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DETERMINATION OF LEVELS OF UNACCEPTABLE DAMAGE TO STATE ECONOMIC SYSTEM: A METHODOLOGICAL APPROACH

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The notion of "unacceptable damage to state economic system" concentrates the essence of both nuclear containment and nuclear strategy as a whole. Different quantitative indicators that formalize this notion form the basis for nuclear employment concepts and determine their shape. Simultaneously it is a powerful factor in bringing pressure to bear on enemy decision-making mechanisms and one of the main factors helping to "convince" the enemy that launching an aggression is a high-risk affair.

However, since the 1960s, when this term was adopted by the scientific community and made part of military organizational development, and to this day its definition is quite subjective and vague, failing to provide a clear and unequivocal idea about concrete quantitative indicators that characterize it. Moreover, politicians and the military view the gamut of unacceptability within sufficiently wide limits, ranging from complete and irreversible destruction of a state economy to some hardly perceptible and undefined facet of psychological or political unacceptability.

Most generally, the damage a state sustains in the course of military operations, or, to put it differently, the "price of war," is a complex category that cannot be recognized as fully established in scientific literature. Its crucial component is military

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casualties, i.e., losses that belligerents sustain as a consequence of a military conflict. These include: loss of life, WME losses, and other materiel losses at the front and in the rear, as well as a damage resulting from disruptions in the ecological balance, etc. Classed in a particular category are political losses that summarize the collapse of those political regimes that cease to exist after a war.[1]

While in the course of old large-scale wars that could last for years and decades the damage caused to state economic systems used to build up gradually and could have been compensated in some way or other in the process of protracted hostilities, a relatively brief nuclear attack at military-economic targets makes a country sustain practically instant (leap-like) human, industrial and infrastructure losses. It must be added to the above that current estimates of nuclear damage to economic potentials traditionally proceed from the amount of basic production assets lost in consequence of direct engagement (of being disabled). In this context, it is believed that the adversary should primarily engage both manufacturers producing end military products and those constituting the economic revival potential (manufacture of building constructions, drags, the food industry, etc.). Population losses and postwar economic rebuilding time can be considered as additional nuclear effectiveness indices.[2]

The spectrum of current criteria used to estimate such damage is sufficiently subjective and very wide. But somehow those criteria are sure to take into account the following:

* failure to meet vital economic and human needs for a long period of time;

* termination of output of end products, primarily military, by an aggressor-state economy. This means that a situation is taken into consideration, where a state economy loses all stability and ceases to serve as the material-technical infrastructure for any armed warfare;

* disruption of state and military governance in an aggressor-state, which bars it from pursuing further military operations on the strategic scale;

* commensurability of economic rebuilding costs an aggressor-state can face and possible economic benefits of a war, etc.

To make a ***qualitative estimate*** of a state economy after a nuclear impact and ***to determine the qualitative parameters*** of damage acceptability framework, we will compare military losses with consequences of economic crises. The latter we will assess on the basis of a *methodology that studies the cyclical dynamism of social system.*[3]

Currently the most studied cyclical dynamism area is the vacillations of economic activities and crises that shake them from time to time. The cyclic nature is the general form of development of social systems and crises are its necessary element. It must be noted that economic crises would arise as long as economic systems are in existence and that they, as a rule, unfold, when one economic cycle is replaced by another. Crises are characterized by different intensity and duration and destroy some outmoded but still prevalent elements of a system that ran out of potential and represent a brake on its development. At the same time, mere is no homogeneity or a strict, mathematically expressed periodicity and duration of crises.

Our further logic implies that we should introduce certain key terms. ***An economic cycle*** is a periodic expansion (rise) and contraction (decline) of real amounts of production against the background of an average economic growth (general growth tendency). It comes in the wake of shocks and balance disruptions that affect an economy

in different periods and possess temporally stable consequences. Production amounts and prices are rapidly modified as a reaction to each shock. Capable of causing rises and subsequent declines, wars are among the main sources of disruptions that tip the balance in economic systems.[4]

In respect of duration and effective periods, economic cycles are subdivided into *short-term* that last three or four years and are mostly due to natural factors (Kitchin cycles); *mid-term* - eight to 12 years - due to generation changes in equipment and technologies (business cycles or Juglar cycles); *long-term* ones due to changes in prevailing technological and economic systems (Kuznets 20-year investment cycles and Kondratieff 50-year grand conjuncture cycles); and *super-long-term* cycles: century-long (multi-century) and thousand-years-long cycles due to the dynamism of global and local civilizations.

The conditions under which a state and its economy function may change in a natural way in consequence of both internal causes (controlling action and natural disturbances) and external, including military (casualty-producing, destructive), actions that disrupt both a system's structure and its objectives. This is why stability and adaptability are a very important property of such systems.

A system's ***stability*** or "stable development" as its ability to withstand external disturbing impacts for self-preservation is a crucial behavior characteristic of such systems that are similar to a state economic system.[5] A strict description of system stability was introduced by A.N. Lyapunov: a state (development) modification trajectory will be described as stable, if for an arbitrarily small ultimate deviation that determines the stability "corridor," such limitations for disturbances can be indicated as would keep the system within the "corridor."[6]

System ***adaptability*** can be represented as a certain degree of capability for absorbing external disturbances without dramatic consequences for its behavior in a transitional or fixed state.[7] Adaptability is not the system's inner property alone and depends on the character and level of external disturbances (action). If a system is capable of "absorbing" all possible disturbances of a certain type, it possesses an infinite adaptability in relation to this class of disturbances. But if the power of a disturbing action exceeds adaptive development capacities, a loss of stability occurs and the system assumes a new state.

Depending on the mechanisms and character of stability loss, one may identify the following types of situations, where such a transition takes place.

Critical situations, such moments of disturbed stability as are prolonged within a system by way of its adaptability on the basis of inner adaptive development mechanisms.

Crises, qualitative transitional states characterized by a gentle loss of stability that lead to a transformation of a system's elements and structure. A crisis is a variant of a critical situation and vice versa. They are differentiated by the "degree" of crisis quality and unified by the fact that the transformations they cause can be overcome on the basis and under the condition of a system's existence.

We will consider as an acceptable crisis economic decline level the situation where no long-term slide in living standards or major sociopolitical upheavals mat can change the system's state take place. At the same time, while defining a loss acceptability

level, one must certainly take into account the subjectivity of its perception by both national leaders and the population.

Disasters, critical situations characterized by a bad loss of stability, which cause the disintegration of a given system. The system makes a leap into a qualitatively different state. Though certain of its elements are preserved, the system as a whole is stripped of its system attributes.

Using the approach suggested by Thomas Saaty,[8] we will assume that the qualitative estimates of conflict consequences can be represented with sufficient fullness by the following five main gradations of damage to the state as inflicted by a nuclear attack: minimal, weak, strong, very strong, and absolute. If some greater descriptive accurateness is needed, no more than four intermediary (compromise) values can be accepted additionally.

If we assume that the parameters of a critical zone or utmost acceptable damage (disturbances) are known (calculated) as coordinates (population losses, loss of industrial capacities), it can be represented on a plane, in the most general form, as a certain curve. The numerous points inside the curve correspond to losses that cannot cause the system to lose its adaptive potential. For the system to reach its adaptation limit and lose stability, the power of disturbing influence (loss parameters) must take the system outside this zone.

In order to obtain some concrete quantitative parameters that will make it possible to formalize the notion of "unacceptable damage," let us consider a formal dynamic model of the state economic system. In making this model, we will use methodological aspects and methodological techniques that were set out in a number of works.[9]

The economy of any state is a dynamically stable totality of self-organization-capable interdependent and interacting macrostractures, totality allowing of a macroeconomic description. For those macrostractures to start crumbling and for the economy as an integral system to begin decaying, strong disturbances are needed.

A formal macro-model of the economic system should be made to identify economic consequences of an attack (a nuclear strike) at a country's territory, its industries, military targets, infrastructure and cities. This model ought to make it possible to estimate how the loss of productive (material) resources and of the productively engaged population influences the main macroeconomic indices that determine the state of the economy and a possible dynamism of its revival. This model must also make it possible to take into consideration such changes in the economic policy as are caused by the need to compensate the consequences of the attack.

The comprehensive model of a controlled economic system is formed by a totality of models of production processes and economic regulation mechanisms that is complemented with a system of influences on the economy. This model enables one to forecast possible structural shifts in the economic system depending on managerial decisions accepted inside the system. They are orientated to obtaining various quantitative and qualitative estimates characterizing consequences of appropriate economic decisions from the point of view of chosen macro- and micro-economic indices and vectors in the economic policy of the state.

Modern economics considers the overwhelming majority of actions by physical persons and legal entities in money terms, something that enables a quantitative expression of macroeconomic notions and opens the way to quantitative analysis

methods. The money value of commodity sets is additive; it is preserved during movements between economic macrostructures and makes it possible to make various statistics-based balances in the money value form in order to analyze, with their help, the quantitative regularities of the general economic process of production and circulation of material benefits. The main macroeconomic indicator characterizing the economy of a state in general is the value added, or ***gross domestic product (GDP)*** - the total value of all commodities and services produced within a year minus the value of commodities and services used within a year by current production.[10]

The size of an average gross domestic product can most generally be described by the equation

$$W^{av} = \frac{1}{T}\int_{t}^{t+T} Y dt, \quad (1)$$

where, W^{av} is the average gross domestic product in permanent prices, or an averaged integrated value of all commodities and services produced during the period T minus the value of commodities and services used, during the same period, in current production;

T is an averaging period defined by an interval of time, during which people realize a change in the economic situation (for example, a period of time between elections);

Y is a certain production function

$Y = Mf(x) = Mf(R^L; M)$, (2)

where, M are integrated industrial productive capacities;

R^L is the amount of workforce used in production that is directly proportional to a country's population numbers.

The macroeconomic ***production function (PF)*** that prescribes the maximal amount of output capable of being produced on the basis of the prescribed set of resources describes the statistically meaningful connection between the GDP and different types of costs or amounts of resources used.[11]

The most widely used PF is the Cobb-Douglas function based on the analysis of the U.S. economy and having the following form:[12]

$Y = f(K_t, L_t) = AK^{\alpha}L^{\beta}$ (3)

where, Y is combined output (revenue) or GDP;

$f(K_t, L_t)$ is the production function;

A is the coefficient characterizing production effectiveness;

α, β are production flexibility coefficients by capital *(K)* and labor *(L)*, respectively, that reflect, within the neoclassical economic theory, the role of production factor in end-product increment or the share of yield from an appropriate factor per unit of combined revenue. Usually it is held that $\alpha + \beta = 1$.

To draw a formal model of the economic system on the basis of equations of material balances with the use of a Cobb-Douglas-type function, let us introduce the following premises.

Let "production" (a national economy) put out a certain homogeneous product, the gross domestic product W, in an amount Y per a unit of time, expending the only resource in the shape of an L amount of homogeneous workforce and using, in the process of production, the basic productive assets K that define the productive power. By

using productive capacities and live labor, the production converts internal flows of raw materials to an end-product flow.

To study the dynamism of macroeconomic systems against this background, a dynamic single-sector economic growth model known as the ***"basic Solow mode"*** is currently used on a broad scale.[13] This model views the economy as a self-contained single non-structured whole producing one universal product that can be both consumed and invested.

This model reflects fully enough the most important economic processes, including reproduction, and is prescribed by the following system of equations:

$Y_t = (K_t, L_t)$; (4)

$Y_t = I_t + C_t = \rho Y_t + (1 - \rho)Y_t$; (5)

$K_t = (1 - \mu)K_{t-1} + I_{t-1}$; (6)

$L_t = (1 + \nu)\, L_{t-1}$,

$t = 1, 2,..., T$, (7)

where, Y is gross domestic product (GDP), a production function of resources: basic production assets and the number of those employed;

I are gross investments, $I = \rho Y$, where p is the share of gross investments into GDP;

C is consumption fund;

K are the basic production assets (BPA);

μ is disposal (wear and tear) coefficient of BPA calculated for one year;

L is the number of production employees;

ν is an annual increase in the number of employees;

$t = 0$ is the reference (basic) year;

$t = T$ is the final year of a period under study.

The Solow model considers five macroeconomic indices: the first three *(Y, I, C)* are flow-type indices (their values build up during a year); the rest *(K, L)* are instant variables (their values can be changed at any continuous time moment).

To draw up a system of criteria and indices estimating consequences of an attack at a state economy, which is due to help the decision-maker to draw a conclusion on the acceptability of military operations in a conflict situation, we will also assume:

* that a nuclear strike delivered at the state economic system hits industrial production capacities (basic production assets) and the population engaged in production;

* that in consequence of that impact the amount of GDP instantly takes a plunge (by a leap);

* that after the impact the main macroeconomic indices, the structure of the economy, the nature of interconnections between its elements and the type of corresponding production function are unchanged. This assumption secures a minimal estimate of the amount of damage, an estimate from below;

* that economic revival term is determined by the length of time, during which production growth will not only compensate the loss of basic production assets (in value terms) but also attain the prewar GDP level.

This model makes it possible to draw up within the coordinates: *K - economy (industrial production capacities, basic production assets), L - population* - areas of possible states of stability and adaptation of the state economy subject to the qualitative

characteristic of damage: levels of population and industrial losses, as well as post-nuclear economic revival period (see Figure).

Assigning different levels of damage to BPA and the population, this model can identify time of economic recovery to the prewar level. The curve linking the damages that require identical recovery time is what defines the boundary of an area corresponding to this or that qualitative state of the economy and a nation in general. Thus, each point in the coordinates *(K, L)* corresponds to the level of losses the state can incur in the course of hostilities. Depending on their quantitative values, the state of a nation as a complex organizational system may be different.

At the same time, it must be clearly realized that in order to restore the economy, after a war, to the prewar level, the state must redistribute its financial, material and human resources between the spheres of state and public consumption, and this will inevitably lead to both a slide in the living standards and malfunctioning of the state machine. This will also impact on a state's status within the world hierarchy and modify the regional and global balances of forces.

This qualitative partition of the phase space is of sufficiently general nature and can serve as the basis for analyzing consequences of nuclear exchanges and a war as a whole. The concrete form and dimensions of each of the areas depend on concrete indices and development level of a state, as well as on subjective characteristics of the ruling elites.

At the same time, it is necessary to note that the aspect of the boundary of economic damage acceptability areas is identical to the aspect of an economy's productive capabilities boundary as described by the classical macroeconomic PPF function demonstrating the "maximal possible amount of production of a certain concrete commodity or type of services, given the preset resources and knowledge a concrete economy possesses within the prescribed amounts of production of other commodities and services."[14]

Consequences of attacks and restoration processes may vary considerably from country to country depending on their economy's specifics and structure, their state governance systems, amounts of resources they have at their disposal, and other factors. This is why it is precisely *the time of economic restoration to the prewar level*, one enabling a comparison between different countries, that is accepted as the determining parameter that is an algorithmic function of the production assets and population loss levels. This function is calculated with the help of an algorithm that uses an apparatus of production functions and the basic Solow function as the main element of a certain iterative procedure.

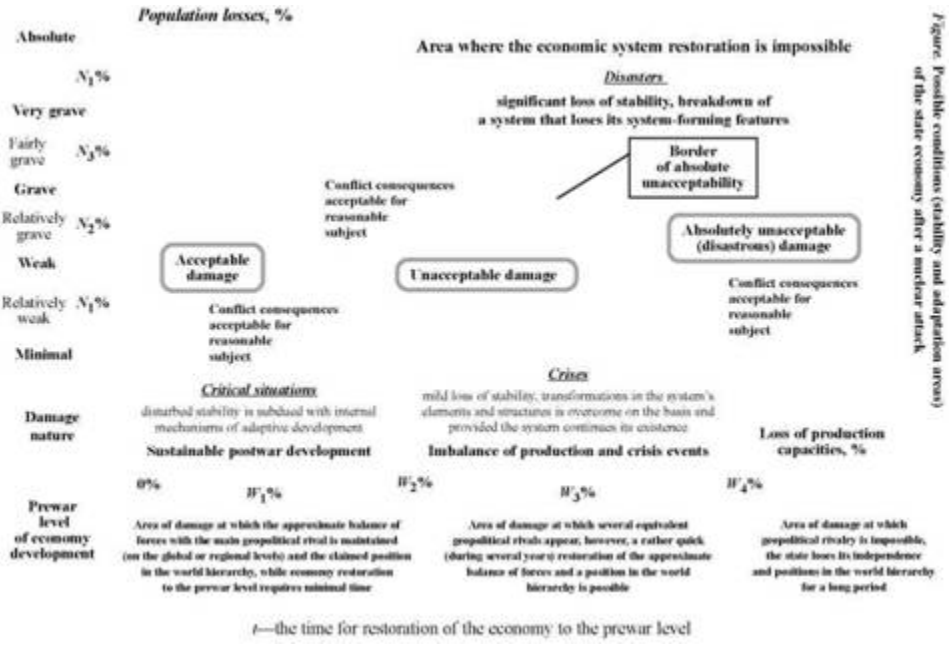

Figure. Possible conditions (stability and adaptation areas) of the state economy after a nuclear attack

The temporal boundaries of areas and quantitative indices of production decline for the accepted possible states of national economy from the point of view of its stability and adaptability (areas 1 - 5 in the Figure) are prescribed by analogy with the following parameters of appropriate economic cycles. Let us show them.

Thus, **the first level of losses** (the right-hand boundary of Area 1) is defined by economic restoration time t_1 that lasts *no more than two years*, something that corresponds to a half of the "Kitchin cycle." It is believed that this period is equal to what it takes to remove a ***minimally acceptable damage*** to the economy that practically is not reflected on the functioning of the state as an integral system, because such vacillations of economic indices are due to natural factors and current economic situation. They occur rather often and are sufficiently habitual both for national leadership and the population.

This type of damage causes a ***disturbed state*** in the economy, some industries and branches face problems, the political situation is aggravated, and substantial ecological consequences crop up. But the main parameters in the life of the state and society are practically the same.

Thus, we will deem that *the first level corresponds to a minimal damage and the state of system survival,* that is, the losses that the state removes sufficiently rapidly, painlessly and within minimal timeframes. Moreover, an approximate balance of forces is retained with the main geopolitical rival both at the global and regional levels. The position in the world hierarchy a country held before the war is practically unchanged.

Compensation of **level two losses** (level prescribed by time t_2, or the right-hand boundary of Area 2) corresponding to a weak damage and destructive effect whose consequences enable a state to secure its sociopolitical survival, while the outer outline of an area corresponding to this level will define the boundary of acceptability of losses or the "price of war," may require ***not less than four years,*** which corresponds to the maximal duration of the "Kitchin cycle."

These losses are characterized by ***a low level of damage*** that brings a national economy to ***a*** tense state, as a result of which *the state starts feeling the pinch of war, the*

habitual way of life is altered, the country's position in the world economic hierarch deteriorates, and long-term ecological consequences arrive.

It can be claimed with a sufficient degree of certainty that national leaders should not let expected losses exceed the said limits because it is in this area of the states space that the system's internal stability persists and political elites remain in power.

Greater losses lead the system to the next area of the phase space that corresponds to a situation where industries are thrown out of balance and crisis phenomena appear in all spheres of state life. A soft loss of stability takes place, which means that though the state still functions as an integral system, its separate elements begin malfunctioning. Given the levels of damage achieved, a country is confronted with several equally strong geopolitical rivals capable of bringing considerable pressure to bear on its home and foreign policies and economic development. But it is still possible to restore, within a sufficiently brief (several years) timeframe, the prewar level of national might and the position in the world hierarchy.

Damage levels one and two comprise an area of stable postwar development. Disruptions of stability of state development lead to a critical situation that is overcome with the use of internal adaptive development mechanisms.

If removal of damage requires ***no less than eight years,*** we get **a third level of losses** (characterized by the right-hand boundary of Area 3) that corresponds to ***a high level of damage*****.** This sort of damage brings a nation into a state, where the crisis, though not breaking the system's structure and the main inner connections and governance mechanisms, causes serious malfunctioning and functional interference. The period 13 practically corresponds to what is minimally necessary for a full replacement of the basic production assets (in peacetime) and corresponds to the lower temporal boundary of the "Juglar cycle."

The state system is ***beset with difficulties,*** the armed forces have *their needs met at the minimal level, a number of industries are paralyzed, production becomes unbalanced, crisis phenomena are observed in the economy, and the population faces considerable problems. Compensating those losses will require a dramatic modification of the national economic policy, specifically a considerable reduction of consumption.*

Level four of losses (t_4, the right-hand boundary of Area 4) corresponds to *a very grave damage* and state of regional survival, that is, *preservation of separate administrative-territorial units with minimal links between them and without a single centralized national leadership.* Political elites come and go and the state development vector may be made to point anywhere depending on a concrete situation in the country, the region or the world.

Repairing this damage will require ***not less than 12 years*** (the upper temporal boundary of the "Juglar cycle); the economy is in ***a critical state,*** it is impossible to provide the armed forces with everything necessary for combat operations and the attainment of war goals; only the minimal needs of the population are met; the country drops out of the world hierarchy for decades, GDP is reduced to the level of certain closest economic rivals, the country loses its competitiveness for decades.

For a reasonable decision-maker the "price of war" involving this sort of losses must obviously be unacceptable. Thus we will deem that the upper limit of permissible (acceptable) economic resuscitation time is the duration of the mid-term economic "Juglar cycle," that is, twelve years, and that the formal war acceptability-unacceptability

boundary is likely to be one between the first and second levels of losses. That this assumption is true is confirmed by an analysis of the latest economic cycles in the United States of America, which show that their duration, as measured by the length of production decline from a maximum to a minimum and a subsequent surge to a new maximum, was from 18 to 74 months, or short- and mid-term cycles. The U.S. economy, in this context, was preserved as a system and never lost its restorative capability.[15]

Level five losses (Area 5) inflict on the economy and the state what is generally an ***absolutely unacceptable damage,*** because they plunge a country in a disastrous state that results in a *collapse of the state, while the population is reduced to a level of biological survival.* Restoring this damage will require, under most favorable circumstances, ***from twelve to twenty years,*** something that practically corresponds not only to the temporal parameters of "Kuznets investment cycles" but actually also to a period of political and popular generation change.

This kind of damage throws the state into ***a catastrophic*** or nearly catastrophic ***state.*** The annihilation of the majority of most important industries paralyzes most state institutions, only minimal popular needs are met, and the state no longer functions as an organized system.

Actually the system loses its stability by a leap and loses its system properties and attributes. In this state, no geopolitical rivalry is possible even at a local level. For a sufficiently long period (dozens of years), the state loses its independence and positions in the world hierarchy, and, more likely than not, ceases to exist as a subject of world politics, disappearing from the map like the Russian Empire and Austro-Hungary after World War I and Germany after World War II did.

An analysis of statistics characterizing economic dynamism of the leading world countries shows that GDP growth indices in the period from 1983 to 2005 are between -21% and + 23.1%.[16] This was a period, when the world saw considerable geopolitical changes, as well as economic and political crises. The USSR disintegrated, the EU sprung up, China made an economic breakthrough, and numerous local wars were waged. At the same time, there were no global military conflicts, the leading countries did not suffer violent attacks and destruction of their economic potential, and the global strategic situation was regarded as relatively stable. This is why it can be deemed with a fair degree of certainty that within the framework of our objective the above figures fit in, under present circumstances, in a certain "acceptability range" as related to vacillations of macroeconomic indices ensuring the state's preservation as an integral functioning system.

Thus, where stability of economic systems is concerned, we can accept that for any real forecast period T, the acceptable deviations of the W^{cp} value should not exceed ± 25%. Consequently, for a decision-maker the level of "acceptability" of damage inflicted in a nuclear attack is unlikely to exceed this value.

Using the above state economic macro-models and also keeping our sights on the indicator of unacceptable damage to basic production assets equal to 25% and the economic revival period of not less than 12 years, we can formulate requirements to the shape and combat capabilities of a nuclear force designed to contain a "reasonable" potential adversary. If, however, an adversary can be estimated as insufficiently "reasonable" or as totally "unreasonable," an appropriate upward adjustment of quantitative unacceptable damage indicators is needed, with account taken of some

specific things characterizing the enemy decision-maker. Specialized reflexive methods are used in the process. As the boundary of unacceptability for an “unreasonable” decision-maker the traditional “McNamara criterion” - 50% of destroyed industrial potential and 20 - 25% of the population - can be taken.

Let us note in conclusion that the more developed and internally complex a state, its economic system and infrastructure are, the more it has unique facilities securing its functioning, the quantitatively smaller damage to BPA may prove unacceptable.

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