Abstract illustration depicting the author's assertion that there are clear parallel predictive patterns observable in the metrics measuring the physical dynamics of stress leading to the collapse of metal structures to metrics measuring the impacts of sociological stress that lead to the destruction of armies in the field and the nation states that sponsor them. (AI-generated image by Charlotte Richter, *Military Review*)

Prediction of War Duration using Models of Structural Dynamics

Nicholas Nechitailo, PhD

Summary. *Wars play a significant role in human history. Often, it is relatively easy to predict dates for when the next war would start due to existing communication channels and information from spies. However, predicting the war duration is a challenging problem. I propose a theory in which war events could be compared to the transient events observed in nonlinear structural dynamics. It seems possible to apply simplified models of elastic-plastic deformations and structural stability to predict the duration of the main war events. Prediction of transient and final post-chaotic states is challenging; however, predicting the* duration *of the system responses seems possible. Recently*

developed simplified analytical solutions were applied to the events of World War II, including its beginning, the battle for Stalingrad, the liberation of all Soviet territories from the German army, and the end of Adolf Hitler's regime. This same approach is also applied to the ongoing Russian-Ukrainian war with an attempt to predict the time window for the war to end, *as well as the subsequent time windows for major instabilities and possible disintegration of the Russian Federation.*

It is difficult to occupy and destroy a large country. Oftentimes, large territories have significant human and material resources to resist an invasion. In many cases, large countries are composed of culturally different groups. Existing inhomogeneity and cultural differences may represent vulnerabilities and potential instabilities. These are like the slenderness, structural inhomogeneity, and material imperfections in structural stability problems. War hardship may trigger regional separatist movements. This may lead to a civil war, ethnic cleansing, and destruction of the economy, pushing it to a level *well below the prewar level*.

Countries can be viewed as nonlinear systems. *Nonlinear equations of motion can describe their development, stability, and collapse*. It appears that models of structural dynamics with geometric and material nonlinearities can be used for better understanding and predicting war events.[1] These relatively simple mechanical models can be used for the *timing and optimization of war efforts*. They can be also used for better understanding of the impact of the speed and quality of weapons supply on the war duration and the overall costs of the war, including expected damages to infrastructure and due to war crimes, as well as the likelihood of the postwar recovery of the adversary, and his ability to start another war in several years.[2]

One of the key elements of the underlying theory is the *optimization of the amplitude and duration of applied force*. Each impulse should be timed with respect to the adversary's actions and conditions. Our counterstrike should be applied at the point of time when the adversary's impulse is already *exhausted* and its internal forces become weak. The goal is to induce local and subsequently global instabilities, and in some cases, the collapse of the adversary's system. The terms "local" and "global" represent similar phenomena observed in structural dynamics, including buckling and progressive post-buckling. *The science of war is based on a series of timed and measured military, economic, and information attacks against the adversary.*

History

There are two main war strategies that are briefly discussed—predominately linear and highly nonlinear. The first strategy is rather straightforward; it is predominantly linear. Countries with superior armies and economies attacked smaller and weaker neighbors. Nazi Germany's blitzkrieg, with its overwhelming power and speed as it quickly occupied several smaller European countries, is a good example of this strategy. From a mechanical modeling point of view, a blitzkrieg requires a large-amplitude, short-term impulse applied to a weak structure. In the related mechanical model, a thin metal plate subjected to a large-intensity pressure pulse, will deform plastically, and then it will rupture.

The second strategy is highly nonlinear and, therefore, less predictable. It consumes more time and resources. It is applicable to larger targeted countries with significant resources and resistance. The nonlinearity comes from the size and inhomogeneity of the adversary country. Based on the theoretical and experimental work, the most effective course of action is to impulsively load a structural element and induce internal instabilities leading to transient chaos with subsequent collapse and "somewhat" predictable final states.[3] In my opinion, this method worked in the Iraq war from 2003 to 2011. The country had preexisting internal tribal and religious tensions, and the impulsive application

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of the external military force with its *rather fast withdrawal* led to the country's collapse, which stabilized at levels well below the country's prewar state.

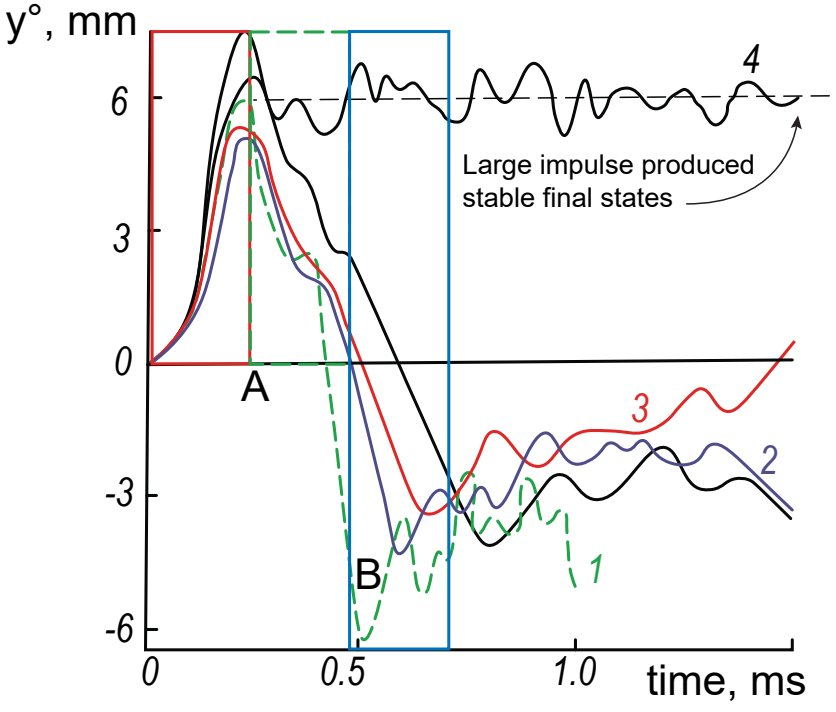
Models

I studied the nonlinear structural dynamics of plates and shells under impulsive and hydrodynamic loads, and I discovered and explained the anomalous and unpredictable motion of ordinary structural elements.[4] There is an "anomalous zone" with highly nonlinear deformation, including "reverse buckling, post-chaotic reorganization, and self-destruction."[5]

An ordinary plate, shell, or beam subjected to an impulse of relatively large amplitude and duration may obtain final deflections in the direction of the applied load. This is similar to the blitzkrieg strategy. However, the same plate subjected to a smaller, carefully timed load may collapse, deform into a shell of unexpectedly complex shape, and it may develop unusual cracks. This is applicable to the war strategy involving two large countries; it is highly nonlinear, it consumes significant time and resources, and it produces transient chaos with "somewhat" predictable postwar results.

Plastic deformations are irreversible. After the external load is removed, the plate will not be able to go back to the same original flat state. Plastic deformations produce points of no return. If the forces of elastic unloading in the plate material exceed its critical buckling force, in the absence of external forces or significant damping, the plate will produce so-called "reverse buckling." The plate will snap, and it will move toward the source of the external load. It will go through transient chaos, likely increasing plastic strains and developing unusual cracks.[6] The final post-collapse shape of the plate will be somewhat predictable; it can be related to the "lowest natural fundamental modes of vibration and buckling."[7]

Like the structural deformation process, wars have several significant stages and no-return points. When a war action is exhausted, the adversary may request peace negotiations to stabilize their current equilibrium state. This may give time for the build-up of the



(Figure by author)

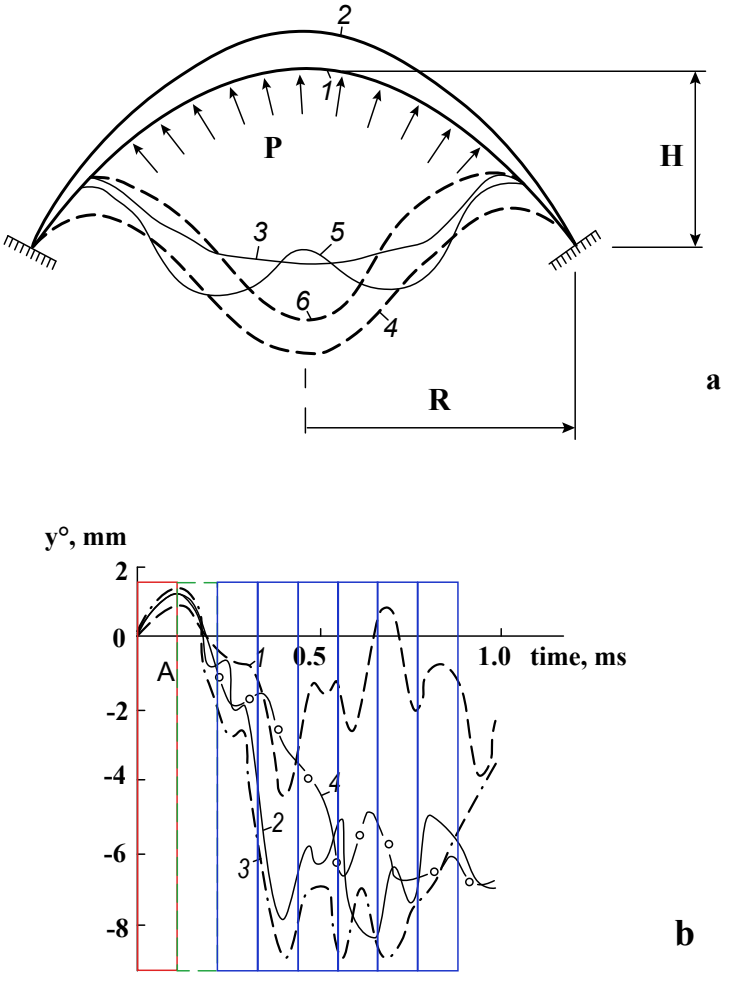
Figure 1. The Motion of the Central Point of a Metal Plate That Was Subjected to a Carefully Timed Pulse Pressure

armed forces and preparation for the next stage of the war.

If we apply the flat plate deformation analogy, the formation of a more stable structure with higher stiffness will need more impulses or longer-duration forces acting in the same direction. Hemispherical domes have higher bending stiffness and stability than shallow panels and flat plates. However, as compared to the flat plates, domes produce more violent buckling behavior and significantly larger structural damage.

Figure 1 (on page 3) illustrates a flat circular metal plate subjected to a uniform pressure pulse.[8] Point A on the time axis corresponds to the anomalous zone with moderate plastic strain when the pulse pressure became exhausted. The red box corresponds to the motion of the plate center from its initial position to its maximum deflection in the load direction.

This theory is based on the observations that after reaching their critical points, such as maximum displacements, structures, and systems cannot move back and collapse "too fast" or "too slow." There is a reasonable and rather predictable time window for their collapse. The time window can be computed based on the natural characteristics of the structures and systems, including their natural vibration modes and periods. In a simplified model, the time window for the structural collapse can be estimated based on the time required to the structure to move from its original position to its maximum deflection.



(Figure by author)

Figure 2. Dynamic Response of a Dome to a Pulse Load

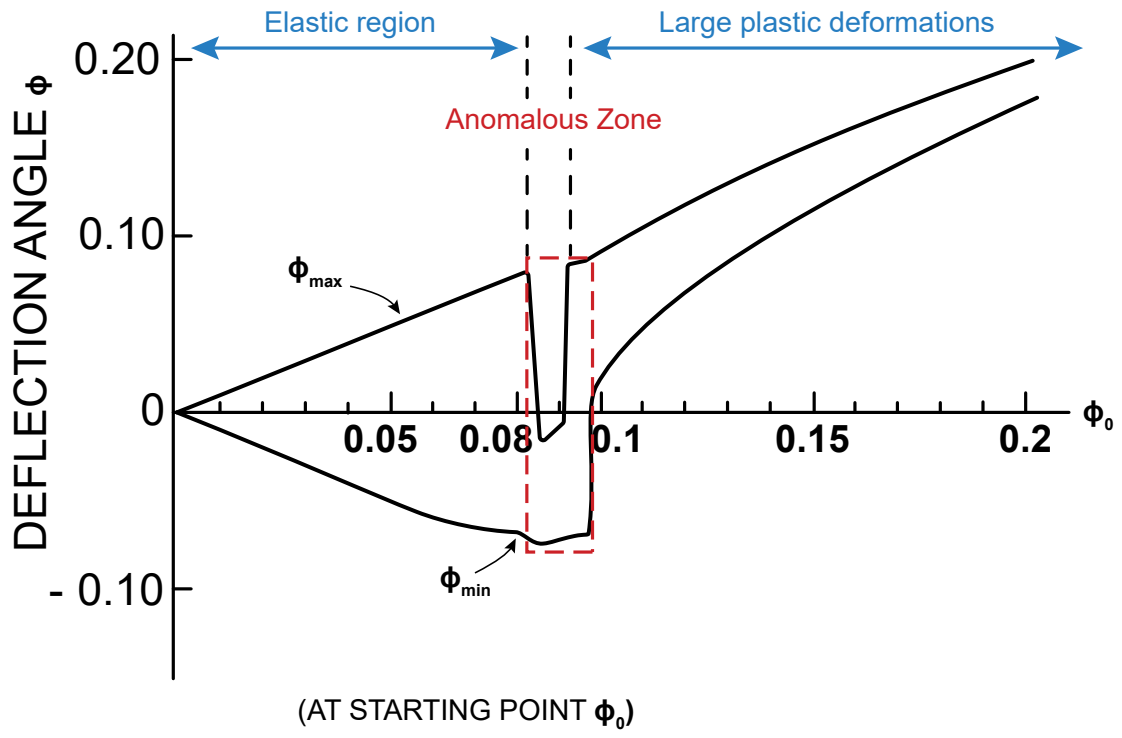
In a simplified war duration model, the time window for the war end can be estimated from the duration of the first successful for the adversary phase, that is, the time interval between the start of the war and the time when the adversary became exhausted.

Different curves in figure 1 illustrate possible paths of the central point, depending on the applied impulse and *perturbations*. One of the main features of the anomalous zone is extremely high sensitivity of the motion to small variations in the model parameters. The most important parameters include external damping, such as resistance forces from surrounding air or water. Three highly nonlinear scenarios are shown in figure 1 as curves 1, 2, and 3:

(1) In the absence of the damping forces, the structural collapse will follow the fastest path show as the green curve 1. It will produce *maximum final damage within the shortest period of time*. This process is somewhat similar to the *free vibrations* of the structural elements under the forces of elasticity and inertia.

(2) Moderate damping forces will slow down the collapse, reducing the final damage to the structure. The purple curve 2 illustrates this scenario.

(3) Large damping forces will lead to relatively small damage to the collapsing structure, and they may



(Figure by author; red box contains the anomalous zone)

Figure 3. Single-Degree-of-Freedom Beam Model under Pulse Load

allow for the structure to rebound and resume its motion in the initial direction. The red curve 3 illustrates the path under strong damping.

The curve 4 represents the case when the external force was large enough to produce significant displacements with fairly large plastic deformations. These forces deformed the flat plate into a shallow dome, and they stabilized the new shape near the final displacement, shown as the dashed horizontal line.

The (2) and (3) curves may illustrate the scenarios involving slow weapon supplies or refusals to deliver the type and the amount of weapons needed for counteroffensive. In addition, peace talks may serve as damping and time-delaying factors giving the aggressor the opportunity to prepare for another major offense.

The dashed green and solid blue boxes in figure 1 have the same duration as the red box. The boxes illustrate the time required for the reverse buckling or collapse. After reaching its highest deflection point, the fastest return of the central point, within the green box, to its original zero level was approximately 0.8 times the duration of the red box. The green and blue boxes illustrate the duration of the global collapse. The search for the final states of equilibrium began at approximately 1.2 times the duration of the red box. This corresponds to the fastest collapse leading to the lowest displacement point B.

Figure 2 (on page 4) illustrates the response of a *more rigid structure* to a carefully timed impulse.[9] Point A on the time axis corresponds to the anomalous zone with *moderate plastic strain* when the pulse pressure is close to zero. At this point, the dome reached its highest deflection point (see figure 2[b], page 4). The red box corresponds to the motion of the dome center in the load direction. Different curves in figure 2(b) illustrate possible paths of the central point, depending on small perturbations. An increase in the external damping forces lead to a delayed collapse with smaller displacements in the negative direction and smaller final damage to the dome. In the case involving significant damping (dashed curve), the dome was able to return to the region of positive displacements.

The dashed green and solid blue boxes have the same duration as the red box. These boxes illustrate the

speed and modes of the dome collapse. After reaching its highest point, the fastest return of the central point to its original position was approximately 0.6 times the duration of the red box. The duration of the global collapse is illustrated by the blue boxes. The search for the final states of equilibrium starts after reaching the lowest displacement point at approximately 2.6 times the duration of the red box. This means that the time required for the complete collapse of this relatively rigid structure is at least 2.6 times the duration of the dome's initial advance from point 0 to point A.

Figure 3 (on page 5) illustrates a simple, single-degree-of-freedom beam model under pulse load.[10] The envelope curves show the range of elastic vibrations, as maximum and minimum deflection angles ϕ_{max} and ϕ_{min}.[11] The final state of the beam is between the maximum and minimum deflection angles. The red box contains the anomalous zone. In the elastic region, the final state will be the same as the beam's initial state. In other words, after the external loading, the beam will vibrate and then return to its original position. With further increase in the external pulse load, the beam will cross the point of no return and develop small and then moderate plastic deformations. This corresponds to the anomalous region in the red box. A subsequent motion under the action of elastic unloading forces, inertia, and damping will include chaotic transitions from large-scale to small-scale chaos and global reverse buckling.[12]

According to the existing theories, chaotic motion is leading to an *infinite* number of unpredictable final states. However, based on my studies, it appears that *the number of final post-chaotic states can be limited*.[13] The final states appear to be governed by the lower fundamental modes of vibration and buckling.

When the same beam is subjected to external loads larger than those causing its anomalous deformation, the beam motion becomes more regular and predictable (shown in figure 3 as a region of large plastic deformations). This region represents rather narrow variations in the *irreversible* deformations and final states, similar to the curve 4 in figure 1.

Hydrodynamic models representing an initial shock wave and subsequent flow of cavitating liquid toward an elastic-plastic plate were also studied.[14] These physical processes can be related to multiple attacks in the same direction, retreats, and influx of additional forces during a war.

Russian-Ukrainian War

In 2014, Russia annexed the Crimean Peninsula. That same year, Russian special operation forces captured Donetsk and Luhansk, two of the main cities in the Donbas region of eastern Ukraine, and created puppet pro-Russian regimes there to further destabilize Ukraine. A substantial percentage of the local population of the Donbas region, predominantly Russian-speaking Ukrainians and ethnic Russians, wanted to join Russia, as the government promised them higher pensions.[15] The average monthly pension in Russia in 2013 was about $285 per month, while the average pension in Ukraine was $160.[16]

The Russian government used its bluffing techniques to threaten the West with the use of a nuclear weapon. The West responded to Russian aggression by expressing their numerous concerns and introducing mild sanctions against Russia, Crimea, and occupied Donbas.

The continued influx of money from the West to Russia, approximately $1 billion per day for mostly gas and oil, encouraged the Russian government to start a full-scale war against Ukraine on 24 February 2022.[17] The goal was to occupy Ukraine, exterminate pockets of resistance, and add Ukraine to the Russian-led union like the USSR. The Russian army attacked Ukraine from the north, east, and south, and used the blitzkrieg method of a massive attack. The Russian government was counting on the fast collapse of the Ukrainian army and the rapid capture of the Ukrainian capital.

Western military experts have grossly overestimated the quality of the Russian army.[18] They predicted the collapse of Ukraine in seventy-two hours, repeating the Russian propaganda mantra that Kyiv will be taken in three days. On 2–3 February 2022, Chairman of the Joint Chiefs of Staff Gen. Mark Milley told lawmakers that Kyiv "could fall within 72 hours" if a full-scale Russian invasion of Ukraine takes place. He stated that the "Russian invasion … could come at a cost of 15,000 Ukrainian troop deaths and 4,000 Russian troop deaths."[19]

The Western experts and leadership were wrong again, in part due to their limited understanding of the Ukrainian culture with deep-rooted military history, ingenuity, and passionate desire to end centuries-long Russian oppression and genocide of the Ukrainian people. The recent history of the Ukrainian fight for freedom included the Ukrainian War of Independence

(Red arrows—Russian army; blue arrows—Ukrainian forces; maps courtesy of "History and Headlines")

Figure 4. Maps of Ukraine Showing Main States of the War and the Regions Occupied by the Russian Army

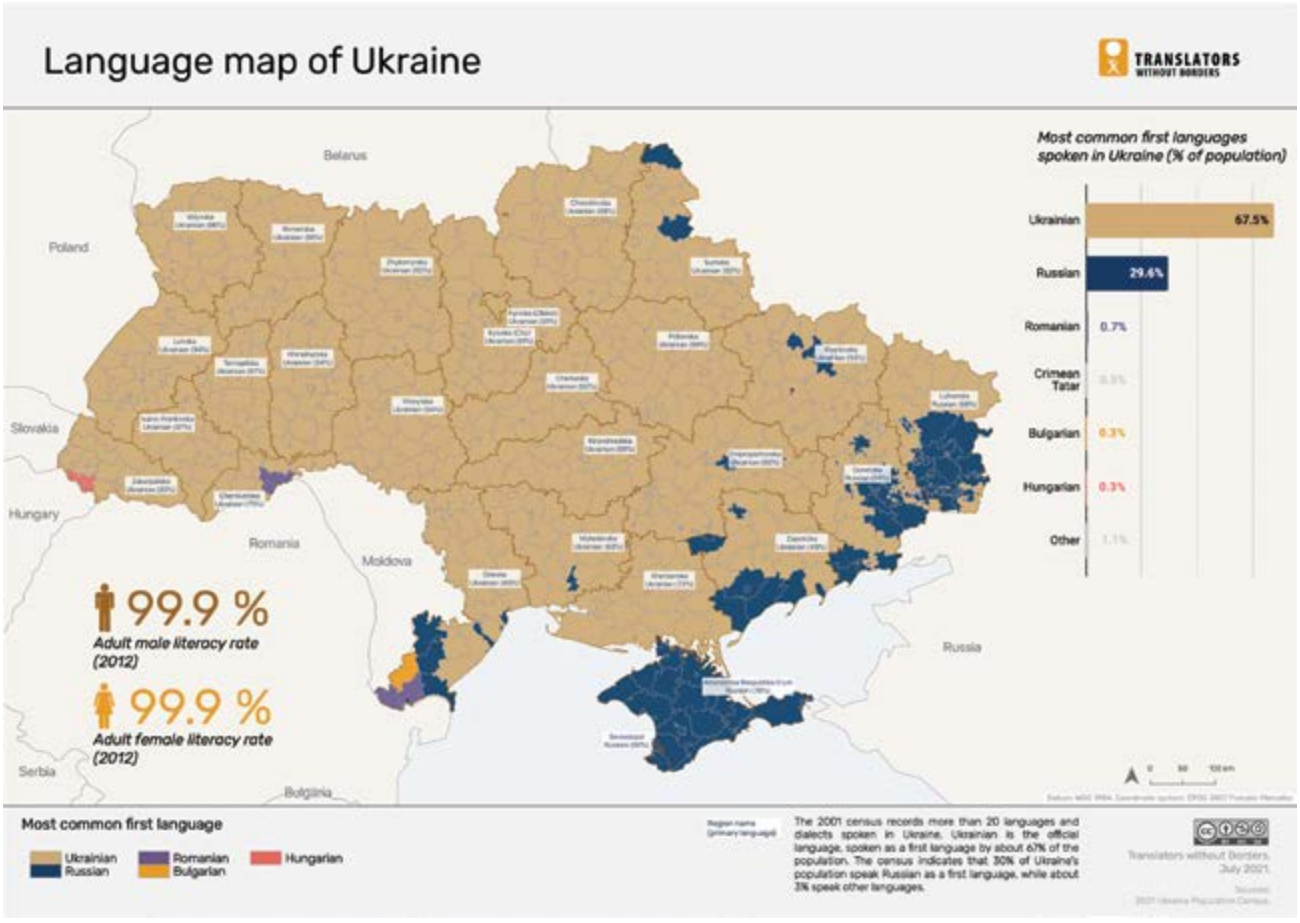
in 1917–1921 and the period between 1942 and 1956 when the Ukrainian Insurgent Army fought in western Ukraine against Russian invaders using trophy weapons.[20] The Ukrainian people demonstrated their unity within the first three days of the Russian invasion. The heroic resistance of the Ukrainian Territorial Defense militia units stopped the invading forces near Kyiv.[21] This gave time to the Ukrainian army to join the fight. The surprised West responded with additional sanctions against Russia and an increased influx of weapons to Ukraine. Figure 4 shows the maps of Ukraine and the main stages of the Russian-Ukrainian war. The red zones identify the territories occupied by Russia.[22]

The Russian army made significant progress between 24 February and the end of March 2022. The army was able to quickly occupy southern parts of Ukraine. This could be explained by the large number of ethnic Russians and saboteurs among the local governments of southern Ukraine. In contrast, predominantly Ukrainian-speaking people of the Kherson region started mass protests within the first days of the Russian invasion.

The largest number of the victims of the Russian aggression were ethnic Russians and Russian-speaking Ukrainians living in Ukraine.[23] Figure 5 (on page 8) shows Ukrainian regions with predominantly Russian-speaking Ukrainian citizens (shown in blue) that coincide with the areas of the Russian invasion.

According to Ukrainian sources, the Russian forces killed twenty-five thousand civilians in the Russian-speaking city of Mariupol.[24] In addition, between twenty thousand and fifty thousand civilians were forcefully deported from Mariupol to Russia. The total number of deported Ukrainian children to Russia was up to 307,000, without any indication as to when they could return to their home cities.[25] According to the Ukrainian Office of the Prosecutor General, nearly eight hundred Ukrainian children had died or disappeared during the deportation process.[26] Torture chambers for Ukrainian children were found after the Russian army withdrew from the city of Kherson.[27] In addition, the Russian Federation created refugees crisis. Over eight million refugees fleeing Ukraine have been recorded across Europe, while an estimated eight million others had been displaced within the country by late May 2022.[28]

The Russian army was able to capture a significant land corridor linking the Crimean Peninsula with Russia-occupied Donbas regions on the east. Russia took control of the water supply to Crimea. This can



(Figure courtesy of Translators without Borders)

Figure 5. Language Map of Ukraine

be considered the first successful phase of the Russian invasion. The Russian government timed its war against Ukraine for days, not months. The Ukrainian strategy was predicated on defense, with the goal of killing as many Russian soldiers as possible. Ukrainians destroyed, captured, and reused many Russian armored vehicles. As of 3 December 2022, the Russian professional army was degraded, and their government has conscripted over forty thousand Russian prisoners and three hundred thousand new recruits.[29] These recruits included Ukrainian citizens living in the occupied Ukrainian territories. A large number of the Russian army soldiers were drafted against their will and were sent to battles with little or no military training. Disproportionately large percentage of the male population of the occupied Luhansk and Donetsk regions was forced to fight against the Ukrainian army.[30] Further attempts of the Russian forces to create new impulses and advance into the Ukrainian territories were failing.

The Russian government is using its resources to soften, fracture, and destabilize Ukraine. The Russian army attacked Ukrainian energy infrastructure to cut off electricity, heat, and water, and increase the scale of the humanitarian disaster in Ukraine during the winter. The Russian government is expecting that the Ukrainian people will not want to suffer any longer and will demand the Ukrainian government to enter peace negotiations. This is the same tactic with the same verbiage used by Nazi Germany in 1940, trying to force Great Britain to surrender.

As of today, one of the main concerns of Ukrainians is the *slow pace* of the weapons influx *from the West*. For months, Ukraine has been asking for air and missile defense systems to close the skies and to protect Ukrainian infrastructure from the systematic

destruction by Russian missiles and drones. Ukraine keeps asking for tanks, modern aircraft, and long-range weapons. The highly motivated Ukrainian army is willing to attack Russian occupation forces in Crimea and Donbas. Rapid defeat of the Russian forces could reduce the number of Ukrainian casualties, especially among the Ukrainian civilians, as well as the overall damage to the Ukrainian infrastructure and the total costs of the war to Ukraine and NATO partners.

Based on my observations, Ukrainian people desire the collapse of the Russian Federation as soon as possible. They want Russian war criminals to be prosecuted the way it was done to German Nazi leaders. Ukrainians want a process of changing the Russian Federation, similar to the processes of German denazification and demilitarization. Russia must destroy or transfer all of its weapons of mass destruction to NATO, and it must not be allowed to develop these weapons in the future. Ukrainians want the reparations for the war damage done by the Russian Federation. Ukraine wants to join NATO or another powerful military block, to make sure that in the future, Russia will be afraid to attack Ukraine again. This is the war for the survival of the Ukrainian people who remember the twentieth century as the century of the systematic Ukrainian genocide by Soviet Russia, including three famines and forced labor and death in the Russian concentration camps.[31]

It appears that the Western partners took a more careful approach to the war, and they are less interested in the *rapid* liberation of the occupied Ukrainian territories. In my opinion, the initial Western plan was to induce economic and political instabilities in the Russian Federation using carefully timed economic sanctions. However, the West underestimated the ability of the Russian Federation to survive economic hardship. As of today, there are no significant instabilities in the Russian Federation. The Russian government was able to stabilize its internal processes. Relatively small antiwar protests in Russia were suppressed and became nonexistent. Approximately 70 percent of the Russians are supporting the war in Ukraine.[32]

It also appears that the West did not finalize its *strategic goals* in the ongoing Russian-Ukrainian war. Most likely, the Western governments are afraid that rapid advances of the Ukrainian forces and liberation of the occupied Crimea and Donbas may cause *uncontrolled instabilities and chaos* in the Russian Federation. Most likely, the West is uncomfortable with the *unknown outcomes* of possible collapse of the Russian Federation.

Back in 1991, the U.S. government was worried about the approaching collapse of the USSR. Secretary of Defense Dick Cheney was the strongest proponent of encouraging the "rapid disintegration of the USSR," because he saw the fracturing of the former enemy as a diminution of threat.[33] However, President George H. W. Bush and his secretary of state, James Baker, believed that "keeping the Soviet Union going," even with a weak center, was the best alternative to violent disintegration.[34] In December 1990, Bush extended the economic assistance to the Soviet Union. This included the extension of $1 billion in agricultural credits in response to food shortages in the USSR. Bush also offered to seek observer status for the Soviet Union with the World Bank and the International Monetary Fund. He visited the Soviet Union in July and August 1991 and held a two-day summit with Soviet President Mikhail Gorbachev. Bush announced that he would seek congressional approval for a U.S.-Soviet trade agreement, together with most-favored-nation trade status for the Soviet Union. Baker signed five bilateral accords dealing with aviation security, disaster assistance, provision of medical supplies, housing construction and finance, and technical economic cooperation.[35] These efforts to save the "Evil Empire" came too late; the USSR was dissolved in December 1991.

If the Washington decision-making culture did not change much over the past thirty years, this may explain why the U.S. government was somewhat reluctant to send several types of weapons to Ukraine. In 2022, Ukraine did not receive long-range weapons, NATO tanks, or American aircraft. In addition, the Ukrainian forces were not allowed to use NATO weapons against Russian military units and ammunition depots located on the Russian territory, just across the border with Ukraine.

At the current stage of the war, the Russian government wants to negotiate and cement its ownership of the annexed Ukrainian territories. If Vladimir Putin succeeds, the Russian government may want to rebuild the Russian economy and army and will start a new war in several years.

The table (on page 10) shows several main events of the Russian-Ukrainian war. It includes predictions based

Table. Main Events and Predictions Using a Simple Structural Deformation Model

Predictive Model	Date	Event
	21-Mar-14	Russia annexed Crimea
1st wave	24-Feb-22	Russia attacked Ukraine
	20-Mar-22	Russia occupied the land corridor between Donbas and Crimea
	24-Mar-22	Russian forces failed to take Kyiv
	24-Apr-22	Russian forces withdrew from northeast Ukraine
2nd wave	24-May-22	Russia announces plans to annex three Ukrainian regions
	24-Jun-22	Ukrainian counterattacks
	24-Jul-22	Russia controls 95% of Kherson Oblast, 70% of Zaporizhs'ka Oblast and 10% of Mykolaiv Oblast
	24-Aug-22	Heavy damages were inflicted to the Russian airbase and supply lines.
	24-Sep-22	Successful Ukrainian counterattacks
	24-Oct-22	The second Russian impulse. Mobilizations in Russia is completed. Untrained Russian troops were sent to Ukraine.
	11-Nov-22	Russians withdrew from the City of Kherson.
	2-Dec-22	Putin personally asked for peace negotiations with the Ukrainian government. A sign of weakness.
	24-Dec-22	Russian prisoners were sent to fight in Ukraine.
Mar 2023		Expected exhaustion of the Russian 2nd impulse
Predictive calculator for the liberation of the Ukrainian territories including Crimea		
Apr - Jun 2023	The earliest possible timeframe for the complete liberation of the Ukrainian territories including Crimea	
Apr 2024	Complete liberation of the Ukrainian territories including Crimea in the case of *moderate* delays with weapon deliveries to Ukraine	
Aug 2024	Complete liberation of the Ukrainian territories including Crimea in the case of *long* delays with weapons deliveries to Ukraine	
Predictive calculator for the collapse of the Russian Federation		
Sep 2023	The earliest possible date for regional instabilities within the Russian Federation	
Jun 2024 - Feb 2025	Regional separations in the Russian Federation	
May 2026	Collapse of the Russian Federation	

(Table by author)

on a calculator utilizing simplified versions of the described above structural dynamics models for the most rapid scenarios. It can be assumed that the withdrawal of the Russian forces from the city of Kherson (Putin's main trophy in 2022) corresponds to point A in figures 1 and 2. The withdrawal from Kherson took place on 11 November 2022. War analysts may argue that the "exhaustion" or turning point for the Russian invasion came weeks later, around 20 December 2022, when Russian prisoners were sent to the frontlines to compensate for the losses of the Russian army.[36] The calculator is used for computing the duration of the Russian-Ukrainian war based on both data points, 11 November 2022 and 20 December 2022. The same calculator was used for the events of World War II, as shown in appendices 1 and 2. The shallow dome model suggests that in the absence of delaying and damping forces, such as delays related to the weapon supplies and weather conditions, the complete de-occupation of all Ukrainian territories including Crimea will occur between 16 April 2023 and 17 July 2023. The flat plate model suggests that under similar conditions, complete de-occupation of all Ukrainian territories will occur between 7 June 2023 and 13 November 2023. These calculations represent optimistic conditions for the advancing Ukrainian army.

In the second set of calculations, the dome and plate models accounted for *moderate and large* delays due to the weapon supplies and bad weather. According to this scenario, the complete de-occupation of Ukrainian territories should occur between 11 April 2024 and 9 August 2024. The failures of the Russian armed forces will likely destabilize the Russian Federation. Figures 1 and 2 may help visualize how undamped and uncontrolled collapse of the Russian forces would produce *larger damages* to the Russian Federation. In contrast, slower, damped, controlled collapse will cause *less damage* to Russia, and a better chance for the *subsequent recovery* of the Russian Federation and Russian armed forces, likely leading to another large-scale Russian war against Ukraine or NATO countries.

The dome and plate models suggested that the *earliest* date for the regional instabilities in Russia is around 19 September 2023. Regional separations and collapse of the Russian Federation should occur between 10 June 2024 and 4 February 2025. According to the model accounting for possible delays due to the weapon supplies, bad weather, peace talks, etc., the collapse of the Russian Federation will likely occur on or around 28 May 2026.

I believe that the collapse of the USSR in 1991 was incomplete, because it did not split its main member—the Russian Federation into several states. The Soviet Union was formed on 20 December 1922. Joseph Stalin's death on 5 March 1953 can be considered as the turning point (point A) in the Soviet history. The same *flat plate model* with the same coefficients was used to estimate the *earliest* date for the collapse of the USSR. The model with very small damping (meaning little or no Western support to the collapsing USSR), suggested the collapse of the USSR on 22 May 1989.

It is interesting to note that 1989 became known as the year of the revolutions and fall of communism.[37] In my opinion, the collapse of the USSR was rapid, with small damping. The delaying and counteracting events included unsuccessful economic reforms by Gorbachev in 1987 and 1988, Bush's extension of the economic assistance to the Soviet Union in December 1990, and a failed in August 1991 military-communist coup in Moscow.[38] The USSR was officially dissolved on 26 December 1991.[39]

According to the models with small damping, when the West provides little or no support to the collapsing USSR system, after hitting the bottom (the earliest predicted year was 1989, and it actually occurred in 1991), Russia should experience a rapid *partial* recovery and waves of imperial expansion using its armed forces. The duration of the first wave of the post-collapse recovery is approximately three times shorter than the duration of the collapse. Subsequent recovery peaks of different amplitude should occur every four to eight years. One can reasonably expect that Russia's recovery peaks should lead to new territorial expansion wars initiated by Russia every four to eight years. According to the simplified models with no damping (no delaying factors), the largest peaks for the Russian aggression should develop in December 2002, July 2013, and January 2021.

The factual data on the recent Russia's war history shows the following. Moscow's aggression against Moldova, one of the weakest republic of the USSR, was started several weeks after the USSR collapse. This war lasted from 2 March to 1 July 1992, and it resulted in the formation of the pro-Russian Pridnestrovian Moldavian Republic.[40]

Two and a half years later, Russia started a war against Chechnya, a small territory in Caucasus. Between 11 December 1994 and 31 August 1996, Russia fought the First Chechen War and subsequently the Second Chechen War (7 August 1999–30 April 2000).[41]

Eight years later, in 2008, Moscow attacked a larger country in the Caucasian region. The Russo-Georgian War was a war between Georgia, on one side, and Russia and the Russian-backed self-proclaimed republics of South Ossetia and Abkhazia, on the other.[42] It lasted 1–16 August 2008 and resulted in separation of South Ossetia and Abkhazia, recognized as republics by Russia. The response of the West to the Russo-Georgian War was mild, which encouraged further Russian aggression.[43]

The next Moscow's target was even larger. Six years later, "in February and March 2014, Russia invaded and subsequently annexed the Crimean Peninsula from Ukraine."[44] The same year, Russian forces started occupation of the Donbas region in Ukraine. Russia created the Donetsk and Luhansk People's Republics.[45] The success of the Russian territorial expansion and the mild response from the West, encouraged Moscow to continue its wars.

One-and-one-half years later, in September 2015, Russia started "aerial bombings across Syria that targeted schools and civilian infrastructures; carpet bombing of cities like Aleppo and various scorched earth tactics."[46] Seven years later, on 24 February 2022, Russian forces invaded Ukraine from the north, east, and south. It can be concluded that the models with small damping, representing weak attempts of the West to stabilize the collapsing USSR, produced results that are close to the actual historical data.

The same models were also used for the cases of *moderate* damping representing moderate Western efforts to slow down the collapse of the USSR. The *flat plate model* with moderate damping predicted the collapse of the USSR around 17 June 2001, and *periodic attempts* of the Moscow government to rebuild the USSR, with its peak efforts around July 2013, August 2025, and September 2043.

The plate model with relatively *strong* damping representing stronger effort of the West to stabilize the collapsing USSR, produced rather soft collapse of the USSR around 1 July 2007, with subsequent recovery and attempts to rebuild the USSR.

The *shallow dome* model with the same coefficients revealed the following. The earliest date for the partial collapse of the USSR should be 22 May 1989. In the case of *moderate* damping, the partial collapse should occur around 17 June 2001. Both cases with small and moderate damping lead to the *complete and irreversible* collapse of the USSR. However, in the case of *strong* damping (meaning strong Western efforts to support the collapsing USSR), the USSR should experience a relatively soft collapse, after which Moscow would start its rather successful restoration of the Soviet Union. ■

Notes

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US ISSN 0026-4148

Appendix 1. Predictive Model for the Fastest Scenario When the Red Army Could Regain Its Territories during the World War II

Variations: the borders as of 1939 and 1941	
What is the fastest scenario for the Red Army to regain its territories during World War II?	
Enter the key dates:	
22 June 1941	The German Army attacked USSR
23 August 1942	The German Army began the battle for Stalingrad (This is not the stopping point since they carried their impulse)
2 February1943	The German Army lost the battle for Stalingrad
Predicted by the model:	
22 January 1944	The earliest possible calculated date for the Red Army to restore USSR western borders as of 1939–1941
27 February 1944	The early date with refined coefficient
19 May 1944	The early calculated date with reasonable delays
Actual data:	
March-May 1944	The Red Army conducted an offensive in Baltic republics and liberated Crimea
1 July 1944	The Red Army crossed its 1941 borders and reached numerous locations of the Pre-World War II borders (as of 1939)

Predictive Calculator					
Jun-41					
Jun-42	17-Jul-42			2-Feb-43	590 days
Feb-43			22-Jan-44	The earliest possible date	
			27-Feb-44	With refined coefficient	
			19-May-44	With reasonable delays	

(Table by author; screenshot courtesy of "Eastern Front animated: 1944/1945," https://www.youtube.com/watch?v=-AUdP-QVEKA)

Appendix 2. Predictive Model for the Fastest Scenario When the Red Army Could Take Berlin

The life cycle of the World War II (started by Nazi Germany and Soviet Russia in 1939).	
What is the fastest scenario for the Red Army to take Berlin?	
Enter the key dates:	
1 September 1939	Germany started World War II
2 February 1943	The Germany Army lost the battle for Stalingrad*
	*The Battle of Stalingrad was August 23,1942–February 2, 1943
Predicted by the model:	
21 February 1945	The earliest possible calculated date for taking Berlin
9 May 1945	The early date with refined coefficient
29 October 1945	The early date with reasonable delays for the Red Army to take Berlin
Actual data:	
End of February 1945	Moscow chose a slower offensive to encircle Berlin
April 1945	Red Army encircled Berlin
8 May 1945	Nazi Germany capitulated

Predictive Calculator						
Sept-39						
Sept-40					1-Sep-39	
Sept-41					2-Feb-43	
Aug-42	17-Jul-42				1250	3.424658
Feb-43			21-Feb-45	The earliest possible date		
Sept-44			9-May-45	With refined coefficient		
May-45			29-Oct-45	With reasonable delays		

(Table by author; screenshots courtesy of "Eastern Front animated: 1944/1945," https://www.youtube.com/watch?v=-AUdP-QVEKA)