity of a new innovation [27]. The key idea is to select excellent mid-level officers who are kin to use innovations and to provide them with high-quality professional opportunities, typically this involves establishing a new arm or branch of service. The key idea is to create an alliance between senior and mid-level officers. Ukraine has also shown how excellent low and mid rank officers were promoted to senior leadership positions especially in high-tech and knowledge-intensive units.
- **The Cultural Model of Military Innovation:** argues the culture is a main driver, that can impact in three main ways: planned change - when the senior service leaders reshape the culture to drive innovations, reaction to external shock and cross-national professional military culture can lead organisations to emulate one another. Once the culture is set it provides opportunities to some innovations but blinds organisations to another. That's the peace Ukrainian army is lacking, the culture of innovation was not well understood by the senior leadership even though they felt the need and the organisation itself still has old soviet-style managerial and legal structure that inhibits innovation spirit.

Let's notice that all four schools of military innovations and most of the major studies argue that military organisations are intrinsically inflexible and as major bureaucracies are designed not to change, meaning they need a huge stimuli to innovate either by some form of competition or civil/military senior leadership push, assuming a top-down approach. Even though there are plenty of known cases of the bottom-up innovations, there are no well-established models and no consensus on how to induce and promote them in a scalable and predictable way, those innovations are viewed as an anomaly. Bottom-up innovations shine when there is a top-down support, either when tactical units are getting new technology and invent brand new ways of exploiting it or when innovations created on the field level are acknowledged, promoted, and scaled by higher ranks.

Conclusions

Defence industries around the globe are struggling with innovations due to several reasons: underfinancing after the end of the cold war; significant consolidation that killed competition; the intrinsic rigidness and conservatism of the military organisations; and finally it's a lack of the necessity, when developed countries with deep budgets and S&T infrastructure don't feel the threat and are more prone to invest those recourses into more competitive and lucrative markets and into more productive economy segments. Another side of the problem is that the governments and bureaucracies are much less efficient then private markets and most of the projects end up overdue and with significant budget overruns, Ukraine is not unique in this but it doesn't have time and spare budget for this inefficiencies.

The R&D and innovations management are well-studied fields of knowledge, but they mostly focused on a private sector where those practices can bring measurable competitive advantage. Considering Defence Innovation Framework Ukraine has a set of catalytical factors (Existential threat and Top-Level Leadership Support) that enables it to grow radical innovations. Leveraging those enablers, best practices from the private sector R&D and innovation management, staying aware of the barriers we can build the framework for

Ukrainian defence industry to build innovation pipelines that will bring strategic advantage on the battlefield.

Main Part

Methodology

Using the tools from the research part we are going to build reflect on the successful cases of military innovations, choose what was helpful and how to scale this. We'll analyse Ukraine from the Defence Innovation Framework and Innovation Value Chain Framework perspectives to highlight what works well and what are the key problems and what part of the problem can be fixed in the short term to have maximum value with limited time and resources.

Reflection on personal innovation experience

Idea-generation and development

The idea itself looks straight-forward and people from the outside could be surprised by how simple it was. But the best way to get it right was to have personal experience in the field. We started with analysing messages that were coming from the battlefield and understood that we can improve the process using modern tools. But to deeply understand the problem we had to spend months with a relevant combat support unit, this experience was essential for the future of the product and it's hard to imagine how a private-sector contractor could afford working in those conditions. That's why we recommend establishing knowledge transfer and cooperations with the military that can provide quick feedback loops.

After gaining enough experience and building a prototype we had to contact a dozen people who had the pain that we were about to solve. All those people didn't just describe the pain, but also were instrumental to help get missing pieces of technology, connecting with relevant developers, companies and people who had resources and power to grow that product. That was a surprise from the point of view of the private market, but it's very common in Ukrainian armed forces where people are interested in solving the common problem and are much less interested in material benefits that they can get from those resources. It's necessary to collect information from different units working in different conditions, we saw opposite examples when the projects were built on the expertise of one unit and it was hard to scale because other units operated in different conditions, had different processes and level of expertise that was too low to use the product or to high that the product had a limited value.

This approach can be scaled, the last hackathon organised by the Ukrainian Ministry of Defence showed the non-surprising result that after almost two years of the full-scale invasion developers are still trying to come up with the ideas that are far from what real soldiers need or something that won't work outside the laboratory. The other common pitfall is that different teams are developing the same solutions over and over again internally, that is ok in the competitive market paradigm, but in Open Innovations terms it could be solved once for everybody.

Counter-intuitevly, the Open Innovations can be a vital framework for the Ukrainian defence sector, by facilitating network-building, knowledge-sharing and institutionalising open innovations centres. Choosing this way we should manage the risks associated with it.

The main risk factors are IP-management, dealing with sensitive information and national cultural specifics (ukrainians have trust-issues and building networks is not their natural way for doing business).

Product management

The other key factor for our product success is product-management orientation. As described in the first part, the successful Open Innovations organisation should employ two kinds of people: Innovations leaders and Intrapreneurs. While finding resources, technologies and clients by building a network of actors was not a problem, the execution part was a weak spot for many teams.

Ukraine had a huge IT sector before the war, but it was mainly development-oriented, dominated by the IT outsource industry and even product companies that had their R&D centres in Ukraine mostly built engineering expertise, keeping product-management, sales and marketing abroad. That leads to a low product management culture. Even though we have thousands of high-skilled engineers that can solve any problems, we don't always know what those problems are and how to build products that solve them in a human-centric way.

In terms of the Innovation Value Chain it means we have less problems with the development but ideas generation, selection and diffusion are struggling.

Ideas generation was covered in the previous section, there are plenty of problems waiting for solutions in the field, the main issue is to build the link between the frontline units that know everything about the problems, to R&D centres that can take those problems and convert them to solutions.

Idea selection is a weaker section, it's common to solve not the problems that are really painful but rather the problems that are easy to solve. We witnessed an infinite resources mindset among the top leadership, when the selection process was formal, it had some parameters that were meant to prioritise these ideas, but in reality we were building everything we could imagine. That meant that important but complex solutions were under prioritised to build something quick and shiny. It's essential to build a better and objective framework for idea selection and prioritisation, relevant best practices could be found in venture capital funds and in the SBIR program, but it's a much more tricky step that it seems, to objectively compare an HR system against a combat support system for example.

And last but not least is a diffusion step. Ideally, innovations should be developed as they are done in the private sector with quick feedback loops, short iterations and close collaboration with the end consumer. It's not always attainable in the military, due to high regulations and small margins for errors. The defence industry is closer to waterfall practices and for a good reason. But after the development is done - the results should be passed to the troops and it's not always easy: it's common to have a top and middle officers resistance due to their conservatism, possible corruption or inefficiencies that may get unwanted highlight or just the gap between working bureaucracy and a new tool; it can be sabotaged by the troops on the ground due to the lack of understanding and the need to learn new tactics or tools; new tools and tactics most likely won't be ideal and more iterations of feedback gathering and improvements may be needed; and even without friction it takes time to propagate some innovations in the organisation of the scale of Armed Forces of Ukraine.

Diffusion is a big problem and it's crucial to work with both championing the new product, collaborating with active and supportive leaders of different ranks and using top-level orders. It commonly lacks the balance, innovations either promoted by the order to use them and is facing a resistance and inventiveness in how to evade orders, or it's just a championing and marketing that sometimes lead to huge gaps in diffusion when most of the units are using them but some part of conservatives are avoiding it. The best way to spread innovations in the military is to combine both practices and work both top-down (as the default way in the army) but to promote it as much as possible amongst the bottom level to build pressure on the middle ranks (who create the most friction from our practice).

Internal competition

Another common problem is a lack of competition. It's clear that we have limited resources and it's not productive to have different teams working on the same solution for the same problem. It's a clear dichotomy with the thesis described in the idea selection paragraph and there is no ideal solution. But after idea generation and selection it's common to see how one selected team starts working on a project with no competition to save resources. But we know how lack of competition correlates with the quality of the results in the private sector, why should it be any different in huge governmental bureaucracies? As discussed before, it's hard to select the problem, it's even harder to select a solution for the problem and even more so to select the team that should deliver the best result. In the case of our product, there were at least three other competitive projects: solving the same problem from a few different perspectives, copying good ideas and learning from the mistakes of one another and being motivated to move as fast as possible to stay on top of the game. But the projects that are initiated from the top are most likely done in the opposite way when one team develops the solution without any objective way of knowing if this solution is better than alternatives and is it developed in the most efficient way possible.

It's hard to come up with one-size-fits-all solution for this issue, but we'd recommend to take a look at the SBIR program in the USA, where the DoD is publishing the description of the problem, than different teams are competing in describing the solutions on the paper and best of them are selected to compete for the development of the prototypes and only after the prototypes are ready the DoD decides what they should invest into. The same logic could be applicable in our case: no need to develop different full scale products for the same problem but the competition should be fierce at least until the working prototypes are ready to be tested and selected.

Roles and people

It seems obvious but worth mentioning, the mobility between roles and even more so between units in the Ukrainian Military is severely limited. And it's common to see the wrong people in key roles. Unfortunately, this problem doesn't have any easy solution so we won't spend a lot of the time focusing on this issue, but it is worth mentioning that in the innovation cycle there are some key roles that require people with different traits. Those key roles are idea scouts, idea connectors, program, product and project managers, idea champions. Those are people responsible for gathering ideas, connecting those ideas with people capable of developing them, people with the focus on some particular field that can analyse and select the ideas, people who can turn ideas into products that are solving the problem, people who can execute the plan and deliver this product to production, and finally people who can push this products through the organisation. These roles require an absolutely different set of expertise, maturity, personal traits and hierarchical ranks. In the military it's common to see people who could do great in some other role but they are doing something else due to their military rank that is too high or too low or just because they were put into this role without any significant consideration and now it's hard to change it due to the bureaucracy.

OODA Loop for innovation

Another well-known concept in the army is an OODA (Observe, Orient, Decide and Act) loop that is used in military tactics. But it's a good idea to apply it to innovation cycles as well to make sure the organisation is developing something that is really useful. As our experience shows, sometimes great initiatives that really were revolutionary at the beginning were swamped by the execution. Let's analyse two different projects:

Project A, grew from the idea that we are lacking some transparency on human resource management, had a successful launch and gathered a lot of interest, but somewhere in the middle of R&D process lost the momentum. What happened was that the top leadership that initiated this project had a vision but were not involved in the project development, middle management that was responsible to deliver the project developed it without questioning what exactly are we solving. As a result we faced a half-finished project that had some development done but no-one really had a unified vision on what problems it should solve and how the finished result should look like.

Project B, somehow was not in the focus of the top management, it was envisioned as one of the infrastructural projects that should add some technical capabilities to the organisational tech ecosystem. No wonder, it seemed hard and boring to non-technical top management, it never showed up in roadmaps and the resources were allocated on the leftover basis. When we were analysing the portfolio of the projects we realised that this should be one of the top-priority projects as the technical capability that should be provided could unblock a lot of the other products. After we restarted the research phase to understand how to deliver this capability we also understood that it can be delivered as an MVP in 4-6 months instead of the initial estimate of 1-2 years. What was going on there, again the initial premise that this project ‘looked similar’ to another governmental project, so we should develop the same one. And this was formulated as a task to the tech team that never bothered to ask ‘why’, they just started developing what they were told, instead of analysing the problem and understanding that those projects were only similar from some helicopter-view and in reality were solving two absolutely different problems.

Both these projects were swamped even though they both had a significant strategic value. The projects themselve and the problems that slowed them down were absolutely different. We could argue that those problems could be mitigated by a more sorrowful research and problem statement at the initialisation phase. But assuming we already made this mistake, and rest assured, whatever initial research you will perform you will make mistakes, they should not be lethal to the project. And this is a pain to governmental projects that should follow strict waterfall design rules multiplied by the reluctance of the actors to push-back in the hierarchical structure of the military organisation.

We propose to manage these risks by OODA loop, that should be done periodically to ensure that the project is going in the right direction.

Observe: constantly observe the context, if nothing is changing are initial assumptions still correct, any new technologies, competitors or tactics are emerging that could affect the project’s outcome, etc.

Orient: where are we in the project’s life cycle, who are our customers and what are their problems, is this information still relevant, how are they solving them now, how are we going to change it, are there any other ways to solve those problems, who will benefit from this, etc.

Decide: This is critical to military organisations, as mentioned before, lower level executives are rarely empowered to make decisions on their own, thay are more prone to search for support to diversify the responsibility at best, mostly they will just continue to execute even if they've got an insight from the first stages due to hierarchical structure and 'that was an order' attitude. So we have to pay much more attention to this stage of the loop.

Act: make the changes according to the decisions, to align the project with a new context. Easier said than done, in a bureaucratic world it's sometimes easier to finish the project and start from scratch than to make the changes. In the ideal world that should be changed, and the lean practices should be legalised, but in the current world we should at least make sure, there are people with power and knowledge who can drive those changes. Repeat the loop.

Designing defence innovation system

Main considerations

Innovations can happen spontaneously; indeed they do happen commonly in the war-time reality of the defence sector. The question is how many of those innovations are recognized, developed, and scaled properly. The trick here is to build a system where they happen reliably often, wherever they originated they should be studied, tested, developed as completely as possible and delivered to the frontlines. Innovations are often associated with novel ideas, the idea itself is not an innovation without a proper implementation and value capturing. Sometimes innovations are reduced to public relations when some good ideas are shown to the public without even going to real development or produced at scale. Sometimes the idea is not novel at all but rather the common sense or well-known best-practice being finally recognized and implemented (like allowing digital spreadsheets instead of paper journals in 2024 Ukrainian army).

Next we'll focus on the creation of software solutions, this is the type of innovations we have a lot of experience in both civil and military. Most of the conclusions should be relevant for hardware as well, in reality they are entangled. Another key point worth mentioning, the model is focused on the war-time innovation management, it's not clear if this will be applicable for a peacetime defence industry.

According to the Value chain framework, working innovation model should keep in mind four separate stages: idea generation, selection, development and diffusion, constantly monitor what's working and what's lacking behind, in this framework the weakest link matters the most, no need to improve idea generation if the weakest link is selection or development.

It's relatively easy to build a pipeline of new ideas and problems, one obvious way is to listen to the frontlines, there are a lot of problems and inventions, we need to build a pipeline from bottom to the top level where those ideas can be selected. Another obvious way is to look up for the partners and the enemy, the third option is the job for intelligence services. We won't cover it in this work, but we still need to build a reliable pipeline of how the idea could get from intelligence officers to wherever the selection stage is taking place. All three scenarios are aligned with the concept of innovation brokers (idea scouts and idea connectors). We need to establish roles responsible for scouting the ideas both internally in the army and externally: abroad and in the Ukrainian private sector. And idea connectors - more mature, experienced and higher-ranking people whose job is to do the initial screening and connecting people with ideas with people who can potentially turn those ideas into projects.

The next stage is the idea selection, people who can officially initiate the project are top generals and the minister of defence, so the idea selection should be done at the level of their deputies. Currently we see a chaos in idea selection, there are some formal points that should be filled in the process of new idea presentation, but they are subjective and have little value. The challenge here is to build an objective framework to analyse and prioritise the projects. It's hard to imagine some global way to compare apples to oranges but at least the framework should work in one type of military.

Development is the best understood stage, we have a lot of conscripted developers and managers with good experience and even some specialised units. Development is not the weak link by far, so we won't focus a lot on what could be done better, even though there are things to improve. The most significant point of improvement is to raise the product management expertise. Most of our development expertise is outsource-based, where product management is something external, the customer is responsible for product management, developers are only responsible for delivering the order. We need to embrace startup culture and think product-first, but we're doing what we can do best. It's also reflected in the top-leadership policies where the software design committee was launched before the product committee, we'd argue it should be vice-versa, first *what* we want than *how* we do this.

Finally the diffusion part. As discussed before, it's not the strongest link as well, the army knows one way: to order to use something. But in reality it doesn't work as expected, especially in times of war it's easy to ignore 'some stupid commands from people who don't fight'. We're lacking communication, feedback gathering and promotion, training, championing, etc. The real path for diffusion will differ for different military and innovation types, target audience, etc. but the framework should include some go-to-market strategy that will address problems like logistics, awareness, education and friction.

Innovation model for Ukrainian defence industry

Institualization of the Innovation Value Chain

Idea gathering, Selection, development and diffusion should work on an ongoing base with clear strategic alignment (see Brazilian case studies). Our hypothesis is that idea gathering and selection are the missing parts. Currently

MOD and Army are focusing on what developments are on the market, skipping vital stages of what real needs are.

Partially idea scouting is already starting the institualization, but as always, wrong people at wrong roles without relevant training and guidance, just ‘hey, you’re the IT-guy, we need somebody responsible for innovations, now it’s your duty to fill some reports that we don’t understand’. Idea scout should be an officer who understand current state of the art in military tech and tactics, who works close to the field staff, talk to soldiers and officers on the tactical level and is able to recognise what ideas or problems are novel and worth attention and can bring the value back to the troops by sharing available knowledge of the innovations applicable for the particular mission planning. This will allow not only in providing both problems and innovative ideas bottom-up but will increase the informal way of innovation diffusion to frontlines. But in order to achieve this the role should be a full time officer on a brigade or at least operational-tactical forces grouping. And it’s crucial to complement the role with the relevant idea connector - people who are able to deliver worthy ideas to the top ranking generals or MOD servants and make sure the idea gets its attention.

Another missing part is the idea selection, it’s not clear how the ideas are getting selected now. Sometimes the projects are not solving any real problems, sometimes they do but in an efficient way. It’s not always clear how to prioritise projects in an objective way, they differ in many ways: by the target audience, by the problem, by the cost to build and to maintain, by the time to deliver, and so on. In general, it’s hard to compare apples to oranges: when one project is a sophisticated human resources management solution that will operate in a classified perimeter, and the other is a simple unclassified program for electronic warfare. To solve this issue we recommend splitting the problems by categories first and to compare apples to apples next. First step is to classify the problem using the NATO C3 taxonomy [28], this will help us compare projects at least in the same category. But even in the same category we’ll have different audiences and needs, for example ‘Human Resources Applications’, we have a classified solution that works on a strategic level and simple applications that automate day-to-day operations for a tactical unit, and different solutions in between. All those systems are still hard to compare but at least we have a similar domain and set of stakeholders to begin with. Another problem will be to compare and prioritise categories between each other. In the business world it’s easier, you can always distil these choices to one question: ‘what will bring us more money’, but in the military it’s much more complicated to calculate the ROI. We propose to prioritise these categories and preallocate some resources based on this prioritisation, then to plan those resources inside the category. To choose best projects in the same category we propose to use the SBIR open approach: formulate problems (that we previously collected at the earlier stages), allow participants to come up with different solutions, chose a few to build the prototype, to better understand both the viability of the proposal and the ability of the team to execute, don’t stop on the one candidate, drive some competition. And don’t forget to include a total cost of ownership to the calculation, it’s tempting to say: ‘hey, we have thousands of the IT guys conscripted, we can build everything’, but this everything will have maintenance costs and the guys will not be conscripted forever.

Implementation

In this part we’ll reflect on the project built and scaled by our team, analyse how it’s aligned with the framework discussed before, highlight the success factors and what could be improved next time.

Idea generation. The idea was raised by people serving in this particular military field for years. And for years there were no good solutions, it was so surprising that we didn’t even believe at first, and lost at least three months of creating other solutions that seemed more promising. But generally there were countless ideas that were generated even in our small unit, focused on one particular category of the NATO C3 taxonomy, in fact, we generated much more good ideas that we could even manage, forget about developing. So as discussed before, idea generation is not the weak link of the framework, there are a lot of processes that can be enhanced and people in the field know them very well. But what is missing mostly is the link between people in the field who know the problems and people in the headquarters who have the capacity to initiate and oversee the project to solve those problems. In our case we were somewhere in the middle: we were not connected to the higher headquarters (at least at first) but our unit commanders were incentivised for innovations, so they just gave us the opportunity to build projects using our own resources. That’s more than an average soldier in the field will get, but even this is not enough to get sustainable innovations: we were lucky to have good military professionals around to consult, significant experience in R&D from civil life and a good network of people who agreed to help on a volunteering basis. If we want to build these innovations at scale, we need to build the link between tactical units and headquarters. This is the job for idea scouts who will work in the fields, sometimes literally going to the frontlines watching how things are done and what problems there could be solved with the technologies. And idea connectors - higher ranking officers with good connections who can deliver those ideas to the relevant people in the top headquarters.

Idea selection. This is the tricky one, as discussed before this is the weakest link in the current state of the military innovations in Ukraine and, arguably, the hardest one to solve. In our experience this stage was not ideal as well, as mentioned in the previous stage, we had the successful idea at least three months before we started even working on some kind of a prototype because we didn’t have enough capacity to do everything and wisdom to select what will really have the biggest impact even in one domain. Imagine solving this problem when you have to compare different problems from different domains on a scale of MOD.

As an example we can take the domain of human resources applications, we have common tactical units like infantry brigades and battalions will have common tasks to automate, special operation units will have similar tasks but the data will be classified, that makes it impossible to use the same application as infantry, higher headquarters has absolutely different needs and are using different software, some parts of the logistics are automated by SAP and needs a separate way of managing the personal related to its operations and so on. Selecting the best solution for each of those subdomains is manageable but not a trivial task (gather different vendors and developers, calculate the total cost of ownership, make some common policies to prioritise inhouse development vs outsourcing or acquiring working solutions etc). But how to prioritise strategic level vs tactical infantry vs SOF needs is not something you can do by simple and objective comparison, you need some IT strategy in place and the communication between different, potentially unrelated, stakeholders. Now imagine, the HR applications domain is just one of 130 domains of the NATO C3 taxonomy, and you need to somehow prioritise the strategic human resource accounting vs tactical system for electronic warfare support, that share no common stakeholders or objectives.

Now that we understand the scale of the problem, let's think of the solution. First of all, we have to realise that 130 categories of the taxonomy with a variety of distinct problems inside each category can easily lead to over a 1000 different IT solutions needed to cover those needs, each solution is not only about the budget to spend for acquisition or development but it’s also human resources to manage the lifetime of the product by rolling out to the production, support and maintenance, education, etc. Unfortunately, the conclusion is that it’s not feasible to solve all those problems. Arguably, just a few percentages of the problems will gain enough attention to get a relevant solution. So, the biggest impact we can achieve is to focus on those problems that will have the most impact on the battlefield. That simple and seemingly trivial conclusion is not something that is so obvious, in fact, our experience shows that projects are selected by some absolutely different criteria: the impact on public relations, the project is solving some problem that the particular high-ranking stakeholder has, the project is comparatively small and cheap, etc.

The narrative itself is mostly about: 'some actor X is presenting the solution Y, do we like this project or not and how easy it will be to implement it'. This leads to three main problems with the selection stage:

- The stakeholders are trying to choose between the projects that are impossible to compare, at each point in time they are presented with different solutions with different costs, timelines and readiness level for different problems in different domains.
- They ignore the fact that the most painful problems may not be presented with the solutions and the selection does not represent the most needed products at all. And whatever choice is made it will be suboptimal.
- After the solution is chosen, there is zero competition, just the team or the vendor that presented the solution. As discussed before, the lack of competition leads us to worse timelines, budgets and the quality of the product in general.

The narrative should be changed to more problem-oriented rather than solution oriented, we need to gather problems and prioritise them against one another, make predictions how the solution for each problem can affect the battlefield and start searching for the solutions for the selected problems. The good example here can be a SBIR program: the MOD is analysing all the problems, prioritising them, selecting the most impactful and publish them in the open competition, the competitors provide the whitepapers with the proposals for the solutions, few proposals for each problem are selected for the POC stage, where they compete for what will be selected as a final solutions and will get a contract. The competing solutions at the POC stage should answer the three main questions: what impact the solution will have, what will be the total cost of ownership and how this solution will scale. This eliminates the mentioned issues and shifts the focus towards the most essential problems.

This approach is promising, and may have a dramatic impact on overall digital military landscape, but it's also much harder to administer, some issues to keep in mind are:

- We need a way to collect the problems, this can be achieved by introducing the idea scouts, by some form that allow soldiers to submit their problems and ideas, by analysing the current state with experts and relevant headquarters, etc. It's not a significant new process and it's costly to perform.
- The prioritisation of the problems may be less costly than the collection, but it's hard to come up with some objective metrics. The most obvious should be: 'how it affects the battlefield and how many lives and assets the solution to this problem will save'. But sometimes this will be hard to assess.
- Each problem will have competing solutions, so less products will reach production, and the initial costs may be higher, even though it should be compensated in the long run by choosing better products with the total cost of ownership in mind.

Let's now reflect on our experience with the particular product. Our unit was focused on one particular category of the NATO C3 taxonomy, so we didn't have the problem with choosing between different categories. But as discussed before, we had a dozen good ideas to bring new capabilities to the field. We were focused on the problems from day one, and were gathering them and trying to analyse what problem will have the most impact in the particular field. The negative side was that we were prototyping the solutions to each problem that looked promising, the only reason we were doing it was to show some results. We understood that it's counterproductive but the higher officers demanded some demos. After we selected half a dozen problems, we started the discovery phase and were looking for who is already doing something in this direction and if there are some products on the market. Some of the problems were covered by existing teams and saved us a lot of effort, even though we had a hard time explaining to the commanding officers why it's not a good idea to develop the same capability inhouse. Finally, we found the problem that didn't have any good solution on the market, we made a research and found that there are a few solutions that were used by the troops but they are outdated and are not efficient, and there are a few other teams that are developing the solutions to the same problem but they chose the way the we thought was not optimal and we decided to invest into the development of the product and to compete with the those other teams. The interesting distinction of this competition compared to the private market was that competitors were ready to share the knowledge, ideas and experience, they believed in their projects but understood that they are fighting the same war and the final result is much more valuable than personal ambitions. After the POCs were done, it was time to consolidate the efforts, different projects merged to use the best parts of one another and to focus on those sub-problems that were best solved by their teams.

The success factors of this stage was:

- focusing on the problems and not investing in something shiny when it wasn't necessary
- The competition that motivated one another to move faster and challenge the ideas.

What was missing:

- Costs. We did not understand not only the total cost of ownership but even such essential metrics like the cost of the client or transaction. Eventually, we built a great system that was used by most of the frontline that was at the risk of closing because the costs were so high we didn't know how to cover them. If that risk materialised, that could cost the lives of the soldiers.

- Think first, prototype later. We spent too much time prototyping solutions for the problems that we abandoned after. It would be much more efficient to analyse the problems, prioritise them, research existing solutions and do the POC only when needed.

Idea development. As discussed before, this is currently the strongest link of the chain and we won't pay much attention to it, but the framework demands for constant review of the state of each link. Now we have no problem with it, but next year we may not have this high number of qualified engineering managers from the civil sector in the army, and the balance can shift.

So after we've selected the best ideas, it's time to develop the product that will solve the problem in a defined by the prototype way. Two main problems we observed were: outsource mindset and waterfall-oriented bureaucracy. Those two problems are of a different nature, let's discuss them separately.

Ukraine has a lot of qualified developers and managers but most of them are from the IT outsource, where the business model is not about building the products but rather about selling the billable hours. They are great at project management but not at product management. They don't have the expertise of creating the product for the customer, building an empathy, understanding what the market really needs and how to solve the problems in the most efficient way. That was a skill that eventually helped us win the competition, by focusing on the customer needs, constantly communicating with the users, observing their work, building the hypothesis and quickly iterating with minimum viable products or features that helped us test the hypothesis, invest in thous that got traction and discard others that did not (nevermind how much we loved our ideas). Those steps are well understood by the western startup world and described in [29] and [22]. Embracing startup culture for military software can significantly increase the value, but here comes the second problem.

Waterfall-based bureaucracy is killing all the best practices created in software development. We were lucky enough to build the product with our own volunteering team and budgets, where those who served were taking roles of product managers, data scientists and backend developers, they worked with real-world data and volunteers worked on some dev data without touching anything sensitive. But it's not a scalable way to innovate, unfortunately Ukrainian laws describing how software solutions should be developed in governmental sectors including military predates agile. We can describe some hacks to avoid this, but the only real solution is to change the laws, and this is far beyond the scope of this work.

Idea diffusion. The last part is about marketing in the broader sense. After the solution is ready for production we need to make sure it's propagated to the users. As discussed previously, depending on the product you can face different sets of problems and inner frictions, even deliberate sabotages. In the army there are two main ways to diffuse the solution: top-down when the top leadership orders to use something or bottom-up when junior officers are starting to use some innovations, sometimes quietly without any formal permissions. In the ideal world we should use both mechanisms. Our case was one of the lucky enough to work this way, we started with our own units, than a couple of neighbours joined, started championing and spreading the word, but we were facing some friction from middle officers: even though our product was gradually maturing and got a real traction, some of middle officers started to disallow using it as they were afraid this of data leaks and legal consequence. At that moment we caught the attention of the highest generals who were searching for innovative solutions and with their support we spread this product to most of the troops in less than a year, but even after a year we had around 20% of units who continued to resist the changes. This is the real success case of both top-down and bottom-up approaches working in harmony, without top level support or bottom initiative the diffusion will not have a desired effect and will jeopardise all the efforts invested into finding, selecting and developing the best ideas. This is the last mile problem, when all the work is done but without the last step it will all be for nothing.

Conclusion

Military innovations are struggling around the world, it's not a unique problem to Ukraine. There are some objective reasons to this fenomena:

- The massive consolidation (and as a result, lack of competition) in the defence industry that happened in 1990-s as a result of the budget contractions that were the answer to the end of the cold war era.
- S&T and R&D shifted towards more productive sectors of the economy and drove the innovations in the private sector. The old dogma that all the high-end innovations are happening in the military and then some of them are diffused to consumer markets was broken.
- Developed countries that could potentially afford disruptive innovations in defence industry lost the catalytic factors like external threats or top-leadership support, and most of the countries who had those stimuli to innovate didn't have the capacity: R&D and S&T infrastructure and deep budgets.

As a result, most innovations we see in the defence industry are incremental, they are notorious for missing deadlines by years and exceeding budgets by billions. They are highly regulated and have the only customer to sell to - the government, this is not a favourable strategic business position, so in order to survive, it's dominated by huge, sometimes state-owned corporations, this doesn't sound like an innovation-friendly environment.

But Ukraine showed surprising results in military innovations both technological and organisational, software and hardware. Those innovations were the result of thousands of highly skilled managers, entrepreneurs and developers who joined the Armed forces to fight the existential external threat and the support of the top leadership. Those two factors placed Ukraine into the unique position when a poor and underdeveloped country with high bureaucracy and low institutional capacity was able to create disruptive innovations. Most of those innovations happened against the system and even more potential innovations were buried by the bureaucracy and inertion. To sustain and improve innovation rate we need to change the system that should become more supportive.

In this work we researched different methods and frameworks for innovations, discussed how defence innovations are done in different countries, how non-defence innovations are done on governmental and corporate levels. We chose the simple yet powerful framework: Innovation value chain that helped us analyse the state of the innovations in the Ukrainian military and reflect on the success case of our military software product through the lenses of this framework.

This analysis allowed us to find the weakest link of the value chain and focus on it. We believe this is the bottleneck of the process and focusing resources on improving this stage will have the best return on investment. The stage is idea selection, where we propose to not only pay more attention to what opportunities we are choosing to pursue, but more importantly to shift focus from the projects that are available to the problems that are most painful. There are different ways to address this problem but we recommend to use the SBIR open innovation challenge experience from the US defence industry case that will drive more competition to solving selected problems in different innovative ways that will not only solve what's really important but to do it in the most efficient way.

This change will not be easy, it will need some institutional changes and a mindset shift, but it's manageable with the right top-level support. Another side note that should be essential to the evaluation is the total cost of ownership, which is commonly neglected currently but will become a problem for future sustainability and innovation rate.

And finally, the framework should be done with constant revisioning (see OODA loop), at the time of writing the weakest link was idea selection and fixing this stage was important, but the situation can change and development or diffusion can easily become a real bottleneck if the experienced developers would finish their service time or the new leadership team will not be as supportive to innovations as the previous one. In that case attention should be shifted to the most problematic stage instead of improving what we are already doing well.

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