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Research Article

Aadaptive Transformation Method of Cyber Informational Cycle

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Abstract

The article describes the method of adaptive transformation of the C4ISR cyber information cycle in a crisis situation. The features of cyber information cycle transformation stages in crisis situations are characterized.

Keywords: Cyber Information Cycle; Cycle Lap; C4ISR; Crisis Situations; Situational Center

Abbreviations

C4ISR: Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance; NATO: North Atlantic Treaty Organization; OODA: Observe, Orient, Decide, Act; SC: Situational Center

Introduction

In the modern world the number of various crisis situations including military conflicts is constantly increasing.

Timely and adequate response to crisis situations needs: combining state security and defense sector capabilities [1], disparate forces and assets integration in a single information and combat space into a C4ISR-type situational complex [2], disparate forces and means management system creation.

Integration of disparate forces and assets is possible.

The technological basis of integration should be a Global Information Electronic Communications Network system, such as the United States Department of Defense Global Information Network and other systems that integrate automated combat control, computing, communications, and intelligence systems (eg, C4ISR) C4ISR development trends and formation issues are highlighted in [5,6].

In the case of crisis situation various forces and assets integration implies such problematic issues as actions coordination by tasks and execution locations, actions time synchronization.

C4ISR type systems practical substitution requires a number of methodological, organizational and technical issues to be solved. First of all it concerns management theory further development concerning cyber information cycles improving. These cycles are realized by the means of the situational control center.

So in [8] it is noted that any activity with a certain degree of assumption can be represented as the OODA cybernetic model (Observe - Orient - Decide - Act). According to this model two important points are crucial for successful realization. The first is that opposing side defeating needs quick passing of cycle laps. The essence of the second point is opposing side OODA cycle destroying (to stop or to break the execution).

Typical informational cycles are described in [9-12].

Basing on C4ISR construction theory [13-15] and cyber-information cycles models [16] analyses the conclusion is made that cyber-information cycles common models are inable to provide the complete situational complex formation and application management process.

The purpose of the study is C4ISR cyber informational cycle adaptive transformation method development in order to increase C4ISR systems effectiveness.

Materials and Methods

In the article the most known, universal cycle models used in military sphere, scientific research, management, etc. analysis results are described.

The basis of the research is the hypothesis that any complex system can be considered as the set of processes meeting certain requirements. Each process consists of a set of operations combined with certain management technologies. Process effectiveness is estimated according to the gain achieved, using its specific criteria (requirements).

Any requirement can be reached using the appropriate means and assets set.

The processor approach makes it possible to apply the following postulates:

- The scope of system determines problem solving quality;
- The system consists of structures set aimed at certain task solving;
- Each structure under the influence of the governing body moves to more effective states with respect to certain goals (requirements);
- Due to structures integration, existing units organizational structures are created to fulfill the tasks necessary to achieve certain requirements.

Based on the hypothesis it is possible to make organizational and technical integration with a specialized situational center (SC) of mixed assets of obtaining information, its transmission and processing S_2, fire (kinetic) and non-kinetic (information, cognitive) damage S_3.

The implementation of r situational system can be described:

$$S^r = \bigcup_k S_k^r, \; k = \overline{1, K}, \qquad \text{-----------(1)}$$

Where $S_1^r \subset S_1$ – the subsystem assets of obtaining information, $S_1 = \{S_{11}, S_{12}, \ldots, S_{1n}\}$;

$S_2^r \subset S_2$ – the subsystem assets of transmission and processing, $S_2 = \{S_{21}, S_{22}, \ldots, S_{2m}\}$;

$S_3^r \subset S_3$ – the subsystem of executive assets, $S_3 = \{S_{31}, S_{32}, \ldots, S_{3v}\}$.

The SC realizes geoinformation, navigation and time provision, formation using infocommunication means and joint information and communication network, which are available in the determined zone (region); the acquisition and processing of information; decision-making support; giving out purposed instructions; the direct control of operations of the available forces and assets for prevention from and elimination of crisis situation. The main determined task of SC is: to provide location coordinated and time synchronized functioning of system elements with minimal time delay between call and maximum effective response (for example, the emergence of counteractive party's object in the restricted zone and its liquidation (damage)); realization of the information cycle (Figure 1).

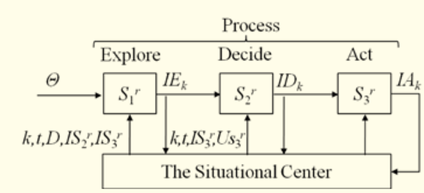

Figure 1: The synchronized functioning of subsystems.

On figure 1 Θ – current situation, k – task number, t – beginning of the task, D – limit of information reliability, IS^r_2– information of the decision-making support subsystem, IS^r_3– information of the executive subsystem, US^r_3 – performance characteristics.

Based on many years C4ISR systems research, authors worked out the following the information cycle: Explore, Decide, Act (Figure 2).

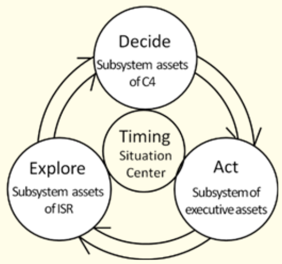

Figure 2: The information cycle.

The “Explore” phase includes active and passive collection of data in a single information and combat space. First and foremost, according to defined goals and tasks, actions are taken to organize and implement information gathering about the opposing side objects, own forces, assets, capabilities, the zone (area) where the operations are planned to be conducted (ground, its geophysical and other characteristics, infrastructure, population, etc.).

For this purpose, general information resources, all available databases, geographic information system resources, information from all technical reconnaissance and other sources of reconnaissance available in the zone (area) are used.

Based on the results of the “Explore” phase it is planned to reduce the entropy of objects, forces, assets, capabilities and actions of the opposing side to a minimum. The output data of this stage is used to display the current status of combat space objects, situations and to refine the situation model.

At the “Decide” phase on the basis of all available information about the enemy concept of operations is determined. The plans of application of kinetic and non-kinetic (electronic, informational, cybernetic, cognitive, etc.) impact, robotic (unmanned) special and military equipment, their optimal distribution in combat space, etc. are developed.

Choosing the best plan is the result of the “Decide” phase.

$$\{\boldsymbol{E}_k, U_{S_3^r}\} \xrightarrow{m_k^n} D_k, \qquad \text{-----------(2)}$$

$$E_{S_3^r}\left(m_k^n\left(E_k\right)\right) \to \max, \qquad \text{--------(3)}$$

$$m_k^n \in M_k,$$

$$n = \overline{1,N},\ k = \overline{1,K},$$

Where m_k^n – n variant of task solving from set M_k.

The “Act” phase includes chosen action plan (decision) practical implementation. The action involves issuing orders or instructions, physical attack, active protection, spatial movement or resource management, information retrieval to improve observation in the next information cycle.

Results and Discussion

To perform the listed above procedures, it is necessary to simulate and organize the relevant subsystems (structures) in advance, to evaluate their functional capabilities, and to check the functional readiness of the components. Therefore, we propose such Cyber Cycles of the SC (Figure 3).

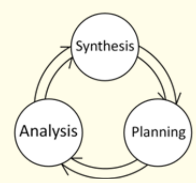

Figure 3: The Cyber Cycles.

“Analysis” phase

Complex real-time processing, systematization and comprehensive analysis of the obtained information to assess the current situation and forecasting based on the findings from the analysis and results of calculations and modeling of the possible nature of the counterparty’s actions and situation development are performed.

For the preliminary quantitative assessment of the degree of ability to solve tasks by the appointment of subsystems at the stage of organization of situational structures, it is proposed to apply the coefficient of functional capacity $G(t)$

$$G(t) = \Psi\left(f(t), S(t)\right), \qquad \text{-------------(4)}$$

Where $f(t)$ – functions of submission; $S(t) = S_{vik}(t) \bigcup_{assoc} S_{org}(t)$ – existing technical and organizational structure of the subsystem, which are united on the basis of the association mechanism.

The coefficient of functional capacity indicates the capacity level of the i-th unit to receive and carry out tasks with available forces and assets at the current time t. It is a generalized indicator

$(\ ) = \omega(\ )\ (\ )\ (\ )$, $0 \le G \le 1$, ----------(5)

Where $\omega(t)$ characterizes the presence of communication with the subsystem forces and assets (presence in the infocommunication network), $\omega(t) = \{1,0\}$, 1 – presence, 0 – unpresence; $G_T(t)$ – the coefficient of technical readiness; $G_H(t)$ – the coefficient of organizational readiness.

The coefficient of technical readiness is

$$G_T(t) = \prod_{i=1}^{n} \left(g_T(t)\right)^{\eta_i}, \quad g_T(t) = \frac{x_i(t)}{x_i^{der}}, \text{----------- (6)}$$

Where $x_i(t)$ is the current value of the functional property of the sample asset or its resource, x_i^{der} – it's normative value, $0 < \eta_i < 1$; $\sum_{i=1}^{n} \eta_i = 1$ – importance coefficients of partial characteristics.

Formula (6) determines the value of the relationship between the current and the normative characteristics of a sample of asset, taking into account the coefficients of importance of these characteristics. The multiplicative form of the indicator is chosen because no partial characteristic can be excluded without loss of functionality of the sample of funds.

The coefficients of importance η_i, ($i = \overline{1,n}$) can be determined on the basis of modeling of processes of application of samples of equipment in typical conditions of crisis situational, or with the help of experts.

The coefficient of organizational readiness $G_H(t)$ characterizes the ability of forces to perform a set list of tasks at a certain point in time.

Based on [17] it is suggested that an organizational structure is capable of performing tasks if all its structural units have structural capacity $G_H^S(t)$ and algorithmic readiness $G_H^A(t)$.

$$G_H(t) = G_H^S(t) G_H^A(t), \text{ ----------(7)}$$

Where

$$G_H^S(t) = \begin{cases} \ni \min g_H(t)\ \forall j\left(g_H(t) \in g_H^d\right), \\ 0, \exists j\left(g_H(t) \notin g_H^d\right), \end{cases} \text{ ------------(8)}$$

$$\left\{g_H^d\right\} = \left\{g_H^d : \frac{h_j(t)}{h_j^{der}} \ge n_j^{min}\right\}.$$

It is shown in expression (8) that, $G_H^S = \min g_H(t)$ provided that for all structural constituents of the subsystem, the requirement of having a minimum number of personnel (forces) in the functional and working state is fulfilled to perform the task. In other cases $G_H^S = 0$.

Algorithmic readiness is the ability of forces to perform within a certain period of time standard models of equipment assigned to them tasks:

$$G_H^A(t) = \begin{cases} 1 - exp\left(-\dfrac{t_{got} - t}{t_{potr}}\right), t_{potr} < \left(t_{got} - t\right), \\ 0, t_{potr} > \left(t_{got} - t\right), \end{cases} \text{ ------------ (9)}$$

Where t_{got} - the time of readiness for its intended use

t_{potr} - the time to use as intended, $t_{potr} = t_{zm} + t_{a}$;

t_{zm} - the total time to move to the location of tasks at a distance D_m with the speed of movement V_T, $t_{zm} = D_m \div V_T + t_{zgort} + t_{rozg}$;

t_{zgort} - the time to fold the position, t_{rozg} - the time to deploy to the position,

t_{a} - cycle of the sample of asset.

Execution of tasks is possible provided.

Index $G(t)$ can be considered as integrated index of partial indicators aggregate. The report reveals the methodology for its evaluation. The evaluation is based on operational information received with given periodicity. Execution of assignments is possible only on condition:

$$G(t) \ge G_{\alpha}, \ G_{\alpha} = \{G_{\alpha}\}, \text{ ------------- (10)}$$

Where G_{α} the limit value of the ability to complete the task by appropriate forces and means. It can be determined on the basis of modeling of execution of tasks on purpose in standard conditions.

The evaluation is based on operational information received with given periodicity.

"Synthesis" phase

On their basis, the problem of rational distribution of forces and assets is solved on the ground of the concept of optimization, which is the determining of the solutions that correspond to the extreme value of the selected efficiency indicator with fixed restrictions, that is,

$$u^{opt} : \max(\min) W(u), \text{-------------(11)}$$

Where $W(u)$ - performance indicator, U - set of admissible options.

The situation changes very quickly and significantly in a crisis. Therefore, management actions should be made during such interval of time, after which it still makes sense to implement them.

The effectiveness of such a system depends on the consistency of the set of criteria. In general, C4ISR must meet the following requirements: to provide the minimum desired time for target destruction (elimination of the crisis situation) t_S; to work out solutions for destruction (suppression) with high reliability D_S; to destruct the target with the maximum probability P_y of an ammunition with the necessary and sufficient damaging factor; to get information redundancy N_S to prevent civilian casualties; which can be represented as follows

$$\begin{cases} t_s \to \min, t_s \le T_{opt}, \\ D_s \to \max, D_s \ge D_{spor}, \\ P_y \to \max, P_{spor} \le P_y \le 1, \\ N_s \to \max, N_{s\min} \le N_s \le N_{s\max}, \end{cases} , \text{-------------(12)}$$

Where T_{opt} – the optimal time for the targe

t task; D_{spor} , $N_{s\min}$, $N_{s\max}$ – limit indicators of reliability and informational redundancy, determined the; P_{spor} – limit indicators of the probability of destruction, determined by assets of kinetic destruction or electronic suppression.

The means of kinetic (fire) damage and non-fire suppression and personnel constitute forces and assets that are organizationally and situationally integrated into the units or parts of system.

"Planning" phase

At this stage, according to the results analisis of ability subsystems to perform purpose tasks, the planning of rational distribution of performing task forces and assets in the form of matrix structure is carried out, decide which subsystems should be adapted and how to reorganize for the new task.

Planning of distribution of forces and assets

The assets of the SC solves the problem of rational (optimal) use of available resources to achieve an advantage over the opposing side. The solution of this problem is possible using the theory of energy-information potential distribution P_r in space and time. According to [18]:

$$P_r = F(E_3, E_1, V, N_{A\hat{I}}, T), \text{--------------(13)}$$

Where E_1 - the information resource, determined by the abilities of the assets of obtaining information, the state of their readiness, the degree of automation of processing of reconnaissance information, the training of the service personnel; T - the time parameter that characterizes the cycle of combat control; V - the n-dimensional space of possible use of forces and assets (combat actions); N_{AO} - the set of objects of the destruction, taking into account the priority of the target; E_3 - the aggregate energy potential of the forces and assets that can destruct the enemy, which can be estimated according to the methodology given in [19] or in [20].

In the process of the allocation of the potential in time and space onto the priority targets, the desired level of the potential, which can be realized for the purpose of destructing an opponent at a given point of space, is formed.

Planning of adaptation

At this stage, in accordance with the changes in the conditions of the implementation of the target tasks, a decision is made to change the values of the parameters of the subsystems. Adaptation provides for the possibility of prompt response in the process of functioning of the system to current information about the changing conditions. The essence of the concept of adaptability is to change the parameters, structure and algorithms of the system's functioning on the basis of not only a priori information, but also the current, as well as predicted to achieve or maintain a given functional capacity and efficiency of the system in case of changes in the conditions of its functioning. The formalization of adaptation is reduced to a known equation [6]:

$$F(t) = \Psi F_0(t), \text{----------------(14)}$$

Where Ψ reflects a control mechanism.

Planning of reorganization

The change in the structure of the new tasks (the introduction or removal of individual subsystems that are intended to perform the corresponding processes) can be described by the equation of the balance of needs - opportunities, which we consider the function of the initial data on the size of needs for the neutralization of the threat and the availability of their capabilities:

$$\dot{S}(t)/dt = F(t,a) - D(t,F,a)\text{, -------------(15)}$$

Where $S(t)$ - changing indicators of structure S_i^r; $F(t,a)$ - the flow of resources provided by the external environment to compensate for the threat in S_i^r, by which it adapts to new conditions; $D(t,F,a)$ - output stream of reworked resources from S_i^r (not from F-stream), which it gives to other systems in the form of services, a - elementary process of specified service execution.

In practice this means that during the reorganization there is a process of organizing of new task execution, for which a structure is created.

Conclusion

Thus, the adaptive transformation method of C4ISR cyber informational cycle in crisis situation conditions has researched. Cyber informational cycle laps are described.

The method allows: enhanced C4ISR systems resources usage, operational speed increase. Forces and assets rational distribution task is solved basing on optimization concept.

Practice confirms the possibility of different types of forces and assets uniting in the operational area as well as solving task of their compatibility and creation of situational reconnaissance strike systems on the basis of C4ISR.

The reconciling of the formats and information types of C4ISR components, the development of information processing methods, representation of information for heterogeneous users need additional research.

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