# INTEGRATED COMPUTER–AIDED SAFETY SYSTEMS

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**ABSTRACT**

Integrated Computer–Aided Safety Systems (ICASS) have been developed as a means of ensuring industrial safety. This paper discusses the structure and characteristics of ICASS, and the methodology of constructing and simulating a hierarchical system.

Statistics of large failures in the world show that steady growth in the number of these failures has taken place recently. This tendency is caused by many factors, the main ones of which are: aging of equipment; growth in the number of high power-consuming enterprises; a large risk of heavy failures and extraordinary situations; slow introduction of new information, communication, and organizational technologies; a low level of automation of safety assurance; and backwardness of the normative base.

The latest results, as well as the experience of creating and introducing Computer-Aided Safety and Life-Support Systems, show that the problem of ensuring safety can be solved only on the basis of prevention and liquidation of all threats. Threats against such objects are complex, multi–factor phenomena, which have a discrete–continuous nature and different forms. These threats are characterized by differences in development, as well as an ability to be displayed in various combinations at extraordinary situations. The most dangerous threats are extraordinary situations (fires, failures, accidents, natural calamities, earthquakes, etc.) and threats to functioning of an object (disorganization of work, management, non-authorized access to information, etc.).

The methodological base to solve this problem is the system approach. Its technical realization is the Integrated Computer-Aided Safety System (ICASS).

ICASS consists of the following subsystems: Fire Safety System; Ecological Safety System; Safety System of Extraordinary Situations; Security System; etc.

The purpose of designing ICASS is to create an effectively functioning mechanism that ensures the necessary level of integrated safety (IS) for an object at all stages of its functioning.

Use of the system approach when creating ICASS should ensure complex realization of the following directions: passive methods, ways, and means of protection; automation of the main processes of IS assurance; operative and operative–technical services' activity; and, effective completion of organizing–administrative measures.

ICASSs are intended to reveal and prevent threats, and to liquidate their consequences. ICASS' main tasks are:

- maintenance of the necessary level of safety at all stages of the object's life cycle by revealing, preventing, localizing, and suppressing threats and liquidating their consequences;
- support of effective functioning of hardware to ensure the required level of safety;
- maintenance of effective management of operative and operative–technical services and divisions;
- ensuring of interaction with overhead structures;
- forecasting of extraordinary situations;
- archiving of data about functioning of the system in its attendant regime and during the action of threats;
- providing information and decision–making support to operators and chiefs of operative and operative–technical services, and to the head of the object, by the use of simulation, forecasts of operative conditions, data bases, knowledge, and recommendations; and,
- training of operators and chiefs of services.

ICASSs have the following characteristic features:

- ICASSs are part of Computer–Aided Safety and Life–Support Systems. They are integrated in a uniform complex with safety systems (fire, security, ecological, etc.), and they interact with life–support systems (electricity supply, heating, water supply, etc.).
- ICASS works at all stages of an object's functioning life cycle (designing, construction, putting into operation, operation, modernization, and scheduled liquidation).
- ICASS operates during the whole time of occurrence, development, localization, and liquidation of a danger's consequences.
- The system provides disposed in–depth, multi–stage protection of an object and staff from dangerous factors.
- ICASS has a distributed, multi–level structure, adapted for a particular object and technological process.
- Modules of the system can work both independently and in the structure of other systems. They are

constructed on a uniform programming, technical, and information base whenever possible.

The main principles of the system approach used in ICASS are (Gubanov *et al.* 1988):

- the principle of final purpose (the absolute priority of final, global, purpose);
- the principle of unity (consideration of the system as both a whole and a set of its parts);
- the principle of connectedness (consideration of any part of the system together with its connections to the others);
- the principle of block structure;
- the principle of ability to work independently and in the structure of the system;
- the principle of hierarchy;
- the principle of functioning (joint consideration of structure and functions when the priority of functions is considered);
- the principle of development (keeping records of changes in the system, its development, expansion, replacement of parts, and accumulation of information); and,
- the principle of distribution (combination of centralization and decentralization of management).

The organizational structure of ICASS includes: a command system; a multi–level system of control, containing relatively independent bodies of management at each level; and a system of coordination. One of the main properties of ICASS is its hierarchical structure. It is also impossible to describe on a "physical level" either the processes which take place at extraordinary situations, or the connections between parts of the system. The hierarchical structure of the system is one of its basic attributes, determining the directions of its development as a difficult teleological system, with mutually connected functional elements (bodies of management, subsystems, etc.) distributed by subordinate levels.

The problem of construction of a difficult hierarchical system is largely related to the problem of mathematical simulation of processes proceeding at the objects, and of logical connections between separate interconnected elements of the object.

Matters of decentralization and coordination of decision making are the basis of the methodology of hierarchical models' construction (Chernyishov and Gadzhiev 1983). Hierarchical complexes of management are expedient for solving large dimension tasks, which have a lot of management variables and are intended for large systems. The model of such a system should ensure the replacement of main large dimension tasks by a set of relatively independent lower dimension tasks and coordinate solving them in a uniform global decision for the initial model.

The main features of the mathematical simulation of ICASS' hierarchical structure in the described approach are:

- representation of the command system as a task decisive global model in the sphere of coordination of management bodies' local tasks;
- constructive decentralization of models by introduction of independent and specialized management bodies;
- theoretical–playing representation of interrelations of management bodies;
- introduction of two kinds of management—functional and by levels;
- allocation in hierarchical models of a special system provided by unformalized and automatic coordination;
- generality of ways of solving the problem, based on the principles of coordination; and,
- realization of synthesizing the models and analyzing their conditions.

Another problem of ICASS model creation—a problem stipulated by the impossibility of representing processes, functions, and connections by determined physical models—is solved by computer on the basis of the principle of self–organizing (Ivakhnenko and Yurachkovsky 1987). According to this principle, teleological testing by several criteria is realized of many models of various complexity, and the model with the optimum structure is found.

A possibility of applying this method is caused by the impossibility of creating a "physical model," in which variables and the field of simulation of all elements and connections are defined by a person on the basis of knowledge about the object. The "non-physical model" then used has the following basic features:

- absence of a full information basis;
- partial reflection of the object's mechanism of functioning;
- connection between instant and average values of factors during various intervals of time;
- approximation of a "basic function" by a rather complex function; and,
- absence of a plain, formalized interpretation of processes and connections inside the object.

Thus, simulation of an object's ICASS should largely rely on a methodology based on the use of mathematical models of complex hierarchical systems, and on the principle of self–organizing of the models.

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