The Mass Approach in the Air War Over Ukraine

Towards identifying a critical mass

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Resumé

Konceptet *massa* är ett välkänt begrepp genom krigshistorien. Antalet krigförande och vapen har ofta varit avgörande för att nå en seger eller ett önskat resultat. Den tekniska utvecklingen av vapen har förskjutit diskussionen inom denna krigföringsprincip mot ökad kraft och effekt med hjälp av banbrytande teknologier jämfört med den enkla numeriska överlägsenheten hos ens motståndare eller fiende. Varje domän av krigföringen och dess militära förmåga påverkas av denna massans dikotomi, när aktörerna strukturerar sina väpnade styrkor och anskaffar vapen. Däremot har denna princip och övergången till banbrytande teknologier för kraftmultiplikation och effektackumulering givits en än mer framträdande roll inom luftstridskrafterna och luftkrigsdomänen. Detta tack vare luftstridskrafternas inneboende egenskaper (d v s hastighet, räckvidd, flexibilitet och mångsidighet). Denna artikel diskuterar principen om massa och spjutspetsteknologi i luftkriget om Ukraina. Följaktligen kommer artikeln att undersöka vilka brister i massan och numerär överlägsenhet som var evident i luftkriget och varför. Vidare diskuteras hur de ukrainska väpnade styrkorna (UAF) reducerade rysk antalsmässig överlägsenhet i luften, liksom beskrivs vilka preliminära faktorer som kan pekas ut för vidare diskussion om mass- och banbrytande teknologier för modern och framtida luftkrigföring.

THE CONCEPT OF mass has been well-known in the history of warfare since early times. Numbers of belligerents and weapons have often been decisive in achieving a victory or a desired outcome. The technological development of weapons has shifted the discussion of this principle of war towards force multiplication using cutting-edge technologies versus the simple numeric superiority of one's adversary or enemy. Each domain of warfare and consequent military capability is affected by this dichotomy of mass approach to structuring one's armed forces and the procurement of distinctive weapons. However, this principle and the shift towards cutting-edge technologies as force multiplication and effects accumulation had an even greater prominence in the case of air power and air warfare thanks to the inherent attributes of air power (i.e. speed, reach and flexibility).

This article will discuss the principle of mass and cutting-edge technologies in terms of their role in the air war over Ukraine. Consequently, it will examine which shortfalls of the Russian mass and numeric superiority were evident in the air war and why. Furthermore, the article discusses how the

Ukrainian Armed Forces (UAF) undermined Russian numeric superiority in the air and it will describe which preliminary points can be singled out for further discussion of mass and cutting-edge technologies for modern and future air warfare.

The rest is structured as follows. First, the principle of mass is discussed in terms of common definitions and strategic thinking. This will be followed by a doctrinal reflection, which will culminate in an overview of the recent academic and military professional discussion of its place in air forces. Second, the reflection of mass is discussed in the context of the war in Ukraine in terms of the different roles and aspects of air power. Finally, the article will discuss the implications of these findings for the overall debate on the mass principle in modern and future warfare.

The principle of mass

The principle of mass has been common in warfare for millennia and it has become an integral part of many theories and strategic teachings on the art of war. It has also been used in the formal military conceptualisation of warfare, which is reflected in many military doctrines. Inevitably, the changing character of warfare has resulted in revisions and different perspectives on this principle and its meaning in the modern military. Consequently, the shape and form of the armed forces and their employment in the battlespace have often been debated. This section will describe some of the perspectives on the concept of mass from the classical strategic, doctrinal and recent professional military and academic discussion of this concept in terms of the modern military and warfare.

From a strategic perspective, the principle of mass has traditionally described the concentration of people and capabilities at a given place and time. Classical strategic thinkers addressed this principle of war as any other. However, neither Sun Tzu nor Clausewitz were convinced that numeric superiority in a mass would guarantee victory. For example, according to Clausewitz, only in the sterile environment of combat stripped of all technological modifications and situational requirements, just as troops' morale, would victory in such combat without form largely be due to numeric superiority. However, Clausewitz remained convinced that the mass principle was only one aspect of how to achieve victory in battle.[1]

For Sun Tzu, numeric superiority was very far from guaranteeing anything on the battlefield. He was more in favour of manoeuvre against larger enemy forces, employing the principle of divide-and-rule: 'The control of a large force is the same principle as the control of a few men: it is merely a question of dividing up their numbers.'[2] Flexibility in terms of troop concentration and dividing had to be conditioned by circumstances. In other words, numeric superiority or its absence would mainly suggest a different way of conducting war and the greater sophistication of the smaller side in dividing the enemy's concentration of force. Hence, even without modern sophisticated technologies, mass was not seen by Sun Tzu or Clausewitz to be a decisive factor in achieving victory.

The conceptualisation of the principle of mass in Western military thinking and military education was reflected in national military doctrines and their cultural takes on defining and interpreting this principle. In the American tradition, it was initially defined as the numeric concentration of force.[3] However, with the diversification of technologies and factors to enable the achievement of diverse outcomes on the battlefield, the focus moved towards massing of effects

and was codified in US doctrine as follows: 'mass – purpose is to concentrate the effects of combat power at the most advantageous place and time to produce decisive results.'[4] By extension, in the case of air power the focus is placed on its flexibility and versatility in adopting both the principle of mass concentration and economy of force when and how it is required.[5]

In the allied environment, the focus is primarily placed on achieving mass through allied joint integration. In the foreword of the recent UK air power doctrine JDP0-30 (3rd edition), Air Chief Marshal Sir Mike Wigston concluded that: "The UK maintains highly credible air power but cannot provide the full breadth of air power capabilities and enablers to generate, coordinate and sustain the mass required to conduct high-intensity operations alone. For that reason, we must always be innovative in our development and application of air power, and the way we integrate it across all operational domains and with our international allies and partners."[6]

These doctrinal reflections illustrate a significant change in thinking about the concept of mass in modern warfare, especially in the last three post-Cold War decades. The concept of mass has changed from numerical superiority to the procurement of cutting-edge technologies as a means of force multiplying and gaining what became known as artificial mass, focusing on Command and Control (C2), lethality, and informational superiority[7] or technological superiority. This change has had a significant impact on the post-Cold War reorganisation of the armed forces across the world, who have reduced their numerical scale and invested in fewer but more sophisticated platforms, with further waves of modernisation and substitution with even newer platforms.[8]

While this change in the concept of mass illustrated the constant catching up with the industrial potential of manufacturing the most sophisticated aerial technologies, it also raised the question of constantly rising costs and the consequent cost-efficiency of many projects.[9] Furthermore, before the full-scale Russian invasion of Ukraine, the revival of peer and near-peer conflict initiated a wave of discussions on how the superiority of the artificial mass of cutting-edge technologies would face an adversary who aimed to catch up with the technological side but was also capable of producing more of the traditional mass.[10]

Professor Heather Venable raised the question of the implications of the reorientation from the conventional to artificial mass by the USAF. Despite the numerical cuts in the American aerial fleet since the Vietnam war, and following the peace dividend in the post-Cold War era and the lack of numeric replacement of the retiring fleet, the USAF managed to compensate with artificial mass by taking advantage of the surprise and swift achievements that air power can provide in the first hours of engagement. However, Venable argues that with the increase in the technological advancement of the adversaries, when faced with similar technologies in the conflict the USAF would find itself in a war of attrition that would inevitably require a more traditional mass to sustain a prolonged war with a peer and near-peer adversary.[11]

Lt Gen David Deptula discussed mass in terms of the US offset strategies in countering peer adversaries. He argues in favour of the third offset strategy of focusing on attributes in structuring national armed forces: quality, quantity, diversity, adaptation and speed. In particular, the importance of the numeric aspect of the force design is conditioned by three challenges: '1) effectively

covering range and geography with tempo and mass; 2) presenting the adversary with sufficient system complexity to complicate their targeting and operational strategy; and 3) withstanding attrition in contested environments to remain operationally resilient and effective.'[12] Deptula emphasises the essential role of time in this context. It is no longer sufficient to wait decades for the new multi-role marvel of aerial warfare, solutions with sufficient technological characteristics and numeric advantage should be sought: 'no longer can the nation afford to wait decades for a single, game-changing, multirole weapons system.'[13]

These classical, doctrine and professional views on the mass principle suggest a few points for exploration in the context of the air war in Ukraine. First, the question is whether numeric superiority combined with the advantage of surprise could provide the desired operational and strategic effects in the air war over Ukraine. Second, the relationship between force multiplication and cutting-edge technologies under conditions when the enemy has both technological and mass advantage is of particular relevance because none of these advantages provided the achievement of the desired objective or effect. Third, the most recent discussions by Venable and Deptula illustrate the crucial question of how much mass is too little or enough, and what can be considered a critical mass in the case of modern warfare. Finally, the question of rates of losses in inter-state warfare dictates the necessity of reconsidering both the sustainability and manufacturing of various platforms and their availability. Hence, any discussion of mass in aerial warfare and structure design should be linked to the national military industry and the extent of its self-sufficiency.

Mass in the air war over Ukraine

Pre-invasion numbers and structuring of the national air forces

After the collapse of the Soviet Union, when it was established the Ukrainian Air Force (UkAF) was the third largest air force in the world after the US and Russia. It had a fleet of 2,000 warplanes and was capable of the full spectrum of aerial roles and missions, including a nuclear strike. However, 'the disastrous belief in the peace dividend and international guarantees of security embodied in the Budapest Memorandum resulted in Ukraine giving away its nuclear stockpile and the elimination of the strategic bombers, with a consequent reduction of the rest of the warplane fleet.'[14] Between 1996 and 1999, 29 strategic bombers and 487 cruise missiles were scrapped. In the following two years, in exchange for gas debt, Ukraine transferred 11 bombers and 581 long-range X-55 strategic cruise missiles to Russia.[15] In the next few decades, within the programme of disarmament, various Ukrainian bombers and attack aircraft were either sold to third parties or chopped to pieces.[16]

The demise and lack of modernisation of the UkAF became evident during the Russian invasion in 2014, which resulted in the loss of 51 servicemen, of which 16 were pilots. The annexation of Crimea and its military infrastructure resulted in the immediate loss of 126 aircraft, of which only 92 were returned.[17] During the next eight years of war, despite the availability of the Ukrainian military industry, substantial improvement in the numbers of the Ukrainian military aviation fleet was not achieved. Instead, the focus was placed on modernisation and repairs of the existing aircraft and the strengthening

of the national air defences. Consequently, according to the recent RUSI report, on 24th February 2022 Ukraine had about 50 Mig-29 and 32 Su-27, and some Su-24 and Su-25 aircraft. Despite the modernisation, the Ukrainian fleet was still technologically inferior to the Russian one, which used more advanced models of the Su-30, Su-34 and Su-35.[18]

There are different sources of information on the Russian air fleet. According to statistics from FlightGlobal, the most common figure of Russian aerial capabilities over the last few years was 4173 aerial assets, of which 3863 were from the Air force and 310 from the Navy.[19] Of particular importance was the number of combat helicopters, which according to one of the sources, was 1543 and was the second in the world after the USA.[20] Despite such a huge aerial fleet, air-to-air refuelling Il-78 takers were around 19 in use in 2019,[21] other sources show that Russia currently might have around 20 of these.[22]

These rough numbers illustrate the significant numeric superiority of the Russian air fleet compared to the Ukrainian air fleet. They also represent a continuity of the Russian Soviet tradition of trying to catch up with the US military capabilities, at least in numerical terms. When compared to the UkAF, Russia also had a technological advantage given that its fleet included multi-role assets. This often meant that Ukrainian aircraft were spotted sooner, and therefore could be targeted earlier. Hence, Ukrainian pilots primarily gained an advantage through their piloting skills, manoeuvre, adaptability and knowledge of the local air littoral.[23]

Besides the obvious numerical differences between the two air fleets, one figure comes of particular relevance when vulnerabilities of the Russian air fleet are discussed—that is the relatively small number of air-to-air refuelling aircraft.

Taking into consideration previous Russian engagements against much smaller adversaries in the last three decades, the primary expectation was that in the war with Ukraine Russia would have an obvious advantage of proximity towards various targets and the availability of military bases in Crimea to facilitate refuelling. In addition, various Ukrainian air bases and airfields, such as Hostomel airport, were to be used as forward operating bases. However, as the war progressed, attack aircraft had to fly more sorties, primarily because air-to-air refuelling was reserved for the strategic bomber fleet.[24] Strictly from the pragmatic perspective of sustainment and logistics, the readiness and availability of numerous aircraft is directly dependent on the presence of infrastructure and logistics for their servicing and sustainment—air-to-air refuelling is just one of them.

Control of the air and air denial

From the first days of the full-scale Russian invasion of Ukraine, the most controversial question became the aerial campaign and struggle to obtain air superiority despite the significant numeric advantage of the Russian forces. There are several reasons why Russia failed to gain air superiority over Ukraine. First, it failed to destroy the UkAF in the first hours of the attack. Anticipating a Russian attack, the Ukrainian aerial capabilities and the mobile air defences were relocated to secluded remote airfields. In addition, overreliance on the success of surprise led to poor readiness in facing counteractions. Hence, the UkAF took greater advantage of the surprise when they met Russian pilots in the Ukrainian skies during the first few days, which allowed previously jammed ground-based air defences to recover. From the mass perspective, Russia used mass assaults

against various strategic targets in Ukraine, but it failed to destroy all of them and also failed to follow up with further raids for their systematic elimination. This was conditioned by the need to face Ukrainian pilots in their home skies and soon they had to face Ukrainian air defences as well. This resulted in immediate high losses among Russian aircrafts, despite their numeric and technological superiority.

Second, from the first days of the invasion, the VKS (Russian Air Force) has illustrated a combination of flaws that are inherent to managing large armed forces without modern and sufficient tools. In this regard, despite the official announcement of the numeric scale of Russian national and international joint military exercises, the reality of Ukraine has illustrated their lack of ability to conduct complex, large-scale operations of inter-state warfare in onerous terrain, such as in Ukraine.[25] Hence, despite the high number of sorties flown by the VKS, 140 daily sorties in the first few weeks, they were not flown in massive packages, the largest being six in a group, with 25 percent flown in singles or doubles.[26]

Third, linked to the previous point, is the Russian approach to targeting and consequent Battle-Damage Assessment (BDA). The practice of modern warfare suggests that the accuracy of striking the target is achieved by improvement of PGMs (technological side) or by revisiting the target again to conduct BDA, and if required to finish it off. Although revisiting the target on various occasions in the post-Cold War era could cause additional danger to the pilots, it also provided accurate BDA under conditions when other means of verification were not available. However, in the case of the VKS, the very choice of targets at different stages was questionable, and was not consistent with potential operational and strategic objectives or effects. Also, many time-sensitive targets and targets of opportunity were ignored. From one perspective, it could have looked like taking advantage of mass by concentrating it where it was needed at a given time. In reality, the extent of that necessity was doubtful. However, with the gradual establishment of the frontline, the focus shifted towards covering the frontline and nearby territory.

Fourth, Russia failed to gain air superiority because Ukraine combined the advantage of air littoral with the full vertical depth in air denial. In this regard, each altitude would be covered by different assets: higher altitudes by Ukrainian attack aircraft, medium altitudes by SAMs and lower altitudes by MANPADS (man-portable air defence systems).[27] Furthermore, the superior manoeuvre skills of Ukrainian pilots would often lure Russian aircraft into traps at lower altitudes, taking advantage of the specifics of national geography. Drones that had previously attacked Russian tank convoys would also be used to lure attack aircraft to lower altitudes and the reach of MANPADS.[28]

The progression of the war illustrated more deficiencies in the Russian quest for numerical superiority. Despite the significant number of the helicopters identified in statistical accounts and traditionally much-praised Russian Airborne Troops (VDV), they proved to be easy targets for MANPADS like StarStreak, Stinger, Igla, Mistral, Chiron etc employed by the UAF. The shooting down of the KA-52 Alligator helicopter became almost daily news over the ten months of the war.[29] The vulnerability of helicopters used for transportation and close air support (CAS) was significantly conditioned by the lack of integration between various segments of the Russian military. This vulnerability could not be compensated by simple numbers of available helicopters since their

utility in the hostile environment under the lack of control of the air significantly undermined their freedom of manoeuvre and the consequent effectiveness that numeric superiority could have provided if applied in a large-scale multi-domain operation.

The case of the fight for air superiority and the achievement of mutual air denial in Ukraine provides some thoughts on the use of mass in this war. Although Russia employed multiple aerial assets against various targets, it was far from what Clausewitz or Sun Tzu would call concentration of force in the decisive points or, in plain words, where and when they were needed. The inherent features of air power, flexibility and adaptability, were demonstrated by the UkAF. Meanwhile, the VKS showed the opposite in terms of air tactics and manoeuvre. and even targeting. Furthermore, the Ukrainian side took full advantage of the divide-and-rule principle, manifested by both Sun Tzu and Clausewitz. This advantage of dividing the enemy's assets was conditioned by the combination of the A2AD bubbles, the distinctive extended geography of Ukrainian territory and the integration of multiple assets from various domains into air defences. To a certain extent, the combination of these different cross-domain assets provided the needed critical and essential mass in establishing functional and systematic air defences of Ukraine. The gradual increase in the number of more sophisticated Western air defences only strengthened that mass in the second part of 2022.

The Ukrainian air defence and approach to air denial can be perceived as layering air denial effects for each altitude using various assets from different domains. Obviously, the success of this approach can be seen in effective cross-domain integration and deconfliction, which was not always smooth[30] and often required areas of responsibility to be divided instead of strengthening centralisation across all levels. Furthermore, Ukrainian soldiers with MANPADs were spread across the country and numerous observation posts were created across the entire country.[31]

When considering the deficiencies of Russian mass in the fight for air superiority in Ukraine, we should bear in mind that despite the numeric superiority of the Russian fleet, these assets were also used to control and defend Russian air space, which is significantly bigger than Ukrainian airspace.

Drones and mass

The place of drones in the Ukraine war has encouraged many discussions about the democratisation of air power and changing the rules of the game. This author is more cautious about the revolutionising nature of new experiences or occurrences in war. However, this war has most certainly illustrated a few characteristics that might prevail in the upcoming wars and the employment of drones. From the first days of the invasion, Ukraine used its previously procured Turkish Bayraktar TB-2 drones for target acquisition, most often employing them against slower Russian military equipment convoys. They were also used for luring Russian aircraft to lower altitudes.

Various smaller military and commercial drones have had an invaluable role to play in providing tactical-level ISR to the UAF and have also been used to drop smaller munitions on various targets on the front. In this regard, various observations and experiences from COIN and urban warfare were confirmed, such as the vital necessity of using smaller aerial assets not only for tactical ISR but also for sweeping buildings with small drones before the ground troops came in. Hence, many argued in favour of the proliferation of drones across different services

of the armed forces of various allied nations, primarily in the provision of tactical-level support and force multiplication from the air, that military and commercial drones can provide.[32] These are valid recommendations that are provided by military and academic experts from various countries.

Under the conditions of scarce aerial capabilities and devotion to other means of firepower (e g, artillery) in other areas, drones were indeed a means of force multiplication, and provided ISR and firepower at a tactical level. However, there are some reservations in terms of focusing on them as the primary source of mass. First, a recent study by RUSI has revealed that 90 percent of drones used by the Ukrainian Armed Forces (UAF) during the first three months were destroyed. On average, quadcopters survived three flights and fixed-wing RPVs could be used for six flights.[33] From the perspective of the mass approach, this finding does not discourage the use of drones as a provision of tactical-level air support and, to some extent, of force multiplication. Instead, it shows the necessity of the relative cheapness of the available drones and the preservation of continuous manufacturing of these capabilities at home, or at least within a very shortened delivery chain and simple logistics for their delivery, deployment and use.

The Ukrainian solution to this problem was two-fold. The centralised solution was to boost and use the national military industry. Several pilot projects were previously developed and initiated by manufacturers. For example, the long-range attack drone Falcon-300 was developed by the Luch design bureau, the reconnaissance and fire coordination UAS Shark was developed by Ukrspecsystems, and AWACS Gekata based on PD-2 drones were produced by Ukrainian Infozakhist Research and Production Center, to name a few.

The second solution was a grassroots initiative, ranging from crowdfunding commercial quadcopter drones for the needs of specific units through more formal platforms such as Back and Alive and individual volunteers such as Prytula Foundation or Serhii Sternenko, the utilisation of the scientific engineering community for manufacturing and customisation of drones for specific characteristics and opening a privately sponsored drones pilots training centre.

Furthermore, besides more centralised and specialised centres for serving heavier and more sophisticated drones, volunteers with relevant skills are developing points to fix and repair broken commercial drones, and then return them to the relevant units of the UAF. Those UAVs that are beyond repair are used for spare parts: 'For example, if the drone falls into water, then 99 percent of the electronics "die", but parts of the body can be rearranged on damaged devices of the same model.'[34] The availability of these repair services has made a significant contribution to reducing costs; for example, purchasing a new commercial drone would often cost $3000, while repairing one would only cost $100.

In the case of Ukraine, the wide-spread use of drones is conditioned by a few contextual national factors. First, the previous procurement of Bayraktar drones and established contracts for further purchases. Second, various segments of supply and sustainment of drones was provided thanks to the allied support and collaboration with the UAF. Third, the availability of the national military industry, which has both manufacturing capacities and a knowledge base to produce drones of various degrees of complexity and functionality. Fourth, the strong support of the knowledgeable rear provides various solutions to reduce costs and times for procurement and delivery be-

cause repairs are conducted much faster and the routes of follow-up delivery are already well-established. Finally, the entire society serves as means of total defence, and hence all the resources and skills are focused on supporting the UAF.

Russian long-range ballistic missile campaign

From the first days of the invasion, Russia started a long-range cruise and ballistic missile attack campaign in support of its invasion. In the first three months of the invasion, more than 2,000 missiles were launched against Ukraine, or on average, 24 per day.[35] During the first stage of the invasion, the focus was placed on targeting military objects of C2 (command and control), various aspects of logistics and some civilian infrastructure. Despite the constant barraging, few if any strategic or operational objectives were achieved: the Ukrainian military continued fighting using all available assets, and barraging did not contribute to gaining more territory.

Hence, in June, a targeting shift towards supply chains, storage facilities, and railway infrastructure took place. The bombing of grain facilities in Odessa, on 23rd July, 2022, was one of the examples of changes in the list of targets. With the successes of Ukrainian counter-offensives and the appointment of a new commander of the Russian forces in Ukraine, General Sergey Surovikin, on 9th October 2022, targeting once again evolved.

From the next day, cruise and ballistic missiles were launched against the entire territory of Ukraine, targeting the electricity grid and various aspects of civilian infrastructure. Several days observed a greater intensity of mass barraging. For instance, on 15th November, 100 missiles and loitering munitions were launched, and 70 were launched on 23rd November. Furthermore, Christmas Eve and Christmas day saw further intensification and even wider targeting of residential areas. According to General Valery Zaluzhny, head of Ukraine's Armed Forces, the effectiveness of the Russian ballistic missile attacks, was calculated as a coefficient of 0,76, meaning that when Russia launched 100 missiles, 24 get through.[36]

This means that the Ukrainian integrated air defence system cannot defend against all types of threats posed by the Russian military every single day. More sophisticated hypersonic ballistic missiles require more sophisticated air defences.[37] Furthermore, Russia continues to adapt its long-range ballistic missile and cruise missile attack campaign, by using more devastating anti-ship missiles like the KH-22 dropped on a Ukrainian apartment building in Dnipro on 14th January, 2023.[38]

In terms of mass and achievement of the posed objectives, this bombing campaign illustrated significant limitations of Soviet-style mass bombardment. Different stages in targeting during this campaign showed that the effectiveness of each previous stage was significantly undermined by the Ukrainian air defences, multi-faceted allied support and agility across domains and the civil-military spectrum.[39] Russians could not destroy Ukrainian military capabilities during the first stage and failed to achieve the desired effect of devastation and disruption by destroying infrastructure during the second and third stages of the bombing. Furthermore, any attempts to achieve psychological effects and suppression of morale by bombing civilians had a reverse effect, as in many other historical examples. The idea of using mass attacks to reduce Ukrainian stockpiles of ammunition for the air defences and their capabilities most certainly has credibility. However, Ukrainians treat high-end mu-

nitions with a very high level of chariness, since these resources are scarce and require mass production and provision of sufficient supply from allies.

As a result, when it is possible Shahed drones, due to their slow speed, are being taken down by less sophisticated and cheaper means such as machine guns and MANPADS. On the contrary, receiving more sophisticated Western air defences such as NASAMs and Patriot systems were aimed for use against more technologically advanced side of Russian arsenals, including hypersonic missiles.[40]

Besides not actually achieving much in this indiscriminate bombing campaign, Russia also illustrates the flaws in its mass approach. First, the numbers of their stockpiles began to run low. Purchasing Iranian Shahed kamikaze drones and their use together with other missiles in August indicated the costs of using ballistic missiles en masse and that their arsenals are not endless. Although the numbers of the actual arsenals vary, the prevailing question is the state of the remaining Russian arsenals stored in different parts of the country. Second, for the mass to be sustainable and continuous, national manufacturing capabilities should be in place and be working for the war demands. Although most Russian military industry was previously considered to be self-sufficient, in reality, it required a lot of cutting-edge technological components from Western countries. For instance, navigation microchips for Russian missiles were produced abroad.[41]

Hence, systematic sanctions eventually had a crippling impact on the Russian military industry.[42] In terms of cost-efficiency, although some more sophisticated missiles would require Ukraine to use respective sophisticated air defence systems, such as NASAMs, the costs of using hypersonic ballistic missiles without achieving any significant operational or strategic objectives cannot be covered, even by utilising cheap Shahed drones or smuggling cheaper ballistic missiles from Russian allies.

On industrial considerations

The primary difference between the Soviet Union and post-Soviet Russia was that the Soviet Union operated as a relatively closed and whole system in terms of mass production. Hence, various segments of the mass production could be reoriented for different needs if and when the time required. The quality might have been lower than under normal conditions but still the industrial system could absorb deficiencies in one segment and compensate in another. It should not be forgotten that during Soviet times, Ukraine, as the core of the Soviet military aviation industry, was part of the union. In contrast, after the collapse of the Soviet Union and the breaking of the supply and manufacturing networks, instead of strengthening the self-sufficiency of the national industry, Russia followed internationalisation and globalisation of the supply chain and manufacturing cycles. Under normal circumstances, this would be an effective means of reducing costs and strengthening internationalisation. However, the Ukraine war and severe systematic sanctions illustrated substantial gaps in the supply chains and manufacturing capacities of Russia.[43]

The mass approach, more than any other, requires self-sufficiency in manufacturing the required mass for the instances of protracted warfare, and the lack of connection between the mass approach and achievement of posed objectives. Although the Russian military industry is diversified, it is still heavily dependent on the old post-Soviet links in the provision of spare parts and components. For instance, even after the 2014 annexation

of Crimea, Russia was still procuring turboshaft and turboprop engines from Ukrainian manufacturers until sanctions were imposed 2015 and 2017.[44] Similarly, several resources were procured from neighbouring countries that under the conditions of sanctions did not want to have anything to do with the Russian military industry. Hence, sanctions and the structure of the Russian military industry undermined prolonged sustainment of the mass.

Discussion

The case of mass in the air war over Ukraine provides various points to discuss the principle of mass for air forces. Although Russia was numerically and technologically superior, its mass did not guarantee that it would gain air superiority and freedom of manoeuvre across domains. The advantages of fighting on one's own battlefield provided significant opportunities for using air littoral with layered multi-asset and multi-domain air defences, which to a greater degree, undermined Russian advantage in the mass.

In the modern discussion of the mass, this case illustrates that Russian numeric superiority, just as reliance on the artificial mass of cutting-edge technologies alone, do not satisfy all demands of full-scale warfare. At the outset of the war, Russia had both numeric and technological superiority over the Ukrainian aerial assets and air defences. Nevertheless, Ukraine managed to overcome this advantage by creating a multi-faceted system of air defences utilising assets from various domains, creating its own critical mass. However, this ad hoc mass needs to be sustained over time, with the constant supply of cheaper capabilities manufactured locally or regionally and the supply of cutting-edge assets by allies. Hence, despite the use of the home ground, the need for mass did not cease to exist. Instead, it was often satisfied by assets from other domains. While as an ad-hoc solution to the immediate necessity of warfighting, this method worked for Ukraine, in the long run, with the refocusing on further regaining the territories, more mass is required across domains for the variety of tasks and missions.

Regarding the Russian side of the air war, the single-role previous-generation Soviet air fleet proved to be less effective in fulfilling even their primary tasks. For instance, the Soviet-era Russian Su-25, which was developed primarily for the provision of CAS, was used for barraging effect in complex areas and proved less effective in targeting moving troops on the frontline.[45] This resulted in greater reliance on more advanced and multi-role aircraft for various missions and consequent wearing out of both materiel and pilots. Similarly, only some more advanced and multi-role aircraft could fly in the darkness.[46] This suggests a few considerations. First, the technological characteristics and consequent performance are interconnected. However, the right piloting skills can often compensate for certain deficiencies of the materiel, which the UAF managed to illustrate and the VKS failed to exploit. In other words, the mass of the previous generation or technologically advanced aircraft combined with the right piloting skills can provide the desired effect and compensate for the lack of the most advanced technology for a certain time. However, if pilot training is insufficient and detached from real warfighting experiences, complex operations and cross-domain integration, then this mass will be insufficient in achieving desired objectives.[47]

Second, one of the constantly emphasised limitations of multi-role aircraft in terms of provision of the actual mass has become evident. Although they most certainly can provide the artificial mass of the layered effects,

their often-scarce numbers do not allow to provide sufficient coverage and result in more pressure being placed on the advanced fleet in assigning more missions and increasing sorties instead of utilising the switching between roles during a single sortie. This does not mean that multi-role aircraft do not provide what they promise. On the contrary, they do. However, not having the critically sufficient number of multi-role models and effective mass of specialised aircraft, which actually can achieve its tasks, may result in more sophisticated platforms being used for simpler missions on top of the more sophisticated ones, and hence wearing them out sooner. In addition, the danger of them being shot down increases with each use.

Third, taking into account the first two points, it can be argued that a critical or sufficient mass for structuring modern and future air forces is required, and this critical mass should not focus between the previous generation or the most technologically sophisticated aircraft alone. The critical mass is successful when combining sufficient numbers of specialised and multi-role aircraft with skilled pilots training to face the real dangers and unpredictability of warfare. This balanced approach to the critical mass resonates with the arguments put across by Venable and Deptula in their respective works. Another important factor is timeliness in the availability of the needed aerial platforms and the ability, if not to manufacture more within the required time, then at least to have a contingency plan for their sustainment under the severe circumstances of warfare.

One of the most important points for discussion is the estimation of critical mass--what is too little and what is enough? The balanced approach is to combine less sophisticated (potentially even specialised) aircraft with more advanced and it most certainly should be continued, with the potential widening of the numbers of the less sophisticated platforms. In this regard, the most important shift should be not just in the political thinking about capabilities and pilot training to fit the requirements of various platforms and their employment but the shift should also be in the industrial support for the military and strategic necessities that widening the fleet would require. Consequently, the primary issue with the older models are their spare parts and the facilitation of their repair. The case of the UkAF illustrates that Soviet-era spare parts had to be gathered from around the world.[48] Hence, crucial changes in the military industry will be required to support sufficient mass and sustainment across what in essence could be two distinctive air fleets due to their technological characteristics.

Although the military industry (like any private entity) is driven by profit, the times of wars dictate their own necessities and time constraints. It is therefore essential to address the time aspects of this discussion. Cutting-edge technological marvels require time for their production, delivery, testing and training. While in peacetime we can expect to have a functional plan for procurement and modernisation and upgrading of one's armed forces, in wartime (especially in protracted warfare), the lack of timely manufacturing of weapons undermines many developments on the battlefield and might result in the victory of the side that was left with more ammunition at the end. One of the discussed solutions in the field is to have a certain contingency planning developed between the national government and the military industry regarding switching manufacturing to wartime requirements. This suggestion is not new, especially in countries where total defence is at the heart of national defence and security policy.[49]

Attention should be paid to the place of mass provided by drones. Depending on the military grade and complexity, they have varied degrees of cheapness and are faster to produce. With commercial drones, the required mass can be built up relatively quickly. However, this scale also needs to be sustained for the prolonged demands of the battlefield, together with the provision of sufficient facilities for repair and sustainment. The provision of drones systematically across services and domains of warfare brings up an important discussion about their contribution to the facilitation of critical mass and the layering of mass effects through integration across domains.

In this regard, Ukrainian air denial has illustrated how assets originating from various domains can be layered across different altitudes and deny the enemy freedom of aerial manoeuvre, and by extension in other domains as well. Hence, the discussion of real mass, artificial or critical mass would be partial without looking at the national capabilities as a system, which can produce desired effects across domains. The key to this systematic approach is not to be driven by an assumption that capabilities in one domain can always compensate for their lack in another domain. On the contrary, a systematic approach to building a critical mass would need to look at capabilities and boost critical mass across domains to have a sufficient layering of effects from those domains. Meanwhile, if critical mass would be absent in one of the services and domains, then it will constantly be distracting capabilities and resources from the domains to cover this gap; hence, creating additional vulnerabilities under the conditions of insufficient or scarce mass.

Another essential factor in the context of establishing critical mass is the availability of trained and skilled pilots, which goes for both drones and conventional aircraft pilots. While drone pilot teaching centres could be established ad hoc and would require a few months of training under the conditions of war, pilots of conventional aircraft remain scarce. From the perspective of critical mass, the presence of skilled pilots in the force is conditioned by the extent to which the force can retain pilots in peacetime. As various countries illustrate, pilot retention continues to be a crucial challenge for modern air forces.[50] In Ukraine, before the invasion, some pilots left the force due to similar challenges as many air forces face today, but they returned when the invasion started. Although fighter pilots are distinctive people, hoping for individual decision-making in the worst-case scenario without providing systematic changes in retaining skilled personnel in peacetime is not a sufficient strategy of force design for the requirements of modern warfare.

Conclusion

This article aimed to show various aspects of the principle of mass in modern air warfare and its consequent reflection in the case of the air war over Ukraine. The conceptual section illustrated the evolution of the principle and concept of the mass from the classical strategic thinking of Sun Tzu and Clausewitz to its doctrinal reflections and consequent modern academic and military professional discussions on its place in structuring modern air forces. The case study showed that numeric superiority, and even certain technological advantages, do not guarantee success in achieving air superiority. On the contrary, the Ukrainian side illustrated that a certain degree of critical mass can be achieved through layering effects produced by assets from different domains and taking advantage of the full vertical depth.

The discussion section illustrated various aspects of this experience for the current and future conceptualisation of critical mass in employing air power and structuring air forces. Consequently, this case study and discussion illustrate that the question of the availability of critical mass and industrial capacities of producing the required mass within war-demanding timeframes is at the forefront of the ability to project power in peer and near-peer conflicts, and the ability to take advantage of what air power can offer in the modern warfare across manned and unmanned platforms.

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