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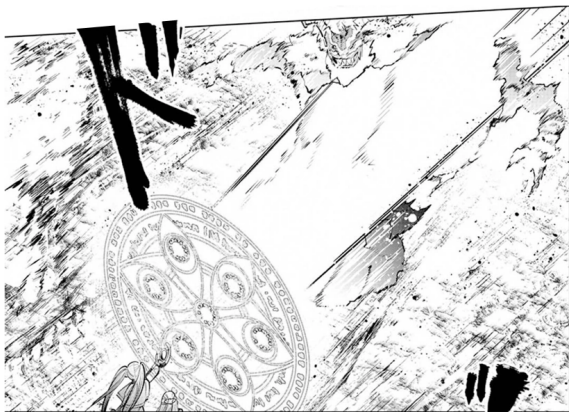
Zoltraak and the dynamics of military innovation: technological diffusion, defensive adaptation, and relative obsolescence in *Frieren: Beyond Journey's End*

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Technological innovation does not end at the moment an artifact or system is created. The literature defines military innovation as a change in operational practice that produces a significant increase in military effectiveness (Grissom et al., 2016, p. 1), and that effectiveness depends on how the innovation spreads (Horowitz, 2010), on the responses developed by adversaries, and on the adaptation that occurs during the conflict itself (Farrell, 2010). A technology that initially produces significant advantages may therefore lose part of its superiority once its principles are understood and its effects are neutralized. This paper calls this process relative obsolescence: the reduction of a technology's advantage in the face of changes in adversaries' capabilities and in the environment of use, which does not imply that the technology disappears or becomes useless.

This dynamic can be examined through Zoltraak, an offensive spell featured in *Frieren: Beyond Journey's End*, written by Kanehito Yamada and illustrated by Tsukasa Abe. Developed by the demon Qual to pierce the magical defenses and magic-resistant equipment used by humans (Yamada & Abe, 2020a, p. 9), the spell was later investigated by human mages, incorporated into their magic system, and met with new defensive resources (Yamada & Abe, 2022a, p. 18). The problem can thus be formulated as follows: how can a technology that was initially able to overcome its adversaries' defensive systems be incorporated by those same adversaries and subsequently have its relative effectiveness reduced by the adaptation of the means of protection?



Frieren eliminates Qual. Panel from the manga (ch. 5: Killing Magic; Shogakukan, 2020).

The analysis does not intend to equate the spell with a real weapon system. The trajectory of Zoltraak is reconstructed in order to identify conceptual mechanisms (initial advantage, investigation of principles, diffusion of knowledge, and transformation

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of the conditions of use after countermeasures), which are then treated as working hypotheses and confronted with the literature and with two documented cases of drone employment, whose recent trajectory offers especially suitable empirical ground. The two-step design is justified because the work presents a clear sequence of innovation, diffusion, and countermeasure, whereas the real cases supply the contrast needed to assess to what extent fiction illuminates historical processes and at what point the analogy ceases to hold.

The paper is organized as follows. The first section examines the initial advantage of Zoltraak and its appropriation by humans; the second section analyzes routinization, diversification, and the relational character of the process; and the third section confronts these mechanisms with the drone cases.

ASYMMETRY & APPROPRIATION: from Qual's innovation to human knowledge

Zoltraak was developed by Qual, called the Elder Sage of Corruption and a member of the Demon King's army. In its original configuration it was known as a form of killing magic, able to cut through human magical defenses and magic-resistant equipment (Yamada & Abe, 2020a, p. 9). The narrative conveys its gravity in quantitative terms: roughly eighty years before his death, Qual caused the death of 40% of the adventurers and 70% of the mages in the region near the Größe Forest (Yamada & Abe, 2020a, p. 9).

These fictional figures are less informative as magnitudes than as evidence of how the advantage was constituted. The problem was not simply the power of the attack but the incompatibility between a new capability and the defensive means then available, compounded by an asymmetry of knowledge: Qual mastered a technique whose principles humans had not yet understood. The advantage was therefore contingent rather than intrinsic. If military innovation is defined by its effect on effectiveness in operational practice (Grissom et al., 2016, p. 1), that effect is always relative to what adversaries are able to do in response, and it depends on the historical conditions of use, on the knowledge available, and on the adversaries' capacity for adaptation.

The sealing of Qual did not end the history of the spell; it opened room for humans to study it. The investigation lasted approximately half a century, until its principles were sufficiently understood to allow Zoltraak to be incorporated into the human magic system and to become part of the conventional repertoire of mages (Yamada & Abe, 2022a, p. 18). The episode turns on the distinction between possessing a technology and understanding it: knowing that a technique exists is not the same as mastering the principles that allow it to be reproduced, modified, or neutralized. Diffusion did not occur here through the simple copying of an artifact but through investigation, learning, and the appropriation of principles previously mastered by another agent.

Read through Horowitz's (2010) framework, which is discussed in more detail below, the case is revealing. The narrative gives no indication that Zoltraak demanded financial intensity in the sense of industrial or procurement costs; what it emphasizes is organizational capital, understood here as a collective and cumulative research effort sustained over decades. That requirement helps explain the slow tempo of diffusion in the narrative and anticipates the contrast (see below) with real cases in which adoption and emulation are much faster. Assimilation also changed the relationship between the spell and its users: from the exclusive weapon of Qual, it became a technique used by Frieren and human mages such as Fern, although with differences between the original variant and the forms developed later.

Three analytical moments can thus be distinguished: the emergence of the innovation, the investigation of its principles, and its assimilation by agents who had previously been vulnerable to it. Each of them changes not only who masters the technol-



Frieren explains the research into Zoltraak. Sequential screen captures from the anime (season 1, ep. 3: Killing Magic; Madhouse, 2023).

ogy but also the configuration of the environment in which it is used.

ROUTINIZATION, DIVERSIFICATION, AND RELATIVE OBSOLESCENCE

Appropriation was accompanied by the development of defensive resources. As the principles of Zoltraak became known, mages created defensive spells and equipment able to respond to its effects (Yamada & Abe, 2022a, p. 18), and the spell that had cut through the available defenses came to be faced by adversaries who knew how it worked. This is what the paper calls relative obsolescence: a reduction of comparative advantage produced by changes in the adversaries' capabilities, not an absolute loss of functionality. Defensive adaptation did not render Zoltraak useless; it altered the degree of surprise associated with its use and the conditions required for its effects to be achieved.

The narrative marks this transformation by presenting Zoltraak as a conventional offensive spell in the work's present day. Individuals born after its incorporation into the human magic system learned to block it reflexively, since defense against the technique became a fundamental part of their training (Yamada & Abe, 2022a, p. 18). The defensive response thus ceased to depend on an exceptional reaction to an unknown threat and became a competence embedded in regular preparation: an extraordinary threat was converted into a routine problem. This routinization differs in locus and tempo from the adaptation described by Farrell (2010), which unfolds during the war itself and does not always require major organizational reform; in the narrative, the change is institutional, is transmitted through training, and extends across generations. The contrast is taken up again in the following section.

The same learning that allowed defenses to be built also expanded offensive uses. Frieren, one of the main collaborators in the investigation of Zoltraak, developed a variant aimed specifically at combat against demons, called demon-killing magic, which was later taught to Fern (Yamada & Abe, 2020b, p. 19). The work also shows differ-



Ordinary magic. Screen capture from the anime (season 1, ep. 3: Killing Magic; Madhouse, 2023).

ences in the use of Zoltraak regarding speed of execution, concentration of mana, size of the shot, and the possibility of performing sequences of attacks: concentrating mana can increase the power of the shot, while the rapid execution of multiple attacks can hinder the adversary's response (Yamada & Abe, 2022c, p. 11; 2021, p. 8). Knowledge of the principles thus permitted specialization and new forms of use, and the effectiveness of the technique came to depend on how it is operated as well as on its original properties. Zoltraak also remained relevant on the battlefield: Solitär presents it as one of the deadliest spells of the war in the Southern Lands (Yamada & Abe, 2022b, p. 11), even after its incorporation and the development of specific defenses.

Taken together, these movements show that innovation is better understood as a relational process than as a property of the artifact. The effectiveness of Zoltraak was never determined by its internal characteristics alone but by the interaction among those characteristics, the capabilities of its users, the knowledge available, and the responses of adversaries. Learning transformed offensive and defensive capabilities simultaneously: the investigation that allowed humans to face the original threat was the same one that allowed them to use the spell under other conditions. Technological adaptation is therefore not a linear sequence in which an innovation appears, is neutralized, and disappears; a technology may lose certain advantages, remain functional, and acquire new applications.

FROM ZOLTRAAK TO THE BATTLEFIELD: drones, diffusion, and countermeasures

The literature organizes explanations of military innovation into distinct interpretive schools (Grissom, 2006). In this field, Horowitz (2010) holds that the diffusion of military power depends mainly on two factors: the financial intensity required to adopt an innovation and the organizational capital needed to incorporate it. Farrell (2010) treats adaptation as the process by which military organizations improve their operational performance during the war itself, which does not always require major organizational reforms. For the case of drones, Calcara et al. (2022) propose that the central mechanism is the contest between those who hide and those who search: drones are vulnerable to air defenses and electronic warfare and depend on support from other assets, and the competition imposes high costs on those who do not master the tactics, techniques, procedures, and capabilities needed to limit exposure to enemy fire and detect targets. These frameworks make it possible to verify whether the mechanisms observed in Zoltraak find correspondence in documented cases. Two widely studied episodes are selected: the Nagorno-Karabakh war of 2020 and the war between Russia and Ukraine from 2022 onward.

In the first case, Azerbaijan's initial advantage was linked less to the isolated power of its drones than to the incompatibility between them and the Armenian defenses. Shaikh & Rumbaugh (2020) report that unmanned aerial vehicles and loitering munitions made it possible to locate, track, and destroy targets far beyond the line of contact, including armored vehicles and S-300 air defense systems, although the figures released may be exaggerated, and that most of Armenia's air defense consisted of obsolete Soviet systems. According to the authors, the TB2s flew too high for those systems, and Russian-origin electronic warfare systems disrupted Azerbaijani operations for only four days. The relationship recalls the initial advantage of Zoltraak: the superiority stemmed not only from the power of the attack but from the insufficiency of the means then available to face it. The same authors, however, warn that drones are vulnerable to defenses designed to counter them and that the lethality of the battlefield resulted from the synchronization of drones, artillery, and missiles, not from an isolated system. Calcara et al. (2022), who analyze this conflict alongside the cases of Libya and Syria, reach a convergent conclusion: drones alone do not pro-

duce the revolutionary effects attributed to them.

The war in Ukraine allows the subsequent phases of the trajectory to be observed. Because many of these technologies are commercial or dual-use, they can be acquired easily, and innovations spread rapidly to the adversary (Pettyjohn, 2024). Ukraine pioneered the use of racing FPV drones in kamikaze attacks, and Russia, as a fast follower, began to employ them to contest the Ukrainian counteroffensive of 2023 (Pettyjohn, 2024). In Horowitz's (2010) terms, the low financial intensity explains the speed of diffusion, but organizational capital determined its effectiveness. Pettyjohn (2024) records that volunteer networks played an unprecedented role in acquiring, modifying, and building drones and led efforts at professionalization, with the identification of best practices and the creation of training courses. Watling & Reynolds (2025, p. 10) describe the institutional incorporation already consolidated in early 2025: most Ukrainian brigades have a drone company or battalion, and dedicated units support front sectors of 40 to 70 km. The contrast with Zoltraak is instructive. In the narrative, the investigation of the spell's principles took approximately half a century (Yamada & Abe, 2022a, p. 18), whereas in open war competition constitutes a continuous process of adaptation and counter-adaptation between the parties (Watling & Reynolds, 2025, p. 3), in which innovations are emulated at much shorter intervals.

Defensive adaptation also displays the routinization observed in the work. Pettyjohn (2024) identifies electronic warfare as the most effective means of deterring drones, alongside countermeasures ranging from simple barriers, such as wire nets, to combat between drones and the location and targeting of operators. Watling & Reynolds (2025), drawing on fieldwork in Ukraine, show how the threat came to shape very different functions: artillery disperses its guns over more than 500 m and installs them in dug-in positions with side and overhead protection and camouflage nets (p. 12); engineers prepare steel cages and nets over the positions closest to the line of contact (p. 13); personnel are trained to stabilize their own wounds, because it is too dangerous for medics to reach the wounded (p. 16); and electronic protection has become indispensable for both sides, with jammers on most vehicles entering the combat zone (p. 18). The authors conclude, for NATO, that counter-drone capability is a requirement for all arms (p. 23). Just as the mages born after the incorporation of Zoltraak learned to block it reflexively (Yamada & Abe, 2022a, p. 18), the response to the drone ceases to be an exceptional reaction and becomes part of the regular training of the combatant. This reading is compatible with the skeptical position summarized by Pettyjohn (2024), represented by Biddle (2023) and Calcara et al. (2022), according to which the vulnerability of drones to electronic warfare and air defense, combined with dispersion and concealment, dilutes their lethality.

The Ukrainian case also shows that the countermeasure does not close the cycle. According to Watling & Reynolds (2025, p. 10), FPV drones were refined with autonomous terminal guidance and wire spools, which makes them immune to electronic jamming, at the cost of poorer flight performance, a range limited to about 10 km, and the risk of tangling on obstacles. The authors record that, in early 2025, Ukrainian forces were not yet widely employing these drones and that the Russian adoption of fiber-optic cable could change the approach to electronic warfare (p. 18). Defense itself generates costs: electronic warfare causes problems of deconfliction and friendly fire, making one's own air operations periodic rather than continuous (p. 18). Pettyjohn (2024) adds that not every adaptation consists of hardening the system: instead of protecting commercial drones against electronic attack, which would raise their costs, both sides preferred to buy more cheap drones, so that resilience stems from replacement. Defense, therefore, produces new offensive innovation, creates new vulnerabilities, and can be answered by distinct economic strategies. This dynamic is

analogous to the diversification of Zoltraak in the work, with the demon-killing variant (Yamada & Abe, 2020b, p. 19) and the differences in speed, mana concentration, and sequence of shots (Yamada & Abe, 2022c, p. 11; 2021, p. 8).

These cases reinforce the distinction between relative obsolescence and loss of usefulness. Watling & Reynolds (2025, p. 10) report that, depending on the sector of the front and the skill of the operators, between 60% and 80% of Ukrainian FPV drones do not reach their target and most of those that do hit it do not destroy armored vehicles; even so, tactical drones account for 60% to 70% of Russian systems damaged or destroyed. Ukrainian officers interviewed by the authors insisted that drones alone are insufficient and that their effect is greater when combined with artillery (pp. 10–11). Pettyjohn (2024) concludes that drones transformed the battlefield in an evolutionary rather than revolutionary way, and Kunertova (2023) argues that the transformative effect depends on the type of drone and the conditions of use, observing that, up to that point, small drones had not yet been effectively contained by air defenses. The reduction of advantage, therefore, is not uniform: it varies with the category of the technology, the environment of use, and the adversary's capacity for adaptation.

The analogy, however, has limits that need to be made explicit. Zoltraak is a technique operated by individuals, whose diffusion depends on study and teaching, whereas drones are sociotechnical systems that depend on supply chains, industrial capacity, procurement procedures, doctrine, and training. Horowitz's (2010) diffusion theory shows precisely that these financial and organizational factors determine the pace and reach of adoption, and they have no direct counterpart in the fictional narrative. Caution is also warranted regarding sources on an ongoing war. Watling & Reynolds (2025, p. 3) warn that their text gathers field research notes rather than an academic study, and Pettyjohn (2024) observes that images and videos released by the belligerents are part of an information war and do not allow the overall effectiveness of weapons to be estimated. The data mobilized here should therefore be read as documented indications, subject to revision. In this framework, Zoltraak serves as a heuristic model of a sequence of initial asymmetry, diffusion, defensive routinization, and transformation, without becoming an explanation for concrete historical processes.

CONCLUSION

The trajectory of Zoltraak in Frieren: Beyond Journey's End offers a fictional case study for examining the relationship between innovation, knowledge diffusion, defensive adaptation, and relative obsolescence. Qual's spell provided a significant initial advantage grounded in the incompatibility between a new capability and the existing defenses and in an asymmetry of knowledge. Its study by humans changed this condition: the defensive response was routinized in the training of mages, while the same knowledge produced variants and new offensive applications. The loss of the initial advantage did not imply the disappearance of the technology.

The main analytical contribution of the study is to treat innovation as a relational and historical process, in which creation, learning, diffusion, and adaptation are interlinked and in which the same learning transforms offensive and defensive capabilities. Confronting this model with the literature and with the drone cases of Nagorno-Karabakh and Ukraine indicated relevant correspondences (initial asymmetry between offense and defense, diffusion through investigation and imitation, routinization of the defensive response, and the emergence of successive countermeasures), but also structural differences. Zoltraak is an individual technique whose diffusion depends on study and teaching, whereas drones are sociotechnical systems that depend on industrial capacity, organization, and doctrine; and the half-century tempo of the narrative contrasts with the continuous

adaptation and counter-adaptation observed in open war.

Two cautions follow. First, the narrative does not allow the conclusion that every innovation inevitably loses its advantage: the documented drone cases indicate that the reduction varies with the type of technology, the environment of use, and the adversary's capacity for adaptation. Second, because Zoltraak belongs to a work of fiction, its representations do not constitute empirical evidence about real conflicts, and the sources on an ongoing war must be read as documented indications, subject to revision. The analogy should therefore be taken as a heuristic tool, not as a causal explanation. Future research may broaden the empirical scope by incorporating other cases of diffusion and countermeasure, such as air defense and electronic warfare in different conflicts, and examine to what extent the concept of relative obsolescence holds up against additional evidence.

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