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Compartmentalization and system ranking as fundamental design requirements for armored vehicles: Ukraine, Switzerland

Abstract. *The proliferation of low-cost FPV drones has fundamentally altered the threat landscape for main battle tanks, elevating crew survivability to the primary design criterion and necessitating a reassessment of historical protection concepts. This study, through a comparative analysis of archival materials from the Swiss Federal Archives, declassified Soviet-era thematic publications, and the personal diaries of development participants, traces the independent emergence of the compartmentalization principle (Ukrainian term – division of the vehicle into compartments isolated from one another) within the Swiss and Ukrainian schools of tank design during the 1970s–1980s. The results demonstrate that both engineering schools, responding to the catastrophic tank losses during the 1973 Yom Kippur War, independently arrived at nearly identical solutions despite complete informational isolation. In the Swiss NKPZ project, «Kompartimentierung» was formally established as a mandatory evaluation criterion, with only two concepts ensuring complete physical separation of the crew, ammunition, and power pack. Concurrently, Kharkiv designers developed a compartmentalized layout based on the quantitative ranking of systems by their contribution to survivability, assigning the highest protection coefficient to the crew, who were placed in the most protected compartment. Both schools independently converged on three fundamental principles: locating the crew in an isolated rear capsule, utilizing the engine compartment as an additional protective barrier, and equipping ammunition compartments with blow-off panels to vent explosive energy outward. This developmental parallelism demonstrates that compartmentalization and system ranking represent an objective regularity in the evolution of specialized vehicles, rather than localized inventions. The timeliness of this research is underscored by the fact that the principles of compartmentalization and layered crew protection, developed in the 1970s as a response to the challenges of their era, are gaining renewed relevance today in light of the widespread use of FPV drones, which once again bring the issues of armored vehicle survivability and the prevention of catastrophic losses to the forefront.*

Keywords: *compartmentalization; tank design; engineering schools; armored vehicles; Cold War*

Introduction.

Commercial FPV drones have emerged as a critical threat to main battle tanks and other specialized military vehicles due to their low cost, effectiveness, accessibility, and low observability. They are capable of striking vehicles in their most vulnerable areas, causing fires in fuel and ammunition stowage. This necessitates a revision of protection concepts and the integration of new countermeasures (Lavers, 2025). Technological advancements promise further cost reductions and increased reliability, solidifying the role of FPV drones as a standard anti-armor means, radically altering the battlefield balance (Sumlenny, 2024). At the same time, main battle tanks are likely to retain a key role on the battlefield, as their significant combat power allows forces to maintain mobility in direct contact with the enemy, despite growing concerns regarding their vulnerability (Reynolds, 2023).

This study examines research aimed at enhancing the protection of specialized vehicles conducted during the 1970s by the Swiss Eidgenössische Konstruktionswerkstätte (K+W) and the Kharkiv KB-60M (KMDB) design bureau. The key finding of this research was the necessity for a radical increase in survivability, as the experience of combat operations, particularly the 1973 Yom Kippur War, vividly demonstrated the vulnerability of existing vehicles. Hits to ammunition or fuel caused catastrophic losses, as vividly demonstrated during the 1973 war. This prompted designers to pursue the concept of compartmentalization (German: Kompartimentierung) – the strict separation of the internal volume into isolated compartments: engine, transmission, weapon and ammunition stowage, a rear crew compartment, and others. This solution, intended to provide the crew with a chance of survival even after armor penetration, fire, or ammunition detonation, became the decisive factor in the selection of advanced layouts.

Of the numerous concepts developed by K+W (30 in total), only two met the stringent compartmentalization and technical requirements: the turretless (casemate) variant 13f with a twin gun and rear engine placement, and variant 23a with a front engine and a turret featuring a limited traverse angle (+130°). Both variants envisioned the use of an autoloader, placement of the entire ammunition load in an isolated compartment near the gun, and a three-man crew always oriented in the direction of travel. However, each concept possessed its own strengths and weaknesses (Bundesarchiv, 1976d).

Kharkiv designers, independently from their Swiss colleagues, arrived at similar solutions (Mazurenko, Morozov, & Nazarenko, 1987).

The relevance of researching compartmentalization as a fundamental principle for designing specialized vehicles has not diminished since the 1970s; rather, it has gained critical importance in light of the analysis of modern armed conflicts. The experience of combat operations in recent decades irrefutably demonstrates that ammunition stowage hit remains one of the primary causes of the irreversible loss (catastrophic kill) of armored vehicles along with their crews, negating any advancements in firepower, protection, and mobility.

Research Methods.

This study, based on an analysis of archival materials from the Swiss Federal Archives (Bundesarchiv) in Bern, an examination of the technical documentation of the NKPZ projects, the personal diaries of A. A. Morozov, industry literature, and a retrospective overview of the development of global tank design during the 1970s–1980s, attempts to objectively determine the conceptual similarity of engineering solutions developed by two leading schools of vehicle engineering that evolved in conditions of mutual informational isolation. Key aspects of implementing the principles of compartmentalization and system ranking by survivability into the practice of designing specialized vehicles are identified.

A comparative analysis of the design solutions and layout schemes of the vehicles under investigation is conducted. The comparative analysis of conceptual similarity is based on six operational criteria derived directly from the primary sources: (1) functional compartmentalization into mutually isolated volumes, (2) location of the crew in a rear armored capsule, (3) use of the engine compartment as an additional ballistic barrier, (4) incorporation of blow-off panels for ammunition compartments, (5) ranking of systems by their contribution to survivability, and (6) alignment of the direction of travel with the primary direction of fire. Each criterion was assessed using a binary scale (present/absent) or a three-level scale (fully/partially/not present). The possibility of direct knowledge transfer was examined by comparing the timelines of the Swiss and Soviet/Ukrainian projects and by checking archival evidence of any technical exchange. The complete absence of such evidence, combined with the identical sequence of conceptual decisions, supports the hypothesis of parallel independent evolution.

Comparing the implementation of compartmentalization concepts in Europe and Ukraine reveals the distinctive characteristics of national engineering schools while simultaneously confirming the convergent nature of global tank development, where similar tactical-technical challenges generate isomorphic technical solutions irrespective of political boundaries. The comparison of the development stages of the prospective tank protection concept in Switzerland and Ukraine is carried out with mandatory consideration of the specific developmental context of their respective industrial complexes. Collectively, this allows for a well-reasoned rejection of the hypothesis of direct borrowing and substantiates the thesis of a parallel, independent formation of an identical protective paradigm.

Results and Discussion.

The concept of compartmentalizing the internal volume of a combat vehicle as a fundamental principle for ensuring survivability was first proposed in the U.S. Army Ordnance Corps technical report «New Tank Main Armament System», in connection with the introduction of completely combustible cartridge cases. Developers encountered a fundamentally new threat: the use of combustible cases, while effectively solving the problem of ejected spent cases inside the turret, created a critical danger of catastrophic fire and detonation of the entire ammunition stowage upon armor penetration. The report explicitly stated that «*a perforated hit which results in a propellant fire is a holocaust*», a circumstance demanding fundamentally new approaches to ammunition stowage and protection (Watervliet Arsenal, 1959).

American engineers proposed placing the entire ammunition load in a turret bustle, separated from the crew compartment by an armored bulkhead. This solution, as emphasized in the document, would "isolate the fire hazard" and minimize the probability of crew casualty in the event of detonation. The design stipulated that in case of ammunition ignition, overpressure would be vented through special blow-off panels, directing the explosive energy outward rather than into the fighting compartment. This concept, first documented in the 1959 report, became the foundation for the subsequent development of the compartmentalization idea.

What is Compartmentalization?

The core requirement of compartmentalization mandates the strict separation of the crew, weapon system/ammunition, and engine/fuel into isolated compartments. As noted by K+W, a tank being developed for service entry by 1985 must no longer be subject to the destructive consequences of a projectile hit resulting in crew loss and the catastrophic kill of the vehicle. Participants (Bundesarchiv, 1976c) were shown a photograph of a T-54 tank from the 1973 Yom Kippur War, its turret separated from the hull by an ammunition hit. All tanks currently in service or being accepted for service, including the Leopard 2, are susceptible to such catastrophic failures. Such an ammunition hit also has a devastating effect on the morale of other tank crews. This is arguably the most significant weakness of modern tanks, and the pursuit of its mitigation substantially influenced the approach to selecting the final vehicle concepts.

The primary objective was to enhance the tank's combat effectiveness, but only in aspects that would not lead to a significant increase in cost. Studies indicated that the greatest increase in combat value regarding protection could be achieved by dividing the internal space into isolated compartments (compartmentalization). This involves partitioning the tank into, for example, three compartments: the engine compartment, the weapon and ammunition compartment, and the crew compartment. The crew is isolated from all elements that could threaten them upon a hit, such as ammunition, fuel, and hydraulic fluid (Fig. 1, 2).

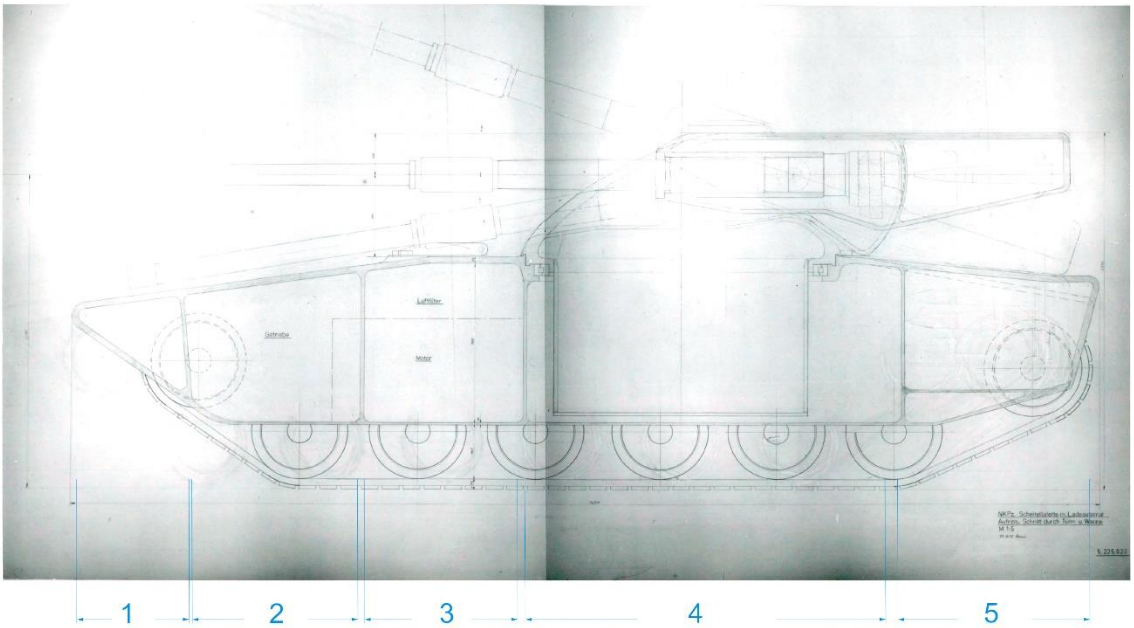


Figure 1. Example of NKPZ chassis compartmentalization (Bundesarchiv, 1976b). 1 – fuel compartment, 2 – transmission compartment, 3 – engine and auxiliary systems compartment, 4 – crew compartment, 5 – ammunition compartment.

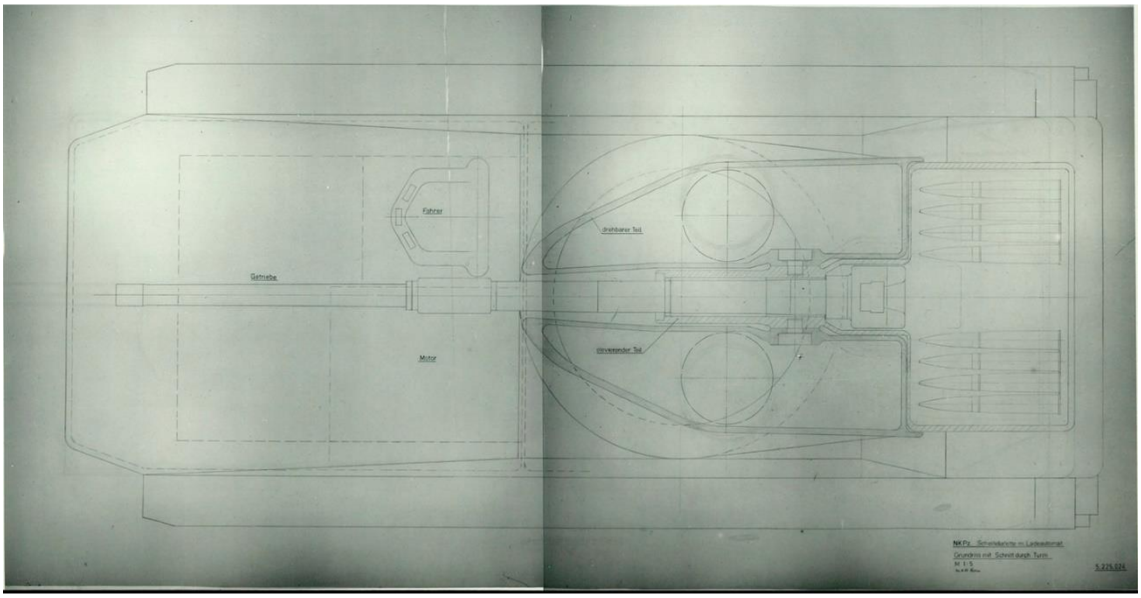


Figure 2. Example of NKPZ chassis compartmentalization, top view (Bundesarchiv, 1976b).

Compartmentalization ensures the maximum possible protection against even current and future munitions. It simplifies the loading process, as ammunition is stowed near the gun. Compartmentalization gives the crew the necessary confidence in their weapon system, as they perceive a chance of survival in combat even against a numerically superior enemy. All these considerations led to the formulation of the Basic Requirements and General Technical Specifications; among all the investigated variants, only two concepts satisfied these criteria.

An example illustrating the advantages of compartmentalization is the use of diesel fuel as a filler in composite armor. It was established that a two-layer armor array with a diesel fuel interlayer not only effectively attenuates a shaped charge jet (with a jet attenuation factor of K = 2.7) but also provides a significant weight saving in protection – approximately 71% compared to monolithic steel (Gadzhibalaev Lubert, Fenenko, & Chernomurov, 1982).

Concept Selection to Maximize the Advantages of Compartmentalization.

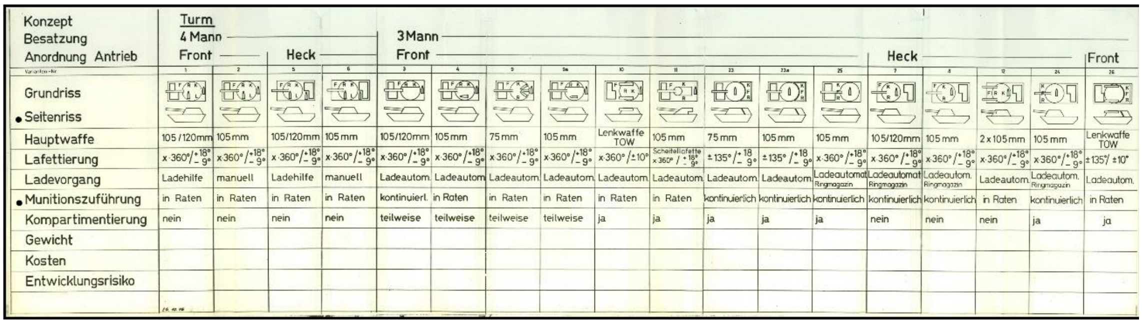
Description of the Turretless (Casemate) Tank Concept with Twin Guns (Variant 13f).

Variant 13f represented a turretless (casemate) layout with a rear-mounted power pack and a twin-barreled gun system. In this concept, the main armament was rigidly attached to the hull, lacking the ability for independent horizontal traversal – a fundamental departure from the classic turreted configuration. The twin-gun system, in turn, was viewed by the developers as a means to radically increase the probability of target engagement through salvo firing, theoretically offering a 10–20% advantage in target kill probability compared to single-gun systems. The K+W designers also identified other advantages in this solution: if one gun was disabled, combat effectiveness could be maintained with the second barrel, thus providing a degree of redundancy; the alignment of the direction of travel and the direction of fire simplified crew orientation on the battlefield. However, this particular variant generated the greatest number of unresolved technical issues, which ultimately predetermined its rejection in favor of the alternative Concept 23a. Critically unresolved problems included the compatibility of the turretless configuration with Switzerland's hilly terrain, the difficulty of maneuvering a unit of such vehicles due to the inability to rapidly re-target the guns without turning the entire hull, and the requirement for high-precision stabilization of the twin weapon system in elevation, which demanded the development of fundamentally new and costly fire control systems.

The persistence of these problems, combined with the opportunity to examine a functioning full-scale mock-up of a similar turretless vehicle, the VT 1-1, in West Germany (Hilmes, 2021, p. 34) – which demonstrated the practical difficulties of implementing the concept – led the developers to favor the more conservative yet more realistic partially-traversable turret variant. Nevertheless, the very fact that the turretless configuration was explored in such depth testified to the readiness of Swiss engineers to fundamentally rethink established tank design paradigms in favor of maximizing crew protection – the primary priority underpinning the NKPZ project.

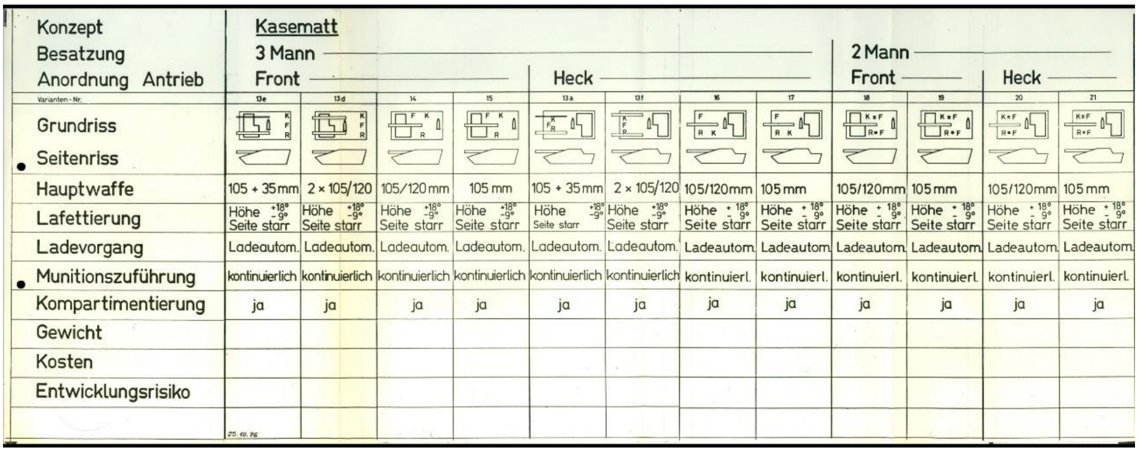
However, the concept had critical drawbacks. The most technically challenging problem was the need for highly precise vertical stabilization of the weapon system. Tactically, questions remained unresolved regarding the suitability of the turretless layout for Switzerland's hilly terrain, the lack of established tactics for maneuvering units of such vehicles (due to the hull-mounted guns), and doubts about the feasibility of target tracking procedures. A significant disadvantage was the near-complete loss of combat effectiveness if the chassis was damaged, as well as the necessity of maneuvering the vehicle to bring suppressive fire from secondary weapons to bear.

Compartmentalization (Fig. 3, 4) is used as one of the key evaluation parameters in the design and assessment of the new tank. This requirement appears both in the list of basic troop requirements and in the evaluation tables for each specific variant (including Variant 23a), featured as a separate line item among the tank's combat characteristics (Fig. 3, 4). For each variant, the Kompartimentierung line indicates "ja" (yes), "nein" (no), or for some, "teilweise" (partially).



Konzept	Turm																	
Besatzung	4 Mann				3 Mann													
Anordnung Antrieb	Front		Heck		Front									Heck				Front
Varianten-Nr.	1	2	5	6	3	4	9	9a	10	11	23	23a	25	7	8	12	24	26
Grundriss																		
● Seitenriss																		
Hauptwaffe	105/120mm	105mm	105/120mm	105mm	105/120mm	105mm	75mm	105mm	Lenkwaffe TOW	105mm	75mm	105mm	105mm	105/120mm	105mm	2x105mm	105mm	Lenkwaffe TOW
Lafettierung	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/±10°	Scheitellafette x 360° / $^{+18°}_{-9°}$	±135°/$^{+18}_{-9°}$	±135°/$^{+18}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	x·360°/$^{+18°}_{-9°}$	±135°/±10°
Ladevorgang	Ladehilfe	manuell	Ladehilfe	manuell	Ladeautom.	Ladeautom	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautomat Ringmagazin	Ladeautomat Ringmagazin	Ladeautom. Ringmagazin	Ladeautom.	Ladeautom. Ringmagazin	Ladeautom.
● Munitionszuführung	in Raten	in Raten	in Raten	in Raten	kontinuierl.	in Raten	in Raten	in Raten	in Raten	in Raten	kontinuierlich	kontinuierlich	kontinuierlich	kontinuierlich	kontinuierlich	in Raten	kontinuierlich	in Raten
Kompartimentierung	nein	nein	nein	nein	teilweise	teilweise	teilweise	teilweise	ja	ja	ja	ja	ja	nein	nein	nein	ja	ja
Gewicht																		
Kosten																		
Entwicklungsrisiko																		
	25.10.76																	

Figure 3. Comparative tables of characteristics for the 30 vehicle concepts considered (Bundesarchiv, 1976d). In the tables comparing dozens of tank concepts, "Kompartimentierung" is listed as a separate evaluation criterion.



Konzept	Kasematt											
Besatzung	3 Mann								2 Mann			
Anordnung Antrieb	Front				Heck				Front		Heck	
Varianten-Nr.	13e	13d	14	15	13a	13f	16	17	18	19	20	21
Grundriss												
● Seitenriss												
Hauptwaffe	105 + 35mm	2 × 105/120	105/120mm	105 mm	105 + 35mm	2 × 105/120	105/120mm	105mm	105/120mm	105mm	105/120mm	105mm
Lafettierung	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr	Höhe $^{+18°}_{-9°}$ Seite starr
Ladevorgang	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.	Ladeautom.
● Munitionszuführung	kontinuierlich	kontinuierlich	kontinuierlich	kontinuierlich	kontinuierlich	kontinuierlich	kontinuierl.	kontinuierl.	kontinuierl.	kontinuierl.	kontinuierl.	kontinuierl.
Kompartimentierung	ja	ja	ja	ja	ja	ja	ja	ja	ja	ja	ja	ja
Gewicht												
Kosten												
Entwicklungsrisiko												
	25.10.76											

Figure 4. Comparative tables of characteristics for the 30 vehicle concepts considered (Bundesarchiv, 1976d). In the tables comparing dozens of tank concepts, "Kompartimentierung" is listed as a separate evaluation criterion.

Description of the Partially-Traversable Turret Tank Concept (Variant 23a). The overall concept is characterized by the strict division of the internal space into three compartments: Engine compartment at the front – Weapon and ammunition compartment in the center – Crew compartment at the rear. This results in a limitation of the turret's horizontal traverse sector from the conventional ±360° to ±130°, which was considered acceptable given the vehicle's equal mobility in forward and reverse.

The front engine placement also provided additional protection for the weapon system, ammunition, and crew (Fig. 5).

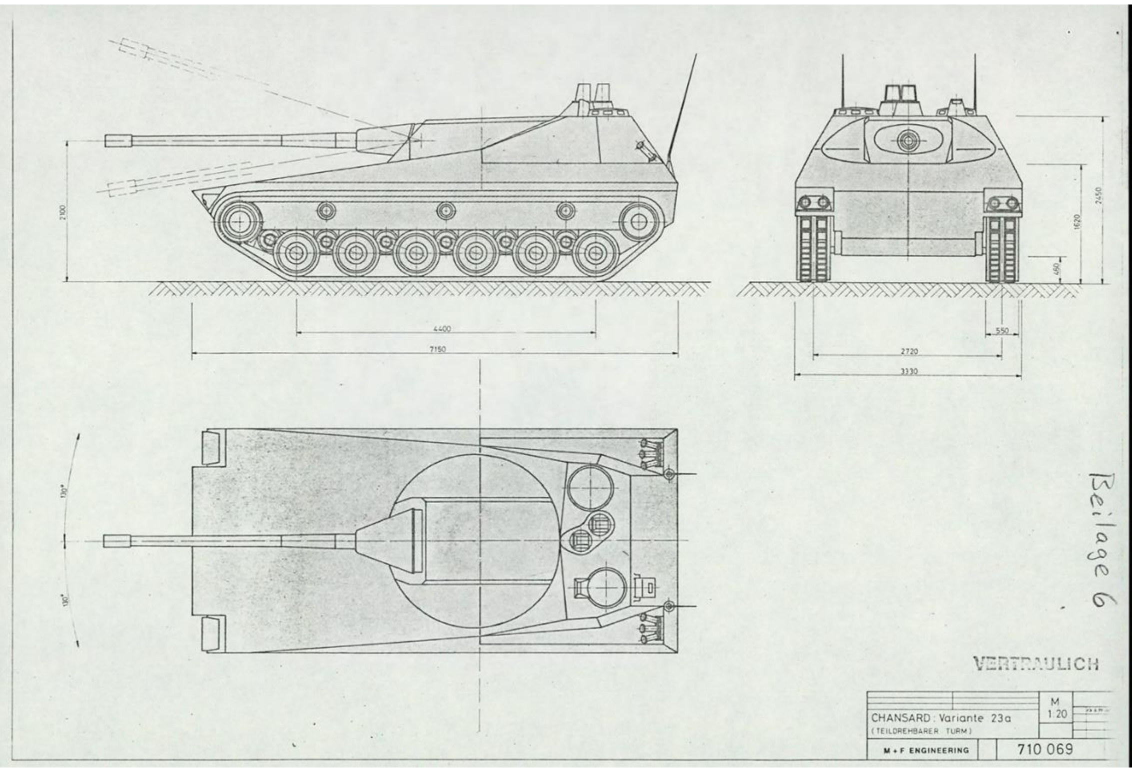


Figure 5. NKPZ Chansard Variant 23a (Teildrehbarer Turm - partially traversable turret).

Placing the entire ammunition load in the weapon and ammunition compartment allows for a relatively simple and reliable autoloader. The enclosed weapon and ammunition compartment is equipped with blow-off panels (covers) on the top and bottom to vent explosive pressure. In the event of an ammunition hit, these panels open under the resulting overpressure, which should practically prevent the destruction of both the crew compartment and the engine compartment. The entire 3-man crew, consisting of the commander, gunner, and driver, is housed together in the crew compartment.

This arrangement also simplifies crew interaction and consolidates crew protection systems (psychological advantages, NBC protection and air conditioning). Furthermore, the driver's placement allows for unlimited forward movement (in combat) and reverse movement (during redeployment) without direction from the commander, so that even in a delaying action, the most heavily protected side can always be presented to the enemy (Bundesarchiv, 1976a). Since the entire crew is in a single compartment, NBC protection and sound insulation are simplified. Additionally, there is no need to extract propellant gases, and there are no fire-prone elements, such as hydraulics, within the compartment.

Table 1. Comparison of Characteristics for NKPZ Variants 13f and 23a (Based on Bundesarchiv, 1976d)

Characteristic / Criterion	Variant 13f (Turretless/Casemate)	Variant 23a (Partially-Traversable Turret)
Overall Layout	Turretless (casemate)	Partially-traversable turret (±130°)
Engine Location	Rear	Front
Crew Compartment Location	Front/Center	Rear
Armament	Twin guns (rigid hull mounting, vertical stabilization)	Single gun (in traversable mount)
Crew Size & Orientation	3, in hull facing direction of travel	3 (commander, gunner, driver together in rear capsule), facing direction of travel
Ammunition Stowage	Isolated compartment near guns	Isolated compartment in center, equipped with blow-off panels (top/bottom)
Autoloader	Yes	Yes
Compartmentalization	Yes	Yes
Protection Philosophy	Maximize crew protection via isolation; engine at rear reduces frontal vulnerability	"Schutz durch Motor" (protection by engine); front engine acts as additional barrier; crew receives maximum protection in rear
Mobility Characteristics	Equal forward/reverse mobility	
Key Advantages	- 10-20% higher hit probability with twin guns - Gun redundancy - Simplified orientation (direction of travel = direction of fire) - Simplified layout with rear engine - Reduced thermal signature (engine at rear)	- Uses conventional turret tactics - Immediate target engagement without turning hull (within ±130°) - Frontal protection enhanced by engine compartment - Simplified crew communication and NBC protection (all in one compartment) - Simple ammunition resupply via rear hatch
Key Disadvantages / Challenges	- Unsuitable for hilly terrain (cannot engage without turning hull) - Complex and costly vertical stabilization required - Difficult unit-level tactics (all guns point same direction) - Loss of chassis = loss of combat effectiveness - Complex target tracking	- Driver placement in rear (unconventional) - Thermal signature at front - Crew requires protection from rear attacks - Limited turret traverse - Front armor must be partially dismantled for engine access - Thermal disturbance affecting observation/sighting

Historical analysis of the Swiss projects shows that by the mid-1970s a stable consensus had emerged among military and technical experts regarding the vulnerability of classical armored vehicle designs. The Swiss projects examined here became indicators of a shift in tank design philosophy: from focusing on firepower and frontal armor to the problem of crew survivability. Turning to procedural aspects, by November 1976 the Swiss NKPz project already had a formalized list of "Basic Requirements" (Bundesarchiv, 1976d), in which the principle of "Separation of crew, weapons/ammunition, and engine/fuel" was placed first. Compartmentalization in Switzerland proved not to be an engineering abstraction but a direct consequence of a military veto on a "simple tank": "The troops need a counter-strike tank that is technically equal or superior to the enemy. A simple battle tank, even if there were more of them, is rejected by the troops." The priority of crew protection was elevated to an inviolable tactical principle precisely under pressure from the end users, not from the developers. The significance of the NKPz lies in the fact that Swiss engineers translated the survivability problem into formal tactical-technical requirements. The strict ranking of protection (crew – ammunition – armament) recorded in the "Military Framework Requirements Specification" remained unchanged throughout the entire project period, marking a transition from the paradigm of "impenetrable armor" to the paradigm of structural survivability: the main task becomes not to prevent a hit, but to localize its consequences.

Compartmentalization in Ukrainian Vehicles Designs Incorporating the Concept of Ranking Primary Systems by Contribution to Survivability.

During approximately the same time period, the idea of compartmentalization was first proposed in the former Soviet Union at the Kharkiv Design Bureau by A. A. Morozov. It is appropriate here to quote an entry dated 1972:

> «*In our opinion, one of the main shortcomings of the existing 'classical scheme' of the tank, which essentially creates all the obstacles to the further enhancement of its tactical-technical characteristics, is the imperfection of its fighting compartment design. It resembles a very cramped one-room apartment or a soldier's duffel bag, in which the crew is squeezed in among the weapons, fuel tanks, ammunition stowage, various mechanisms, linkages, wiring, and numerous other devices and components, some of which pass through en route to the engine-transmission compartment. Furthermore, all of this moves, rotates, emits smoke, is a source of noise and injury, presents an explosion and fire hazard, creates crew isolation, complicates crew evacuation from the tank, fails to provide basic conditions for work and habitability, and much more.*
>
> *In the proposed layout, the so-called fighting compartment of the tank is subjected first and foremost to a fundamental change, by dividing it into separate, mutually isolated, independent compartments: fuel, ammunition, armament, crew compartment, and engine-transmission compartment.*

> *Thus, while the layout of a modern tank of the "classical scheme" essentially divides the tank into two separate compartments – the engine-transmission compartment and the fighting compartment – the proposed layout scheme already provides for 5 sealed compartments: engine-transmission compartment, ammunition compartment, crew compartment, fuel compartment, and armament*» (Chernyshev, 2007).

Within the design criteria of the ideology described above, a preliminary design for the tank «Object 450» was developed. Work continued in the second half of the 1970s by A. I. Mazurenko, E. A. Morozov, and others.

Ukrainian engineers, analyzing the experience of World War II and post-war conflicts, concluded that a fundamental revision of the classical layout, which had dominated global tank design for decades, was necessary (Gnedash, Mazurenko, & Morozov, 1991). In their view, the critical flaw of the traditional scheme was the lack of logic in the distribution of vulnerable volumes: ammunition and fuel were dispersed throughout the hull, making their involvement nearly inevitable upon armor penetration, leading consequently to catastrophic detonation or fire. The solution was seen in creating a layout where tank systems would be ranked according to their contribution to combat effectiveness, and their level of protection would correspond to this rank (Mazurenko, Morozov, & Nazarenko, 1987).

Figure 6. Variant of a non-traditional tank layout scheme with two guns. Author's reconstruction based on source (Apukhtin, Mazurenko, Morozov, & Nazarenko, 1980): 1 – hull armor, 2 – transmission compartment, 3 – fuel compartment, 4 – engine compartment, 5 – crew compartment, 6 – ammunition compartments with loading mechanism.

Description of the Turreted Tank Concept with Two Guns.

Structurally, the tank follows an unusual scheme featuring division into isolated compartments and a rotating weapon platform. The hull is divided into transmission, fuel, engine, and crew compartments. The main feature is the placement of the two-man crew in a stationary armored capsule in the rear part of the hull. Around this capsule rotates a platform with heavy frontal armor and two guns. This not only removed the crew from the "carousel" of rotation but also eliminated the main weakened zone of the classical turret – the gun mounting apertures, which traditionally constitute the most poorly protected area of the frontal aspect (Hilmes, 2021, p. 29).

Beyond firepower superiority, the proposed layout, with guns and autoloaders located in side compartments, fundamentally solves the problem of tank survivability and crew safety. In this scheme, the ammunition load is completely isolated from the crew and located outside the main armored volume. Even in the event of ammunition detonation in one compartment, the explosion energy is directed outward, preventing the catastrophic loss of the vehicle and crew fatalities. Moreover, the disablement of one of the two independent autoloaders does not deprive the tank of its ability to fire – engagement can continue from the undamaged gun, ensuring high combat resilience.

Considerable attention in the project was devoted to crew working conditions and control automation. Both crew members (commander-gunner and driver) are seated in an ergonomic capsule with enhanced radiation protection and air conditioning. They are always facing the front of the vehicle, maintaining spatial orientation regardless of turret position. Fire and mobility controls are duplicated and integrated into unified consoles with displays, allowing either operator to perform the other's functions. All-around vision is provided by screen-type devices based on fiber optics. Reducing the crew to two, combined with locating armament and ammunition outside the habitable compartment, not only reduces vehicle weight and dimensions but also creates prerequisites for a fully automated combat system of the future.

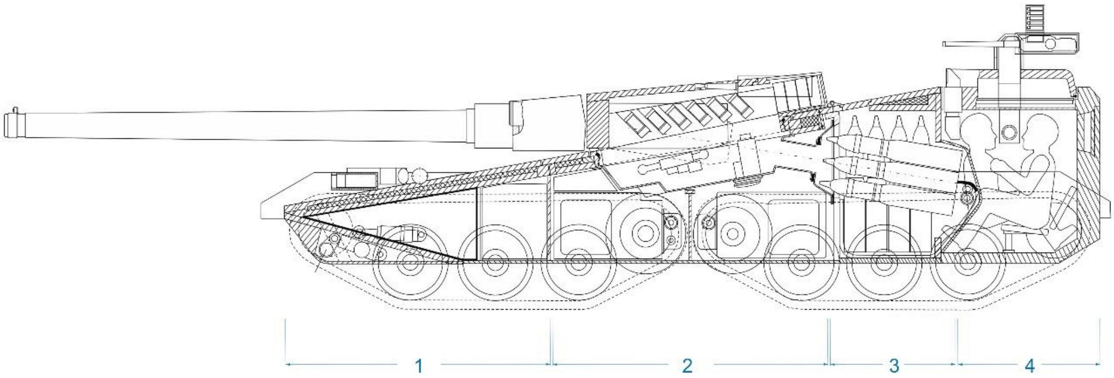


Figure 7. Variant of a non-traditional tank layout scheme. Author's reconstruction based on source (Gnedash, Mazurenko, & Morozov, 1991).
1 – fuel compartment, 2 – engine-transmission compartment, 5 – ammunition compartment with loading mechanism, 6 – crew compartment.

Description of a Turreted Tank Concept with a Non-Traditional Layout Based on Combat Property Ranking.

Analysis of the evolution of tank design shows that the layout scheme first implemented in the T-34 tank became classic for decades. Its key features – front location of the driver's station, central placement of the fighting compartment in a rotating turret, and rear location of the engine-transmission compartment – provided a successful balance of firepower, protection, and mobility for its time. However, the constant growth in tactical-technical characteristics has exacerbated the internal contradictions of the classical scheme. Increased mass negatively affects mobility, caliber growth complicates ammunition and crew placement in the turret, and the pursuit of enhanced protection conflicts with volume and weight constraints. This necessitates the search for fundamentally new layout solutions departing from established canons.

> «*Over 10 years, I understood the weak points, or rather the 'dead-end' points of the modern tank, which cannot be 'cured' through modernization, but which are amenable to 'treatment' through a fundamentally new layout scheme*,» noted the project developer (Mazurenko, 2015).

As one possible direction for overcoming these contradictions, a non-traditional layout scheme is proposed, based on the longitudinal division of the tank hull into five functionally isolated compartments. From front to rear, they are arranged in the following sequence: fuel compartment, power pack compartment, main armament compartment (turret with gun), autoloader compartment with ammunition stowage, and finally, the crew compartment. This linear arrangement allows for the implementation of the layered protection principle, where each subsequent compartment is shielded by the preceding ones, and their armor protection level increases in proportion to the combat significance of the components housed within.

The key advantage of this scheme is the radical enhancement of tank survivability (Hilmes, 2021, p. 41). The fuel compartment, with minimal protection, absorbs the initial impact of the most prevalent weapon types, shielding the power pack. The placement of two engines with independent transmissions for each of the four track runs allows the vehicle to retain mobility even if part of the power pack or running gear is damaged. The autoloader, protected by three front compartments, is fitted with blow-off panels in the floor in case of ammunition detonation to vent explosive energy, minimizing hull damage. The crew compartment, located in the most heavily protected rear section, receives 2-2.5 times thicker armor than the front compartment, ensuring an unprecedented level of personnel survivability even upon hull penetration.

Thus, the proposed layout provides a differentiated level of protection in strict accordance with the significance of each element: the least critical systems (fuel) shield the more important ones (engine, ammunition), while the crew receives the maximum possible protection. This approach allows for a high probability of maintaining tank combat effectiveness under intense fire without a proportional increase in armor mass. Implementing this scheme requires an integrated design approach from the earliest stages; however, it is precisely this departure from classical solutions that opens the path to resolving accumulated problems and creating a tank with a fundamentally new level of combat effectiveness and survivability.

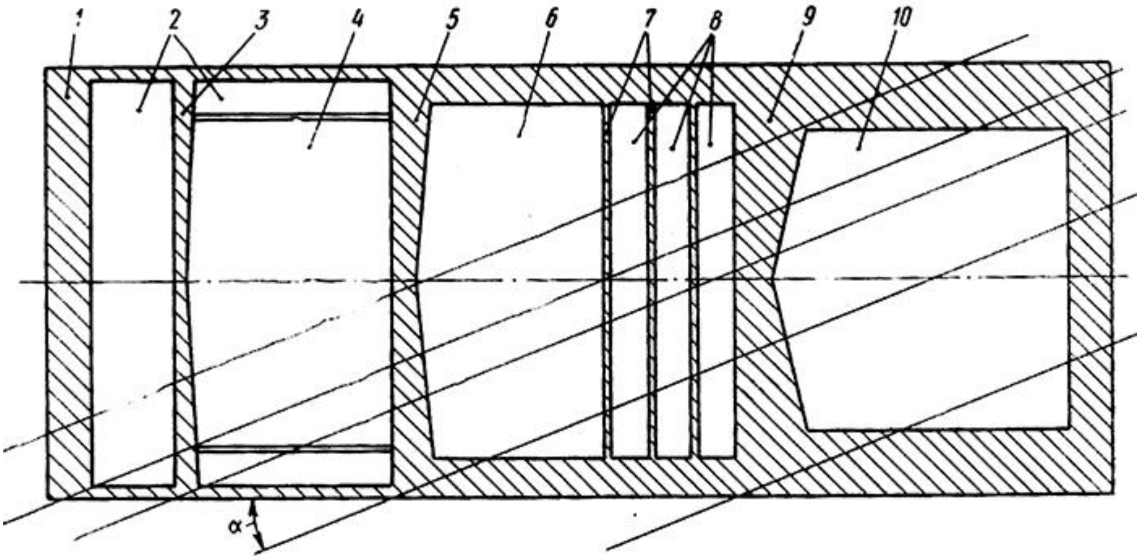


Figure 8. Schematic diagram (plan view) of a tank with sequentially arranged compartments (Mazurenko, Morozov, & Nazarenko, 1987)
1 – front plate; 2 – fuel compartment; 3 – fuel bulkhead; 4 – engine compartment; 5 – engine bulkhead; 6 – fighting compartment; 7 – ammunition stowage bulkheads; 8 – ammunition stowage compartments; 9 – crew compartment bulkhead; 10 – crew compartment; 11 – engagement angle for the most powerful weapons α.

The concept proposed by the Kharkiv designers was based on a strict ranking of systems in descending order of their importance for maintaining combat effectiveness. According to this approach, the highest priority (protection coefficient K=1.0) was assigned to the crew, whose incapacitation meant the total loss of the tank. Following this were the ammunition stowage (K=0.9), whose detonation led to catastrophic loss; the weapon system (K=0.8); the engine-transmission unit (K=0.6); and finally, the fuel (K=0.5) (Mazurenko, Morozov, & Nazarenko, 1987). Based on this ranking, a layout scheme was developed in which five isolated compartments were arranged sequentially along the vehicle's longitudinal axis, with protection levels increasing from the front to the rear: the fuel compartment, the power pack compartment, the autoloader compartment with ammunition stowage, and finally the crew compartment in the rear (Gnedash, Mazurenko, & Morozov, 1991). This configuration, a form of "layered protection," ensured that more important systems were shielded by less important ones. Fuel, having the lowest priority, acted as an additional barrier to protect the engine, while the engine and autoloader shielded the crew. Furthermore, the design incorporated blow-off panels in the floor of the ammunition compartment to vent pressure during detonation, directly echoing American developments from the late 1950s (Watervliet Arsenal, 1959).

The historical analysis conducted demonstrates that the principles of compartmentalization and layered protection, developed in the 1970s–1980s, represent not a random historical phenomenon but a fundamental regularity whose significance only increases in the context of modern armed conflicts. Thus, T. Giurgiu and colleagues (Giurgiu, Virca, Grigoraș, & Năstăsescu, 2023) directly point to the evolution of the protection concept: from the classic «iron triangle» (armor – firepower – mobility) to the primacy of survivability in the face of fundamentally new threats. The widespread use of unmanned aerial vehicles has transformed traditional all-around protection into hemispherical protection, where top cover is critically important. This fully aligns with the main conclusion of our study: it was precisely the threat of crew casualties and catastrophic vehicle loss, demonstrated by the Yom Kippur War, that became the driver for the appearance of isolated compartments in the K+W and Kharkiv design bureau projects.

Moreover, the critical importance of crew survivability, foundational to the Swiss and Ukrainian layouts, today acquires new, deeper economic and operational justification. A. Kumar and S. Sahu (Kumar & Sahu, 2025), using India as an example, demonstrate the paradox of the modern arms race: attempts to protect 50-ton vehicles from swarms of cheap drones and tandem warheads lead to a disproportionate increase in tank cost. Resources are spent not on enhancing lethality but on survivability, calling into question the operational value of heavy armored vehicles. This conclusion directly resonates with the key requirement of the NKPZ project – increasing combat effectiveness without a significant cost increase – where compartmentalization was seen as the most effective way to achieve this. The principle articulated by the Kharkiv designers gains even greater significance today: the loss of a trained crew in the conditions of a "transparent battlefield" becomes even more critical than the loss of the most expensive vehicle.

Finally, the conceptual similarity between the Swiss and Ukrainian solutions, identified in our study, finds confirmation in contemporary forecasts for the development of tank design. A. Gat (Gat, 2023) asserts that ground forces stand on the threshold of a revolution – a transition from kinetic protection (heavy armor) to electronic protection, where active protection systems become the foundation. He draws a direct analogy with the decline of the era of heavy battleships, which gave way to aircraft carriers. However, our historical analysis shows that this transition would not have been possible without conceptual groundwork. It was the principle of compartmentalization that first allowed the engine, fuel, and ammunition to be considered not merely as vulnerable points, but as part of a layered protection system that absorbs the impact and gives the crew a chance of survival. In this sense, Gat's ideas about the inevitability of implementing active protection systems are not a rejection, but a direct continuation and development of the philosophy that originated in the 1970s in Switzerland and Ukraine. Passive compartmentalization, supplemented by active threat interception, represents the synthesis that will enable the creation of a specialized vehicle combining high protection with operational flexibility, as also discussed by Kumar & Sahu (2025), who advocate for the development of lighter and more networked systems.

The conceptual breakthroughs achieved by the Swiss and Kharkiv design schools in the 1970s were not isolated events. They reflected a broader and growing recognition within the international military-technical community that the traditional layout of armored vehicles had reached a fundamental impasse. As explicitly stated in the U.S. Army Test and Evaluation Command document *Armored Vehicle Vulnerability to Conventional Weapons* (TOP 2-2-617, 1975), "the three major concerns in vulnerability analysis are: protection of the crew, protection of vehicle mobility, and protection of firepower. Of particular concern in this regard is protection against detonation of stowed ammunition and uncontrolled burning of the fuel, for if either occurs, the results could be catastrophic" (p. 2). Compartmentalization, as developed in Switzerland and Kharkiv projects, directly addressed this threat. By isolating the crew in a rear capsule, separating the ammunition stowage with blow-off panels, and using the engine and fuel compartments as additional barriers, the new layout made it possible for a vehicle to suffer a mobility or firepower kill without inevitably progressing to a catastrophic kill.

This logic resonates with the observation that "when damaged, it is desirable to repair those components that are fairly vulnerable and, when damaged, have a serious effect upon the firepower or mobility of a vehicle" (TOP 2-2-617, p. 5). The ability to survive a hit, evacuate the crew, and possibly repair the vehicle became a deliberate design goal rather than an afterthought. The continuity of this engineering philosophy is demonstrated by the later development of ammunition compartmentation in the U.S. Abrams tank. As reported by Conant (2013), "the U.S. Army Research Laboratory, then the Ballistics Research Laboratory, developed effective ammunition compartments in the past, to include the development of the Abrams bustle compartment back in the 1980's. This success was achieved primarily through extensive test and evaluation" (para. 2). The fundamental principle remained unchanged: separating the ammunition from the crew and providing venting for explosive pressure. Conant further notes that "when hit with large hostile fire weapons, internally stowed ammunition may react resulting in catastrophic loss of life and system" (para. 1). This statement echoes almost verbatim the concerns raised by Swiss and Ukrainian designers a decade earlier. Moreover, the 21st-century research described by Conant demonstrates a direct methodological lineage from the compartmentalization experiments of the 1970s. The Army Research Laboratory is now "developing modeling and simulation methodologies to improve the survivability of combat fighting vehicles beginning with hypotheses synthesis and phenomenology studies underpinned by experimentation" (Conant, 2013, para. 4). The enduring relevance of compartmentalization is further underlined by the observation that "as the Army modernizes its fleet, effective ammunition compartmentation will again be needed to ensure vehicles and crew members survive hostile fires" (Conant, 2013, para. 3).

Conceptual Similarity of Solutions from Two Leading Engineering Schools. The comparative analysis conducted of design materials from the Kharkiv KB-60M and the Swiss K+W during the period of the 1970s–1980s reveals not a mere coincidence of individual technical solutions, but a profound conceptual kinship of engineering thought that emerged under conditions of complete informational isolation and the absence of direct experience exchange. Both schools, starting from the analysis of the same tragic lessons of the Yom Kippur War (1973) – where ammunition hits led to the catastrophic destruction of vehicles along with their crews – independently arrived at the conclusion that a change in the layout paradigm was necessary. The similarity is evident on three key levels: protection philosophy, structural implementation, and functional ranking of internal systems.

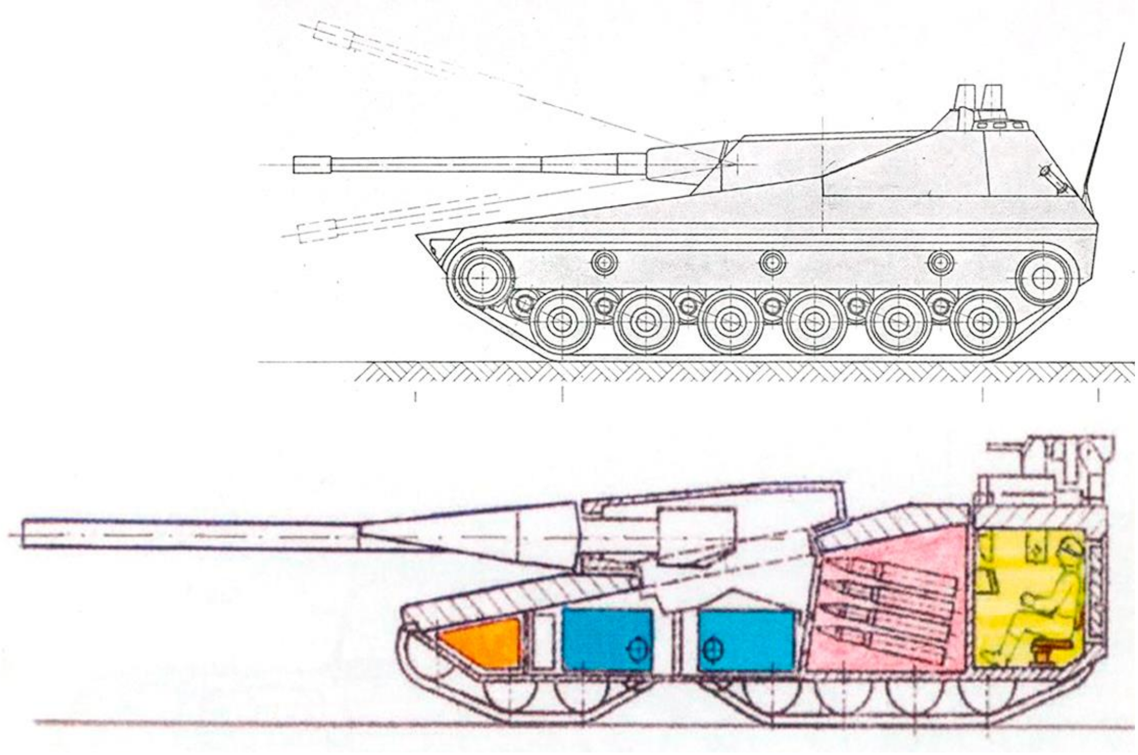


Figure 9. Comparison of side profiles of the Chansard variant 23a (Switzerland) and the tank with a non-traditional layout scheme based on combat properties ranking (Ukraine).

First, both engineering schools rejected the traditional augmentation of frontal armor thickness as the sole or primary means of enhancing protection. Instead, they adopted the principle of compartmentalization as the foundation – that is, the strict functional division of the vehicle's internal volume into sealed and mutually isolated compartments. In the K+W documentation, this principle is established as a separate mandatory criterion for evaluating combat characteristics ("Kompartimentierung: ja/nein"), while in A. A. Morozov's diaries, it is justified by the necessity to abandon the traditional cramped fighting compartment, where the crew is confined among explosive and fire-prone elements. Both Swiss and Ukrainian designers aimed to ensure that a fire or ammunition detonation in one compartment would not lead to the guaranteed destruction of the crew and the catastrophic loss of the entire vehicle.

Second, a structural similarity is observed in the arrangement of key elements. This is most strikingly evident when comparing the Swiss Chansard 23a variant and the line of Ukrainian designs (from the preliminary design «Object 450» to later concepts documented in articles by A. I. Mazurenko. Both concepts place the crew (three in the Swiss design, two in the Ukrainian scheme) in an isolated compartment in the rear of the vehicle. The rear location of the crew compartment was deemed optimal, as it provided maximum protection from the main direction of combat (the front) due to shielding by the power pack and fuel compartments, and also facilitated evacuation. In both cases, the engine (in Switzerland – at the front; in the Ukrainian concept – in the center or front) serves not only as a power source but also as an additional barrier (German: Schutz durch Motor), absorbing penetrating elements. Both solutions stipulated that a mobility kill was preferable to a catastrophic kill.

Third, and most importantly, a unified approach to handling the ammunition load is evident. The Swiss variant 23a provided for the placement of the entire ammunition load in an isolated weapon compartment, separated from the crew by an armored bulkhead, with this compartment being mandatorily equipped with blow-off panels (covers) to vent explosive pressure outward. Ukrainian developments went even further in detailing this principle. In the concepts based on combat property ranking, the ammunition load (K=0.9 in significance) is not merely isolated but is also layered in accordance with the concept of ranking primary systems by their contribution to survivability: it is positioned behind the engine (K=0.6) and fuel (K=0.5), which absorb the primary impact. At the same time, in the Ukrainian projects, the ammunition compartment is also equipped with blow-off panels, representing a direct development of ideas first documented in the American Watervliet Arsenal report (Watervliet Arsenal, 1959).

Finally, both schools arrived at an understanding of the need to synchronize the direction of travel and the primary direction of fire to simplify crew operations. In the Swiss variant 23a, the driver, commander, and gunner are located in the rear compartment and are always oriented in the direction of travel (forward), regardless of the turret's position. In the Ukrainian twin-gun concept with a rotating platform, the crew in the stationary capsule is also always facing the front of the vehicle, preserving spatial orientation and reducing psychophysiological load. This similarity demonstrates a shared understanding of combat ergonomics: personnel should not become disoriented when the turret rotates or when firing to the rear.

Thus, the commonality of engineering thought manifested in the developments of two isolated schools convincingly demonstrates that the principles of compartmentalization and layered protection are not a random or localized invention, but an objective regularity in the evolution of armored vehicles. The prioritization of crew survivability over firepower and mobility, achieved through volume separation and system ranking, became the conceptual bridge connecting Swiss pragmatism and the Ukrainian engineering school in the quest for the tank of the future. Ignoring these principles when defining requirements for the development of advanced vehicles, as occurred with the «Boxer» R&D project in 1979 (The State Archive of Kharkiv Region, 1979), ran counter to the conclusions already reached by the science of the industry.

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The author declare no conflict of interest.

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Компартменталізація та ранжування систем як фундаментальні вимоги до проєктування спеціальних машин: Україна, Швейцарія

Анотація. *Поширення дешевих FPV-дронів докорінно змінило характер загроз для основних бойових танків, висунувши живучість екіпажу як головний критерій проєктування та зумовивши необхідність перегляду історичних концепцій захисту. У цьому дослідженні на основі порівняльного аналізу архівних матеріалів Швейцарського федерального архіву та розсекречених тематичних видань радянського періоду, а також щоденникових записів учасників розробок простежено незалежне виникнення принципу компартменталізації (поділення машини на ізольовані один від одного самостійні відсіки) у швейцарській та українській школах танкобудування в 1970–1980-х роках. Результати демонструють, що обидві інженерні школи, реагуючи на катастрофічні втрати танків у війні Судного дня 1973 року, незалежно одна від одної дійшли практично ідентичних рішень, незважаючи на повну інформаційну ізоляцію. У швейцарському проєкті NKPZ «Kompartimentierung» була офіційно закріплена як обов'язковий оціночний критерій, і лише дві концепції забезпечували повне фізичне розділення екіпажу, боєприпасів та силової установки. Водночас харківські конструктори розробили розділену на відсіки компонувальну схему, засновану на кількісному ранжуванні систем за внеском у живучість, із присвоєнням найвищого коефіцієнта захисту екіпажу, розміщеному в найбільш захищеному відсіку. Обидві школи незалежно дійшли трьох фундаментальних принципів: розміщення екіпажу в ізольованій кормовій капсулі, використання моторного відділення як додаткового захисного бар'єра та оснащення відсіків* *боєприпасів вишибними панелями для відведення енергії вибуху назовні. Даний паралелізм розвитку доводить, що компартменталізація та ранжування систем є об'єктивною закономірністю еволюції спеціальної техніки, а не локальними винаходами. Своєчасність дослідження зумовлена тим, що розроблені в 1970-х роках принципи компартменталізації та ешелонованого захисту екіпажу, будучи відповіддю на виклики свого часу, сьогодні набувають нового звучання у світлі масового застосування FPV-дронів, які знову висувають проблему живучості бронетехніки та запобігання безповоротним втратам.*

Ключові слова*: компартменталізація; танкобудування; інженерні школи; броньовані машини; Холодна Війна*

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