Mechanics of the Ukrainian Army's 14th Mechanized Brigade pass by a damaged main battle tank 20 February 2023 at the brigade's workshop in the Kharkiv region of Ukraine. (Photo by Yasuyoshi Chiba, Agence France-Presse)

Analysis of Land Army Maintenance Techniques in the War in Ukraine

Col. Marinko Aleksić, PhD, Army of Montenegro, Retired
Col. Sead Cvrk, PhD, Army of Montenegro, Retired
Col. Dražen Božović, PhD, Army of Montenegro, Retired

As seen in the first images from the battlefield, the war in Ukraine has a predominantly technical dimension. Both the Russians and Ukrainians employ a huge number of tanks, armored vehicles, and artillery systems in combat operations. However, according to unconfirmed information from various sources, by the beginning of July, both sides had suffered huge losses of combat equipment.[1] Numerous photographs illustrate these losses, but numerical data will not be presented here. History shows us that estimates of combat losses are often far from reliable as they are subject to all kinds of distortions caused by the "fog" of war, wishful thinking, outright lies, and other factors.[2] Instead, this article analyzes the maintenance of combat technical systems in support of ground operations on both sides in the initial period of the war.

Tanks, armored vehicles, trucks, and weapon systems, in addition to suffering damage in combat, often fail under conditions of intensive use and increased stress. This equipment cannot be constantly replaced so maintenance and overhaul are very important as elements of the logistics of mechanized operations and should be analyzed. For example, armor battalions with relatively old M1A1 tanks averaged only 74 percent operational readiness during rotational training at the U.S. Army National Training Center from 1999 to 2001; four out of twenty-two battalions achieved less than 70 percent, which is often considered the breaking point for combat readiness.[3] The importance of maintenance in combat conditions is shown by the claim of French maintenance experts that up to a third of all tanks of a unit are constantly defective and are undergoing needed repairs.[4]

The system of maintenance of armed systems requires the use of technical resources that are significantly different from those normally used outside of the military.[5] When possible, national military-industrial overhaul capabilities are put into operation, and at the corps level, the technical potential of the maintenance system is based on four main elements: recovery vehicles, mobile workshops with universal equipment, special tool sets, and sets of spare parts.[6]

Ukrainian and Russian Military-Industrial Repair Capabilities

The heavy losses of both sides could be mitigated by the rapid repair of malfunctioning armored vehicles and massive refurbishment of old Soviet-era stocks, but how, and who can do it?[7] Major damage requires work at the level of a general overhaul, which can only be done in a stationary factory. For major repairs, facilities are needed with cranes and specialized workshops for complex systems and provisions for surface protection.[8]

A general overhaul can be cost-prohibitive in peacetime.[9] However, in wartime conditions when there might be no new production, the ability to overhaul broken equipment is one of the keys for any army to continue the fight. For Russia and Ukraine, it is vitally important to bring back to life the tanks and combat vehicles that have otherwise been rusting in vehicle graveyards for years.[10]

Ukrainian capabilities. The former Ukrainian Soviet Socialist Republic had a well-developed military-industrial complex and numerous industries capable of mobilization for mass repairs of military equipment. Most of the Ukrainian repair facilities were inherited from the USSR, and many military factories and overhaul facilities have been preserved.[11] Also, after 2014, several new companies appeared in the country, mainly related to the production and repair of armored vehicles.[12]

Before the Russian attack, there were about twenty large enterprises in Ukraine for the production, modernization, and repair of vehicles and armored vehicles (e.g., Kharkiv Mechanical Design Bureau Morozov, VA Malyshev Factory, Kyiv Armored Factory). They are located all over the country. Particularly large concentrations (clusters) of military factories have been in Kyiv and Kharkiv since Soviet times; the Kharkiv cluster is known for its legendary Soviet school of tank construction.[13] Their production programs contain many new models and modifications of some well-known models.[14] They are important for supplying the armed forces of Ukraine, and their maintenance systems are complex.[15]

During May 2022, the Russians destroyed the military-industrial complex and large repair facilities in Kiev and Kharkiv as well as in the interior of Ukraine.[16] At the beginning of the operations in the north, the Kyiv and Kharkiv clusters, due to the partial encirclement of these cities, were not able to accept damaged vehicles, nor could they send new or repaired weapon systems to the front.

According to available information, of the twenty largest enterprises of the armored vehicle industry of Ukraine, up to 20 percent continued or tried to

continue their normal operations by moving to a safe area or using suitable civilian facilities for repair in an urban area.[17] Ukrainian sources point out that those facilities are meeting their daily production schedules 100 percent every day.[18] They also point out that in addition to the repair and maintenance of the Ukrainian equipment, they also mastered the repair of the Russian captured equipment.[19]

A very important factor in equipment repair is the availability and management of overhaul and production documentation. Since the beginning of the invasion, Ukraine has worked to strengthen the resilience of the Internet in the country, which is important for maintaining and protecting documentation. Thanks to Microsoft, the management of digitized documents is carried out and maintained in a "cloud" warehouse outside of Ukraine.[20] Ukraine has also received some SpaceX Starlink transceivers to ensure secure satellite communications.[21]

It can be assumed that with the ongoing hostilities, the Ukrainian military-industrial complex will continue to decline due to the daily bombardment, but only if the Russians have enough long-range cruise missiles.[22] A report by the U.S. Congressional Research Service confirms that Ukraine's capacity to repair and maintain its military equipment has been severely undermined by Russian missile attacks on production sites.[23]

Russian capabilities. During the Cold War era, Russia maintained a large capacity for producing tanks and armored vehicles.[24] According to the information available in the Russian Federation, the largest producer of tanks at the moment is the UralVagonZavod; another large producer is the Chelyabinsk Tractor Factory.[25] UralVagonZavod is not currently producing the desired number of tanks, but instead it has focused on repairing damaged combat equipment.[26] Another factory reportedly lost its ability to manufacture tanks due to sanctions that hindered its ability to procure parts.[27]

A report by the Main Intelligence Directorate of the Ministry of Defense of Ukraine says that directors of Russian overhaul factories are refusing to repair severely burnt equipment brought back by rail from the war in Ukraine. This applies mainly to tanks and armored infantry vehicles. The reason is that much of the equipment is returned with burnt bodies, and repair requires demoralizing and expensive sanitation.[28] The report also contends there is a lack of components and money for this type of repair. Now,

Col. Sead Cvrk, PhD, Army of Montenegro, retired, graduated from the Naval Military Academy in Split, Croatia. He attended his master's and doctoral studies at the University of Montenegro. Cvrk performed command duties on ships and commands of the Yugoslav Navy and the Army of Montenegro for about twenty-eight years. In the Ministry of Defense of Montenegro, he performed the duties of adviser for the maintenance of naval assets. He is currently employed at the Maritime Faculty of Kotor, University of Montenegro, as a teaching associate.

Col. Dražen Božović, PhD, Army of Montenegro, retired, is an assistant professor at Adriatic University, Bar. He graduated from the Infantry Military College and received his master's degree and doctorate in crisis management from the Faculty of Security at the University of Belgrade. For fifteen years, he held command duties in special units of the Army, and then in the Ministry of Defense of Montenegro as an advisor for strategic planning and head of the Directorate for Arms Control (Verification Center of Montenegro).

Col. Marinko Aleksić, PhD, Army of Montenegro, retired, is an associate professor in the Maritime Faculty Bar and head of research and development in the defense industry Poliex Berane, Montenegro. He holds a PhD in maintenance engineering from War College–Military Technical Academy Belgrade and a BSc in industrial electronics from Military Technical University Zagreb. During his career as colonel, Aleksić served at the Naval Repair Facility Tivat as a specialist for the maintenance of army and naval complex systems and as head of the Standardization and Codification Department in the Montenegrin Ministry of Defense. He was the director of the National Codification Bureau of Montenegro. Aleksić received an award for his contribution to NATO codification as a member of the Main Group Directors of NATO Committee AC 135 in November 2018.

The UralVagonZavod factory in Nizhny Tagil, Russia, shown here in 31 July 2005, is the largest producer of tanks in Russia. The factory cannot produce enough tanks to meet the needs of the Russian Army and has switched its focus to repairing damaged equipment. (Photo courtesy of Wikimedia Commons)

however, there is no officially confirmed information from the Russian side.[29]

According to the Ukrainian intelligence services, Russia recently initiated the complete mobilization of companies in Russia to support its war efforts, potentially because of the problems with the repair of the returned military equipment.[30] Russian legislation now obligates companies to enter into contracts for government orders under military conditions. This means "working night shifts, working on holidays and weekends, and changing vacations."[31] In Russia, however, contracts concluded under military conditions do not provide compensation for overtime work. This law, says Ukraine, will support material resourcing from state reserves, mobilization capacities, and locations.

Recovery of Damaged and Defective Combat Equipment

For damaged or defective combat equipment to be repaired, it must first be evacuated to safety. This can be very difficult; a very striking example from the beginning of the war is when a convoy of Russian tanks, armored vehicles, and self-propelled artillery stopped in the vicinity of Kyiv. According to the British Ministry of Defense, the convoy was stopped in part by determined Ukrainian resistance but also because of mechanical failures and Russia's inability to recover and repair its broken vehicles.[32]

Recovering damaged assets and systems from the battlefield is a very important task. It is necessary to tow a damaged vehicle a safe distance to where there are facilities for maintenance and repair. Russian battalion tactical groups, combined battle formations of up to a thousand soldiers, have on average only one heavy BREM-1 and one light BREM-2 recovery vehicle, though there are more at the regimental or brigade levels.[33] Ukrainian forces use the same or modernized type of recovery vehicle.[34] During short-range operations, this is not a problem. Combat formations have organic capabilities to create effective security in the area where they are located on the battlefield. Recovery vehicles can quickly pick up broken equipment with a minimal escort, as friendly units are always nearby. Short towing distances allow recovery vehicles to make multiple turns in a short time,

A disabled Pacir-S air defense vehicle sits mired in the mud in Ukraine. Disintegrated tires on Russian combat vehicles and trucks in Ukraine are a sign of poor basic maintenance. (Screenshot courtesy of Crux via Youtube)

allowing Russian forces to settle for a minimum number of battalion-level recovery vehicles.[35]

None of this applies during deep operations. Damaged vehicles must be towed up to a hundred kilometers, and due to the lack of recovery vehicles, combat vehicles are often diverted to towing. Only a heavy recovery vehicle or a tank can tow another tank.[36]

Long road marches lead to a large number of broken-down vehicles, which significantly exceeds the means for recovery in the Russian battalion and regimental formations.[37] This is not only a Russian problem—it is common to all armies around the world.[38] In the north, the Russian army carried out deep penetration attacks, penetrating up to 120 km deep into Ukrainian territory. At first, not a single unit was left to secure the line of communication. This meant that the faulty vehicles were either abandoned or combat vehicles had to be diverted to tow them. Based on multiple images that appeared online, after a certain time, the Russian commanders decided to abandon their vehicles. The crews were initially left with them, but as partisan resistance from the Ukrainian side emerged, the Russian army stopped leaving the crews, fearing that they would be captured or killed.[39]

An Example of Poor Basic Maintenance

Experiences from the 1990s war in the Balkans have shown that basic maintenance is often poor or insufficient due to the high intensity of the fighting. Due to frequent battles with dangerous exposure to enemy fire, crews do not have time to devote to maintenance.[40] Moreover, poor maintenance can be attributed to the lack of crew training, especially for those replacing other crews lost in combat who did not have time for such training. According to Russian tank experts, basic maintenance is even more important than repair, because it is proper and timely maintenance that can maximally delay the a combat vehicle's departure for repair.[41]

Based on the available photos, we can talk about the poor basic maintenance of some Russian trucks. Trucks are the backbone of any modern motorized military force. The photo we refer to shows potential tire damage on a multimillion-dollar Pancir-S mobile missile system. With such an expensive combat system, it is expected that its maintenance would be first class. However, this vehicle was left stuck in the Ukrainian mud just a few weeks after the war began.[42]

If trucks are not moved often, the rubber on their wheels becomes brittle and the tire walls are susceptible to cracks and tears. The problem is common when tires are used with low pressure to cope with the muddy conditions that Russian forces have faced in the Ukrainian plains. When military truck tires are left in one place for months on end, the sidewalls become brittle in the sun and fail. No one has used that Pancir-S for probably a year.[43]

For Western experts who specialize in U.S. Army truck maintenance issues, the condition of Pancir-S is a revealing mistake. "If you don't do preventive maintenance for something that important, then it's very clear that the entire fleet was treated similarly," they say.[44] Photos provide evidence of other trucks with similar problems.[45]

Maintenance in Field Conditions

As mentioned, mobile workshops with universal equipment, special tool sets, and spare parts kits are very important for field maintenance.[46] In the Ukrainian army, the assumption is that big repairs are mostly carried out in hidden sites in rear urban areas to conceal the maintenance and repair process since the Ukrainians are exposed to bombardment by Russian long-range and cruise missiles.[47]

There is more information available regarding the Russians. According to the International Institute for Strategic Studies, the Russian army has "10 material-technical support brigades, supporting 11 combined armies, one tank army, and four army corps"; the Russian "Western and Southern Commands each have three armies and three material-technical support brigades to support them."[48]

The Russian army has formed mobile repair teams from these support brigades that are sent to the battlefield to repair less damaged and unburned equipment on the spot, installing new parts and assemblies. However, the establishment of forward repair and maintenance points, which are close to the battle lines, is very dangerous. Once the repair begins, the vehicles become immobile and cannot be moved in the event of indirect fire or attack by enemy forces in the rear.[49] For this reason, most maintenance is done in the rear in so-called repair bases. An example is the Tenth Special Regiment for Repair and Evacuation, which deployed a repair base in Crimea for the repair and overhaul of weapons and military equipment of the Russian army. This regiment is mobile, ready to deploy anywhere, and ready to carry out any type of overhaul of any complexity and at any temperature.[50]

Repair bases are equipped with all the necessary tools and accessories for carrying out any type of repairs, regardless of complexity and weather conditions. In these bases, craftsmen and engineers deal not only with defective equipment but also with its planned maintenance. Maintenance and repairs are conducted in a rather comfortable environment in tents with heating and light. Civilians work alongside military foremen. Samples of the equipment under warranty are provided by industry representatives from the companies where they are produced.[51]

In such conditions, aggregate replacement is the fastest and most common method of repair.[52] For example, if a car with a damaged chassis arrives at the repair site, then the wheels will not be repaired, but new ones will simply be put on. If a tank arrives with a damaged engine, it will not be repaired either, but a new one will be installed.[53]

Provision of spare parts is always a problem. Therefore, in combat conditions, cannibalism is imposed as a way of providing spare parts for damaged systems in repair bases. The Russian overhaul battalion cites an example with four damaged cars. If there are spare parts, the cars can come out the very next day. If there are none, then the principle is four cars entered, two will surely exit.[54] In peacetime conditions, cannibalism is considered an unfavorable way of securing spare parts, and its use is a clear indication that there is a lack of spare parts on the Russian side.[55] The Ukrainians also use cannibalism, but in a different way. In their territory, there is a large number of damaged and disabled Russian tanks and combat vehicles of the same type that they use.[56] Each brigade has a technical reconnaissance unit dedicated to searching fields for abandoned vehicles and equipment, then transporting them to repair sites. When a part is removed from a battle tank, it is disabled, but "the number of confiscated working tanks could be counted on one hand. Those that needed repair but will eventually pass is probably another 30 percent. And the last 50 percent was garbage that requires a lot of work."[57] Thus, cannibalism

is imposed on them as a natural way of providing spare parts.

System Modernization Weaknesses

The use of a specific item of equipment in war quickly proves if that equipment works as intended or is flawed in some way, and the repair process provides an opportunity for improvements or work arounds to be made on that equipment to correct any deficiencies.[58] In this war, tanks of Soviet and Russian origin, which are normally used by both sides, showed two very important weaknesses that needed to be addressed.

The first weakness is in the design of Russian tanks and armored personnel carriers. Early development of Russian combat vehicles focused on replacing humans with machinery such as the automatic tank loader. This change specifically meant that ammunition was stored in a rotating "transporter" under the feet of the crew.[59] Tanks of Western origin are similarly automated to reduce the number of crew members, because the technological solution is cheaper than training, housing, and paying soldiers. For the Russians, it allowed the Russian army to invest more in firepower as well as reduce the silhouette of the tank.[60] However, the weakness of the Russian design is that when a tank is hit by an antitank missile, it activates ammunition under the crew compartment that explodes, ejecting the turret from the tank. Terrible pictures show that the crew in such cases has no chance of survival. In the Balkan area, for example, many Yugoslav M84 tanks (made under the T-72 license) suffered the same fate in 1991 during the battles of Vukovar, Croatia. The tanks fought without infantry support, and many were destroyed in the battle on Trpinja Road.[61]

Pictures from the war in Ukraine show these catastrophic kills to be common. This is why the new Russian Armata tank is designed with ammunition storage in the rear part of the turret, like tanks of Western origin. All crew members are seated in a well-protected armored cell separated from automatic loader and ammunition.[62]

Another weakness relates to protection against the tandem warhead on antitank missiles. To protect tanks from this threat, they are covered over the basic armor with explosive-reactive armor.[63] Reactive armor reacts to the impact of a projectile with a counterexplosion to reduce the damage to the vehicle from the round. It is most effective in protecting against cumulative rockets and especially solid kinetic energy penetrators.[64]

However, the problem is with the upper side of the turret. Modern rockets such as the Javelin strike their targets on the top where the armor is thinner and not protected by explosive-reactive armor plates. Russian tank crews have recently begun fitting slatted armor over the turret to their main battle tanks, specifically designed to protect against a top-down impact from a Javelin antitank missile or a drone bomb.[65] This type of improvised cage armor, which is increasingly appearing on Russian T-80 and T-72 tanks in this war, has been seen before in Syria.[66]

The extra cage armor on top might reduce the effectiveness of certain top attack-guided missiles to some degree. However, while the metal structures on top of the tank's turret could potentially interfere with an RPG's detonation sequence and reduce the likelihood of penetrating the base armor, the cage armor alone is unlikely to provide significant protection against an advanced antitank guided missile like the Javelin. Tests just before the war showed the ineffectiveness of this protection, and there is no evidence from the battlefield that this protection was effective.[67]

Technology Theft

Another characteristic of this conflict is the theft of technology from both sides. Both sides captured many weapons systems and armored vehicles.[68] As soon as such interesting systems are captured, they are sent to military factories or institutes for detailed examination and analysis. Western donor countries are assessing the risk of revealing sensitive technology to the Russian military if their donated equipment is captured. Technological trophies routinely change hands in modern warfare, and there have been reports of Ukrainian forces turning the tables and gaining insight into Russian equipment seized on the battlefield. What is new is that risk assessments of equipment falling into Russian hands are becoming more deeply embedded in new donation decisions, as a generational change in the quality of weapons entering Ukraine is underway.[69]

The Ukrainians presented the analysis of advanced electronic chips taken from the guidance system of a

Russian Kh-101 cruise missile that did not explode.[70] This analysis showed the Russian military industry relies on its own but also on Western sources of supply. Some media claimed the large presence of advanced electronics of Western origin are proof that Western sanctions are extremely effective in stopping Russian military production. Michael Kaufman, director of Russian studies at the Institute in Arlington, expressed skepticism about claims that sanctions have forced some Russian tank factories and other defense companies in Russia to shut down their facilities: "It's still too early in the war to expect significant supply chain problems in the Russian defense industry."[71]

As an example of the loss of sophisticated Western weapons, the British Brimstone missile stands out. The first undamaged British Brimstone missile, which has built-in target recognition technology, ended up in the hands of the Russian army in July 2022.[72] Ukrainian forces used it in the Zaporizhzhia region, but the missile fell undamaged into the hands of the Russian side during the fighting. It was immediately sent to Russia for analysis of its construction and technology.[73] Another example is how Russian troops captured two French Caesar self-propelled guns in Ukraine. According to available information, the howitzers have already been sent to Russia, where they will be analyzed by Russian designers from the UralVagonZavod concern.[74]

Variety and Complexity of Combat Systems as a Maintenance Problem

Both warring parties use many diverse systems. The Foundation for Defense of Democracies from Washington identified in its report more than 6,300 relevant weapons systems used by Ukraine.[75] The Russian side noticeably used very old systems, which some Western analysts interpreted as the fact that they did not have sufficient technical means to replace the destroyed ones.[76] However, it may be that using older, known systems makes training to employ them easier. Additionally, using known systems facilitates the acquisition of spare parts and maintenance. If there are known systems, then there is a developed maintenance system for them.[77]

The production and maintenance of tanks and other armored vehicles is a very complex and demanding process that requires a strong industrial base in the country. To have a complete maintenance process, one must have the ability to perform a general overhaul, which is considered the most complex type of maintenance. Repairing heavy battle damage is categorized as a general overhaul operation.[78] However, the general overhaul process is very complicated, requiring educated and experienced engineers and craftsmen. In addition, facilities, technical overhaul documentation, special tools, instruments, spare parts, and equipment are needed.[79]

> The lack of unified documentation is one of the most serious obstacles to technological improvements and the organization of military overhaul of complex models of armored vehicles.

The current models of armored weapons and equipment that the Russian and Ukrainian forces are equipped with represent myriad systems belonging to different services or specialties of the ground forces (e.g., missile and artillery weapons, armored weapons, engineering, chemicals, communications). This wide variety is where the problems arise when this equipment needs to be repaired.

The lack of unified documentation is one of the most serious obstacles to technological improvements and the organization of military overhaul of complex models of armored vehicles. According to Russian sources, experts must use fifteen to twenty books on vehicle operation and as many books of documentation for repairs.[80]

Leo Peria-Peigne, a weapons expert at the French think tank IFRI, confirms that the battle tank is the most complex military vehicle of the army in terms of maintenance.[81] To illustrate the complexity of the maintenance tasks related to armored combat systems, in the table (on page 41), we provide an overview of the assemblies of the fire control system and the gun of

Table. Illustration of the Complexity of the M-84 Tank Fire Control System

Function	Description
Optoelectronics optics	Aiming devices, laser receiver-transmitter channel, and night channel with a passive light amplifier, periscope TNPO-168V and two periscopes in the cover for side observation, passive-active periscope PPV3 with a light amplifier, IR beacon FG-125S
Hydraulics	Hydraulic booster with hydraulic pump and electric motor, horizontal cylinder, hydraulic motor, installation
Electrics	Power junction box, starter, ignition circuit, installation, electric motors, electric motor of hydro booster, block relay KP-1
Power electronics	Power circuits, acorn power circuits, static converter
Electronics	Electronic ballistic computer, gyro block, interface, amplifier box, meteorological sensor, control panel computer, 2 Motorola MC6802 microprocessors, day-night aiming device DNNS-2
Precise electro mechanics	Gyroscopes, Box K-1, Box K-2
Electro mechanics	Cannon loading machine – rotating "transporter," programmer
Artillery mechanics	Automatic machine, cradle, shutter, tube with linings for cooling, powder gas extractor

(Table by authors)

the Yugoslav tank M-84. The fire control system of this tank is an electro-hydraulic modular type, automatic with stabilization in both planes, integrated with a ballistic computer and a laser range finder, a day-night sight device, and an automatic loader.[82]

Related to this example, an interesting question is how and who will maintain the Slovenian M-84 tanks that were sent to Ukraine. Out of fifty-four M-84 type tanks in Slovenia, only thirteen were overhauled and modernized; the other tanks have been in reserve since 2013 and with outdated equipment.[83]

The Ukrainians have begun to receive complex Western systems, but there is not much time for training on how to use them, let alone maintain them. It was reported that Bulgaria will not deliver weapons but will instead provide "military-technical assistance"; in other words, it will repair damaged Ukrainian weapons and maintain military equipment.[84] Slovakia also offered the Ukrainians the use of overhaul capacities in state-owned enterprises owned by the Ministry of Defense, but on a commercial basis.[85]

The assumption is that combat use will quickly lead to the required level of training for use, but maintenance is a far greater challenge that cannot be solved during combat operations. An example is the seven Panzerhaubitze 2000 self-propelled howitzers Ukraine received from Germany. After a short training and intensive action in combat, there were no problems with use. However, the loading mechanisms began to fail and the barrels wore out as the Ukrainians fired a large number of shells in a short time. Repair and overhaul will have to be carried out by the Germans, which requires the howitzers be transported to Poland.[86]

If the variety of incoming weapons presents them with a logistical headache, military analysts agree that Ukrainian technical support has shown an exceptional ability to adapt to it. Peria-Peigne said that Ukraine has a significant number of specialists who can accept a variety of Western equipment.[87] However, maintenance training efforts for the Ukrainian side will only pay off if the West sends sufficient tanks and armored vehicles. If, for example, Great Britain sent only ten Challenger2 tanks, it would be a "poisoned chalice."[88]

Russian military journals point out that the experience of combat operations in Ukraine is very important

for their army. Here, the crystallized need for the standardization, or "unification," of combat systems will be singled out, so much so that the importance of unification is placed first concerning innovations and the development of new systems![89] They use the slogan "Унификация важнее инноваций" (unification is more important than innovation). Unification of military equipment was insisted on even in the Soviet Union, reaching its peak by the end of the Second World War. In the Red Army, until the end of the war, there were only two main models of tanks on the production line: T-34 and IS (KV), with one V-2 tank engine, in two versions for medium and heavy tanks. Self-propelled guns were also built based on these platforms.[90]

This approach in the Soviet Union contrasted to the German approach at the time. The technical innovations that the Germans introduced on the fronts of the Second World War were impressive, but they seriously complicated logistics, maintenance, and repairs. The famous German general of armored units Guderian recalled this in his memoirs: "Hitler's orders that required constructive changes in the production process of combat vehicles, and therefore the creation of countless different types with many spare parts, were a big mistake. All this led to the overhaul of tanks in the field becoming an intractable problem."[91]

The situation regarding the unification of Russian main battle tanks is interesting. The Russian army uses three lines of armored vehicles with modifications: T-72, T-80, and T-64. These are the three crowns of the Kharkiv, Leningrad, and Nizhny Tagil schools of design. However, the interchangeability of parts or subsystems of these tanks ends at the ammunition; the engines, transmissions, and chassis are completely different.[92]

When considering that the Ukrainian military production program contains a lot of new and modified models of tanks and combat armored vehicles, and with various types of equipment arriving from the West, it is clear that there are problems with maintenance and supply of spare parts for both warring parties. At the same time, of course, Russia has an advantage, because it still has undamaged storage capacities from which spare parts can be obtained.

Conclusion

So far, no new features have been observed in the maintenance systems that were not seen in earlier wars, including the war in the Balkans. It can be concluded that the main characteristics of this war include a large number of irretrievably destroyed equipment and a large number and variety of technical systems for which it is necessary to plan and carry out maintenance. Such a model indicates that one of the most important lessons from this war is the need for unification in all elements of technical systems, similar to what Soviet forces successfully achieved against Wehrmacht forces in World War II. According to NATO standards, this is called interoperability among allies, which strives for the highest level of compatibility—that is, the level of interchangeability when it comes to ammunition, fuel, and supply and service systems. ■

Notes

1. Ministry of Defence of Ukraine, "Total Combat Losses of the Enemy from 24.02.2022 to 24.07.2022," Ukraine Government Portal, 24 July 2022, accessed 28 February 2023, https://www.kmu.gov.ua/en/news/zahalni-boiovi-vtraty-protyvnyka-z-24022022-po-24072022.

2. Jeff Schogol, "The US and NATO Disagree over an Estimate of 40,000 Russian Casualties in Ukraine," Task and Purpose, 24 March 2022, accessed 28 February 2023, https://taskandpurpose.com/news/ukraine-nato-united-states-russian-casualties/.

3. Eric Peltz et al., "The Effect of Age on the M1 Tank: Implications for Readiness, Workload, and Recapitalization" (research brief, Santa Monica, CA: RAND Corporation, 2019), accessed 22 January 2023, https://www.rand.org/pubs/research_briefs/RB3032.html.

4. Agence France-Presse, "Logistical Challenge Looms for Ukraine over Promised Tanks," France24, 13 January 2023, accessed 28 February 2023, https://www.france24.com/en/live-news/20230113-logistical-challenge-looms-for-ukraine-over-promised-tanks.

5. Army Techniques Publication 4-33, *Maintenance Operations* (Washington, DC: U.S. Government Publishing Office, 2019), 1-1, accessed 26 December 2022, https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/ARN19571_ATP%204-33%20C1%20FINAL%20WEB.pdf.

6. Tomasz Smal and T. Smoła, "Transition Modification of Mobile Workshops System – Polemic Article," in *Deterioration, Dependability, Diagnostics*, ed. Rosická, Zdena, Jiří Stodola, and Jiří Šťastný (Brno, CZ: University of Defense, 2011), 130.

7. John Hall, "Perhaps They Should Have Held on to Them: Hundreds of Rusting Tanks Abandoned in Secret Ukrainian Depot Unveiled as Russia's Armored Vehicles Line Its Streets," *Daily Mail* (website), 3 March 2014, accessed 28 February 2023, https://www.dailymail.co.uk/news/article-2572149/Stunning-images-huge-abandoned-tank-graveyard-Ukraine-machines-come-retirement-tensions-Russia-continue-escalate.html.

8. Darko Petković, Marinko Aleksić, and Petar Stanojević, *Maintenance Concepts* (Zenica, BA: University of Zenica, Faculty of Mechanical Engineering, 2020), 96.

9. Marinko Aleksić, Darko Petković, and Petar Stanojević, *RCM - Reliability Centered Maintenance* (Zenica, BA: University of Zenica, Faculty of Mechanical Engineering, 2011), 118.

10. Hall, "Perhaps They Should Have Held on to Them."

11. Alexey Volynets, "Military-Industrial Inferiority Complex" [in Russian], Russian Planet, 13 December 2014, accessed 27 December 2022, https://rusplt.ru/ukraine/kompleks-voennopromyishlennoy-nepolnotsennosti-14852.html.

12. "Map of the Armored Industry of Ukraine: Up to 80% of Large Enterprises Are Blocked or under the Control of the Russian Federation" [in Russian], MashNews, 14 March 2022, accessed 14 March 2022, https://mashnews.ru/bronetankovaya-otrasl-ukrainyi-do-80-krupnyix-predpriyatij-blokirovanyi-ili-pod-kontrolem-rf.html.

13. Ibid.

14. Roman Pagulych, "Losses in the War: How the Ukrainian Armor Suffered and How the Army Is Strengthened" [in Russian], Crimea Realities, 16 June 2020, accessed 28 February 2023, https://ru.krymr.com/a/chem-usilivayut-ukrainskuyu-armiyu/30674187.html.

15. "Map of the Armored Industry of Ukraine."

16. Jack Detsch and Robbie Gramer, "Russian Troops Are Taking Putin's Orders to Demilitarize Ukraine Literally," *Foreign Policy* (website), accessed 28 February 2023, https://foreignpolicy.com/2022/05/04/russia-demilitarize-ukraine-arms-facilities/.

17. "Map of the Armored Industry of Ukraine."

18. Elena Roshchina, "Ukroboronprom Has Mastered the Repair of 'Captured' Military Equipment of Russians" [in Russian], *Pravda* (website), accessed 28 February 2023, https://www.pravda.com.ua/rus/news/2022/03/29/7335426/.

19. Kelsey Vlamis, "Mechanics in Ukraine Are Repairing Russian Tanks That Were Damaged and Captured in Battle So They Can Be Used by Ukrainian Forces," Business Insider, accessed 28 February 2023, https://www.businessinsider.com/ukraine-mechanics-repair-russian-tanks-for-use-by-ukrainian-forces-2022-5.

20. Roshchina, "Ukroboronprom Has Mastered the Repair of 'Captured' Military Equipment of Russians."

21. Tara Copp, "Five Reasons Why Russian Forces Are Struggling in Ukraine," Defense One, 1 March 2022, accessed 28 February 2023, https://www.defenseone.com/threats/2022/03/five-reasons-why-russia-struggling-ukraine/362636/.

22. "Map of the Armored Industry of Ukraine."

23. Dan DeLuce, "The West Should Help Ukraine Get More Russian-Made Weapons and Ammo from Around the World, a Think Tank Says," NBC News, 6 July 2022, accessed 28 February 2023, https://www.nbcnews.com/news/military/west-help-ukraine-get-russian-made-weapons-ammo-world-think-tank-says-rcna36809.

24. "Soviet Armored Vehicle Industry," Global Security, accessed 25 June 2022, https://www.globalsecurity.org/military/world/russia/industry-ground-intro.htm.

25. Hleb Kanevsky, "Putin's Favorite Factory. Tanks of the Largest Producer of the Russian Federation Have Been Under Sanctions Since 2014, But They Travel in Ukraine. How Did It Happen?" [in Ukrainian], Forbes Ukraine, 10 May 2022, accessed 28 February 2023, https://forbes.ua/inside/ulyubleniy-zavod-putina-koli-vin-pide-na-dno-10052022-5933?fbclid=IwAR1CK-KLp_C2IQ46IFLAZE98nOqanbQjBFD7v-VfELuj9IJEctrwXaTgDak; "Chelyabinsk Tractor Plant - Uraltrac Ltd," Army Guide, accessed 28 February 2023, http://www.army-guide.com/eng/firm1366.html.

26. Boyko Nikolov, "Russia Doesn't Produce Tanks, Uralvagonzavod with Half Production," BulgarianMilitary.com, 8 July 2022, accessed 28 February 2023, https://bulgarianmilitary.com/2022/07/08/russia-doesnt-produce-tanks-uralvagonzavod-with-half-production.

27. "Russia's Only Tank Factory Closes," Rebellion Research, 27 March 2022, accessed 28 February 2023, https://www.rebellionresearch.com/russias-only-tank-factory-closes.

28. Boyko Nikolov, "Burnt Tanks Return to Russia, Repair Plants Refuse Repairs," BulgarianMilitary.com, 6 July 2022, accessed 28 February 2023, https://bulgarianmilitary.com/2022/07/06/burnt-tanks-return-to-russia-repair-plants-refuse-repairs/.

29. Ibid.

30. "Russia: New Law Obliges Companies to Assist Govt. with War Mobilization," Business & Human Rights Resource Centre, 26 September 2022, accessed 27 December 2022, https://www.business-humanrights.org/en/latest-news/russia-new-law-obliges-multinational-cos-to-assist-with-war-mobilization/.

31. Nikolov, "Burnt Tanks Return to Russia."

32. "Ukraine: Why Has Russia's 64km Convoy near Kyiv Stopped Moving?," BBC News, 3 March 2022, accessed 28 February 2023, https://www.bbc.com/news/world-europe-60596629.

33. Bonnie Berkowitz and Artur Galocha, "Why the Russian Military Is Bogged Down by Logistics in Ukraine," *Washington Post* (website), 30 March 22022, accessed 27 December 2022, https://www.washingtonpost.com/world/2022/03/30/russia-military-logistics-supply-chain/.

34. "BREM-1 Armored Recovery Vehicle," Military-Today.com, accessed 28 February 2023, http://www.military-today.com/engineering/brem1.htm.

35. Alex Vershinin, "Feeding the Bear: A Closer Look at Russian Army Logistics and the Fait Accompli," War on the Rocks, 23 November 2021, accessed 28 February 2023, https://warontherocks.com/2021/11/feeding-the-bear-a-closer-look-at-russian-army-logistics/.

36. Ibid.

37. Berkowitz and Galocha, "Why the Russian Military Is Bogged Down by Logistics in Ukraine."

38. Ryan T. Baker, "Logistics and Military Power: Tooth, Tail, and Territory in Conventional Military Conflict" (PhD diss., Columbian College of Arts and Sciences, George Washington University, 17 May 2020), 8.

39. Robert Dalsjö, Michael Jonsson, and Johan Norberg, "A Brutal Examination: Russian Military Capability in Light of the Ukraine War," *Global Politics and Strategy* 64, no. 3 (2022): 7–28, https://doi.org/10.1080/00396338.2022.2078044.

40. Marinko Aleksić and Rajko Vidojević, *Self-Propelled Anti-Aircraft Gun 30/2 mm – Praga*, New Bulletin 5, COBISS.CG-ID 59547394 (Belgrade, RS: Military Publishing House, 1997), 83.

41. Roman Skomorokhov, "No Panic: Lend-Lease Is Not a Recipe for Victory" [in Russian], Military Review (Tanks and Stuff), 11 May 2022, accessed 11 May 2022. https://topwar.ru/195895-bez-paniki-lend-liz-ne-est-recept-pobedy-tanki-i-prochee.html.

42. Dylan Malyasov, "Russian Pantsir-S1 Stuck in Mud in Southern Ukraine," Defence Blog, 28 February 2022, accessed 28 February 2023, https://defence-blog.com/russian-pantsir-s1-stuck-in-mud-in-southern-ukraine/.

43. Brad Lendon, "What Images of Russian Trucks Say About Its Military's Struggles in Ukraine," CNN, 14 April 2022, accessed 28 February 2023, https://www.cnn.com/2022/04/14/europe/ukraine-war-russia-trucks-logistics-intl-hnk-ml/index.html.

44. Ibid.
45. Andrew Bogie, "Are Tire Issues Hampering Russian Military Progress in Ukraine?," Tyre Press, 4 March 2022, accessed 28 February 2023, https://www.tyrepress.com/2022/03/are-tyre-issues-hampering-russian-military-progress-in-ukraine/.
46. Smal and Smoła, "Transition Modification of Mobile Workshops System," 129–35.
47. "Map of the Armored Industry of Ukraine."
48. Vershinin, "Feeding the Bear."
49. Ibid.
50. Valentin Gvozdev, "In Full Readiness: How Military Equipment is Maintained for a Special Operation in Ukraine" [in Russian], Zvezda TV, 11 March 2022, accessed 11 March 2022, https://tvzvezda.ru/news/202231174-0dp0I.html.
51. Ibid.
52. Nikola Vujanović, *Reliability Theory of Technical Systems* (Belgrade, RS: Military Publishing News Center, 1990).
53. Stanislav Ivashchenko and Maxim Kryukov, "Armor Healers: How the Repair Battalions of the RF Armed Forces Repair Military Equipment Right in the Field during a Special Operation" [in Russian], Zvezda TV, 2 June 2022, accessed 2 June 2022, https://tvzvezda.ru/news/202262517-Ymfrv.html.
54. "Put on the Move: How the Repair Battalions of the RF Armed Forces Give a Second Life to Failed Equipment" [in Russian], Zvezda TV, 23 May 2022, accessed 23 May 2022, https://tvzvezda.ru/news/2022523738-IFLk2.html.
55. John C. Johnson, "Days of Cannibalizing Military Aircraft for Spare Parts Coming to an End," *National Defense* (website), 20 November 2018, accessed 28 February 2023, https://www.nationaldefensemagazine.org/articles/2018/11/20/maintainers-cannibalizing-interchangeable-parts-to-end.
56. "Ukrainians Search Destroyed Russian Military Vehicles for Spare Parts," Reuters, 20 September 2022, accessed 28 February 2023, https://www.reuters.com/news/picture/ukrainians-search-destroyed-russian-mili-idUSRTSBEFMR; Samantha Schmidt, Isabelle Khurshudyan, and Serhii Korolchuk, "Captured Russian Tanks and Equipment Are Coveted Trophies — and a Headache," *Washington Post* (website), 27 December 2022, accessed 28 February 2023, https://www.washingtonpost.com/world/2022/12/27/ukraine-russia-tanks-military-vehicles/.
57. Schmidt, Khurshudyan, and Korolchuk, "Captured Russian Tanks and Equipment."
58. Aleksić and Vidojević, "Self-Propelled Anti-Aircraft gun 30/2 mm – Praga"; Evgeny Fedorov, "The Real Unification of Military Equipment is an Important Consequence of the Special Operation 'Z'" [in Russian], Military Review, accessed 12 June 2022, https://topwar.ru/198694-totalnaja-unifikacija-boevoj-tehniki-vazhnejshee-sledstvie-specoperacii-z.html.
59. Asymmetric Warfare Group, *Russian New Generation Warfare Handbook* (Fort Meade, MD: Asymmetric Warfare Group, 2016), accessed 28 February 2023, https://info.publicintelligence.net/AWG-RussianNewWarfareHandbook.pdf.
60. Lester Grau and Charles Bartles, *The Russian Way of War: Force Structure, Tactics, and Modernization of the Russian Ground Forces* (Fort Leavenworth, KS: Foreign Military Studies Office, 2017), accessed 28 February 2023, https://www.armyupress.army.mil/portals/7/hot%20spots/documents/russia/2017-07-the-russian-way-of-war-grau-bartles.pdf.
61. Davor Runtić, *Vukovar and the Eastern Battlefield*, book 2 (Vinkovci, HR: Vinkovci Publishing, 2009); Petar Horvatić, "(Video) Memento on the Eve of the Storm – Marko Babić and His Heroes 'Stacked' a Huge Tank Cemetery on Trpinjska Road!" [in Croatian], Narod HR, 5 July 2019, accessed 5 May 2022, https://narod.hr/kultura/video-5-srpnja-2007-memento-uoci-oluje-marko-babic-i-i-junaci-stvorili-groblje-tenkova-na-trpinjskoj-cesti.
62. "Armata - Main Battle Tank," Military-Today.com, accessed 28 February 2023, http://www.military-today.com/tanks/armata.htm.
63. Joseph Trevithick, "U.S. Army M1 Abrams Tanks in Europe Are Getting Explosive Reactive Armor," The Drive, 29 June 2019, accessed 28 February 2023, https://www.thedrive.com/the-war-zone/8144/u-s-army-m1-abrams-tanks-in-europe-are-getting-explosive-reactive-armor.
64. Deb Sheershoo, "Explained: How Explosive Reactive Armor Works?," DefenceXP, 25 February 2021, accessed 28 February 2023, https://www.defencexp.com/explained-how-explosive-reactive-armour-works/.
65. Dylan Malyasov, "Ukraine Demos a 'Big Surprise' for Russia," Defence Blog, 23 December 2023, accessed 23 December 2021, https://defence-blog.com/ukraine-demos-a-big-surprise-for-russia/.
66. Sebastien Roblin, "Russian Tanks Massing Near Ukraine Sport Mods Against Drones, Javelin Missiles," *Forbes* (website), 29 November 2021, accessed 1 March 2023, https://www.forbes.com/sites/sebastienroblin/2021/11/29/russian-tanks-massing-near-ukraine-sport-mods-against-drones-javelin-missiles/?sh=605091bc65e9.
67. Thomas Newdick, "Ukrainian Troops Test Javelin Missile Against Russian Cage-Style Improvised Tank Armor," The Drive, 23 December 2021, accessed 1 March 2023, https://www.thedrive.com/the-war-zone/43648/ukrainian-troops-test-javelin-missile-against-russian-cage-style-improvised-tank-armor.
68. Schmidt, Khurshudyan, and Korolchuk, "Captured Russian Tanks and Equipment Are Coveted Trophies."
69. Sebastian Sprenger, "The Race to Arm Ukraine Highlights West's Worry of Losing Tech Secrets," Defense News, 8 June 2022, accessed 1 March 2023, https://www.defensenews.com/global/europe/2022/06/08/the-race-to-arm-ukraine-highlights-wests-worry-of-losing-tech-secrets/.
70. Howard Altman, "Captured Russian Weapons Are Packed with U.S. Microchips," The Drive, 27 May 2022, accessed 1 March 2023, https://www.thedrive.com/the-war-zone/captured-russian-weapons-are-packed-with-foreign-microchips.
71. Ana Swanson, John Ismay, and Edward Wong, "U.S. Technology a Longtime Tool for Russia, becomes a Vulnerability," *New York Times* (website), 2 June 2022, accessed 1 March 2023, https://www.nytimes.com/2022/06/02/business/economy/russia-weapons-american-technology.html.
72. "There Was a Photo of the Latest British Weapons for Ukraine" [in Russian], Lenta, 8 May 2022, accessed 23 June 2022, https://lenta.ru/news/2022/05/08/brimstone/.
73. Ibid.
74. "UralVagonZavod Conveyed 'Gratitude' to Macron for the 155-mm Caesar Self-Propelled Guns Delivered to Ukraine" [in Russian], Military Review, 23 June 2022, accessed 23 June 2022, https://topwar.ru/198172-uralvagonzavod-peredal-blagodarnost-makronu-za-postavlennye-ukrainu-155-mm-sau-caesar.html.
75. Ryan Brobst, John Hardie, and Bradley Bowman, "Non-NATO Sources of Soviet and Russian Arms for Ukraine," FDD Visuals, 6 July 2022, accessed 1 March 2023, https://www.fdd.org/analysis/2022/07/06/non-nato-sources-of-soviet-and-russian-arms-for-ukraine/.

76. Alberto Nardelli, "Russia Turns to Old Tanks as It Burns through Weapons in Ukraine," *Japan Times* (website), 15 June 2022, accessed 1 March 2023, https://www.japantimes.co.jp/news/2022/06/15/world/russia-old-tanks-ukraine/.

77. Fedorov, "The Real Unification of Military Equipment."

78. Federal Secretariat for National Defense, *Technical Service Rule* (Belgrade, RS: Federal Secretariat for National Defense, 1979 [obsolete]), accessed 9 March 2023, https://www.kupindo.com/Vojna-literatura/71966933_Pravilo-tehnicke-sluzbe.

79. Marinko Aleksić, *Ship's Artillery Overhaul Designing*, New Bulletin 6, COBISS.CG-ID 59547394 (Belgrade, RS: Military Publishing House, 1998), 77.

80. Valery Kovalev, Leonid Kutarov, and Ivan Stepanchuk, *Military Overhaul - Process Complex* (Minsk, BY: Belarusian Digital Library, 2014), accessed 24 May 2022, https://library.by/portalus/modules/warcraft/readme.php?subaction=showfull&id=1407042233&archive=&start_from=&ucat=&.

81. Agence France-Presse, "Logistical Challenge Looms for Ukraine over Promised Tanks."

82. M. Đorđević, "Thirty Two Years of the M-84 Tank," *Defense* 232, special supplement 119 (Belgrade, RS: Military Publishing House, 2015).

83. "Slovenian M-84 Tanks on the Way to Ukraine," Obrama, 15 July 2022, accessed 1 March 2023, https://www.obramba.com/novice/kopno/slovenski-tanki-m-84-na-poti-v-ukrajino/.

84. Christopher Nehring, "Bulgaria: Government Crisis, Secret Weapons Shipments and a Stroke of Genius," Deutsche Welle, 5 October 2022, accessed 1 March 2023, https://www.dw.com/hr/bugarska-kriza-vlade-tajne-isporuke-oru%C5%BEja-i-jedan-genijalan-potez/a-61746136.

85. Michal Hudec, "Slovakia Offers to Repair Ukrainian Military Equipment," Euractiv, 17 April 2022, accessed 1 March 2023, https://www.euractiv.com/section/politics/short_news/slovakia-offers-to-repair-ukrainian-military-equipment/.

86. "Ukraine Reports Problems with German Self-Propelled Howitzers," NTV, 29 July 2022, accessed 1 March 2023, https://www.n-tv.de/ticker/Ukraine-meldet-Probleme-mit-deutschen-Panzerhaubitzen-article23495312.html.

87. Agence France-Presse, "Logistical Challenge Looms for Ukraine over Promised Tanks."

88. Ibid.

89. Fedorov, "The Real Unification of Military Equipment."

90. Ibid.

91. "How Tanks Were 'Patched' during the War, Hitler's Mistake and the Soviet 'Letuchki' (Welding)" [in Russian], Zen, 29 December 2019, accessed 24 May 2022, https://dzen.ru/media/eurowelder/kak-latali-tanki-vo-vremia-voiny--oshibka-gitlera-i-sovetskie-letuchki--svarka-5e08749378125e00aeec689f.

92. Fedorov, "The Real Unification of Military Equipment."