REVIEW
of the official reviewer for dissertation work of
Mukhit Zhanuzakov on the theme «Research of fault-tolerance algorithms for reliable information processing» presented for the degree of Doctor of Philosophy (PhD) in the specialty «8D06103 – Computer Science».

№	Criteria	Eligibility (one of the options must be checked)	Justification of the position of the official reviewer
1.	The topic of the thesis (as of the date of its approval) corresponds to the directions of development of science and/or state programs	1.1 Compliance with priority areas of science development or government programs: 1) The thesis was completed within the framework of a project or target program financed from the state budget (indicate the name and number of the project or program) 2) The thesis was completed within the framework of another state program (indicate the name of the program) 3) The dissertation corresponds to the priority direction of the development of science, approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan (indicate the direction)	1) This dissertation was carried out as part of the scientific project AP09259208 entitled «Development of a scalable fault-tolerant information system for enterprise digitalization using Big Data technologies» 0121RK00369 (2021 – 2023) 3) The dissertation corresponds to the priority direction of science development approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan, namely «Advanced Production, Digital and Space Technologies» direction.
2.	Importance for science	The work makes/does not make a significant contribution to science, and its importance is well disclosed/not disclosed	The dissertation makes a significant contribution to the development of modern science in the field of computer science. The obtained results have scientific novelty, as they are aimed at improving fault-tolerance methods in enterprise systems. The importance of the

			conducted research is generally well demonstrated: the author substantiates the relevance of the topic, shows the necessity of solving the set tasks, and outlines potential areas of application for the developed approaches.
3.	The principle of independence	Self-reliance level: 1) High; 2) Medium; 3) Low; 4) No independence	The level of the candidate's independence is assessed as high. In the dissertation, the author independently formulated the aim and objectives of the research, conducted a comprehensive analysis of existing approaches in the field of fault tolerance, and proposed original solutions, including the development of models and algorithms for calculating the optimal checkpoint interval.
4.	The principle of inner unity	4.1 Justification of the relevance of the thesis: 1) Justified; 2) Partially justified; 3) Not justified.	The relevance of the dissertation is fully justified. The study convincingly demonstrates that with the increasing complexity of distributed computing systems, the risk of failures also increases, which necessitates the development of effective methods for ensuring fault tolerance and reliable information processing.
		4.2 The content of the thesis reflects the topic of the thesis: 1) Reflects; 2) Partially reflects; 3) Does not reflect	The content of the dissertation fully reflects its topic. The structure of the work is logically organized and includes all the main elements

			necessary to address the stated research theme: an analysis of existing approaches to ensuring fault tolerance was conducted, new models and algorithms were developed, and their implementation and experimental evaluation in distributed enterprise systems were carried out.
		4.3. The purpose and objectives correspond to the topic of the thesis: 1) correspond; 2) partially correspond; 3) do not correspond	The aim and objectives of the research correspond to the dissertation topic. The formulated aim is focused on the development and analysis of methods for fault-tolerant information processing for distributed systems and enterprise servers, which fully aligns with the research theme dedicated to fault-tolerant algorithms for reliable information processing.
		4.4 All sections and provisions of the thesis are logically interconnected: 1) completely interconnected; 2) the interconnection is partial; 3) there is no interconnection	All sections and provisions of the dissertation are fully interconnected. The work is structured in a logical sequence: from the analysis of existing approaches and identification of the scientific problem to the development of models and algorithms, their implementation, and subsequent experimental validation.
		4.5 The new solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with the known solutions:	In the dissertation, the author conducted a critical analysis of existing solutions, methods, and

		1) there is a critical analysis; 2) partial analysis; 3) the analysis does not represent one's own opinions, but quotes from other authors 4) the analysis is absent.	approaches. A comparison of various scientific results is presented, and their advantages and disadvantages are identified. Based on this analysis, the feasibility of the proposed new solutions is justified, and these solutions logically follow from the reviewed material.
5.	Scientific novelty principle	5.1 Are the scientific results and provisions new? 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The scientific results and provisions of the dissertation are partially novel. A significant part of the obtained results contains elements of novelty expressed in the modification and development of existing approaches to reliable information processing, as well as in the proposal of new solutions.
		5.2 Are the dissertation findings new? 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The conclusions of the dissertation are fully novel. In particular, the novelty is reflected in the integration of an empirical model and an optimal algorithm based on queuing theory, as well as in the results of experimental evaluation of their effectiveness in distributed enterprise systems. The obtained conclusions refine and further develop existing scientific concepts, but do not form a completely new theoretical foundation.
		5.3 Technical, technological, economic or management decisions are new and reasonable: 1) completely new;	The presented dissertation contains scientifically substantiated technical and technological solutions with a

		2) partially new (25-75% are new); 3) not new (less than 25% are new)	high degree of novelty. The author proposes original algorithms and a model for calculating the optimal checkpoint interval based on queuing theory, which have undergone both theoretical and experimental validation.
6.	The validity of the main findings	All main conclusions <u>are</u>/are not based on scientifically significant evidence or well-grounded (for qualitative research and areas of training in the arts and humanities)	All main conclusions of the dissertation are based on scientifically sound evidence and are sufficiently well-founded. The reliability of the results is confirmed by the use of theoretical, analytical, and experimental research methods, as well as by their testing in both simulated and real-life-like conditions.
7.	The main provisions for the defense	It is necessary to answer the following questions for each provision separately: 7.1 Is the provition proven? <u>1) proven;</u> 2) rather proven; 3) rather not proven; 4) not proven 5) in its current wording, it is impossible to verify whether the statement has been proven. 7.2 Is it trivial? 1) yes; <u>2) no</u> 3) in its current wording, it is impossible to verify whether the statement is trivial. 7.3 Is it new? <u>1) yes;</u> 2) no	7.1 Provenness — 1) proven. 7.2 Triviality — 2) no. 7.3 Novelty — 1) yes. 7.4 Level of application — 3) wide. 7.5 Provenness in the article — 1) yes.

		3) in its current wording, it is impossible to verify the novelty of the statement. 7.4 Application level: 1) narrow; 2) medium; 3) wide 4) in its current wording, it is impossible to determine the scope of application of the statement. 7.5 Is it proven in the article? 1) yes; 2) no 3) in its current wording, it is impossible to verify whether the statement has been proven in the article.	
8.	The principle of reliability Reliability of sources and information provided	8.1 Choice of methodology - is justified or the methodology is described in sufficient detail 1) yes; 2) no	Yes. The choice of methodology is well-founded and described in sufficient detail. The work applies a comprehensive approach, including theoretical analysis of fault-tolerance algorithms, modeling of distributed systems, as well as the development and experimental validation of the proposed algorithms.
		8.2 The results of the thesis were obtained using modern methods of scientific research and methods of processing and interpreting data using computer technologies: 1) yes; 2) no	Yes. The results of the dissertation were obtained using modern scientific research methods. In particular, methods of algorithmic design were applied, as well as experimental studies using computer technologies. Data processing and interpretation were carried out based on distributed system modeling and comparative

			analysis of the efficiency of the proposed algorithms under different load and failure scenarios, which complies with modern requirements for scientific research in the field of computer science.
		8.3 Theoretical conclusions, models, identified relationships and patterns have been proven and confirmed by experimental research (for areas of training in pedagogical sciences, the results have been proven on the basis of a pedagogical experiment): 1) yes; 2) no	Yes. The theoretical conclusions, developed models, and identified patterns in the dissertation are well-founded and confirmed by the results of experimental research. Modeling and testing of the proposed algorithms were carried out under various conditions, including distributed systems close to real-world environments, and a comparative analysis with existing solutions was performed, which confirms the reliability of the obtained results.
		8.4 Important statements are confirmed / partially confirmed / not confirmed by references to current and reliable scientific literature	The key provisions and statements of the dissertation are based on an analysis of modern and relevant scientific literature in the fields of fault-tolerant systems, distributed computing, and queuing theory. The work presents a review of existing approaches, identifies a research gap, and appropriately uses scientific sources, which confirms the reliability and validity of the conclusions drawn.

		8.5 Used literature sources are <u>sufficient</u>/not sufficient for a literature review	The volume and content of the sources used are sufficient for conducting a high-quality literature review. The work covers key research areas in fault-tolerant systems, distributed computing, and related fields, which made it possible to reasonably identify the research gap and correctly position the obtained results.
9	Practical value principle	9.1 The thesis has theoretical value: <u>1) yes;</u> 2) no	The study significantly extends existing theoretical understanding of fault-tolerance mechanisms by introducing approaches that take into account dynamic parameters, such as variable computational load and the frequency of failures.
		9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice: <u>1) yes;</u> 2) no	Yes. In the course of the research, concrete algorithms for reliable information processing in distributed enterprise systems were developed and implemented in software. The proposed methods underwent comprehensive testing not only in simulated environments but also in physical environments close to real operating conditions. The application of the proposed queuing theory-based algorithm made it possible to achieve system availability of up to 96.27% and improve overall efficiency by 3–4% compared to traditional approaches.

		9.3 Are the practice suggestions new? 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	Partially novel (25–75% are new). The proposed practical applications are partially novel and can be integrated into existing enterprise systems. Their novelty lies primarily in the application and integration of fault-tolerance methods to ensure reliable information processing, which overall increases the reliability of system operation.
10.	The quality of writing and design	Academic writing quality: 1) high; 2) average; 3) below average; 4) low.	The dissertation text is characterized by professionalism, academic rigor, and clarity of presentation, which fully meets the requirements for doctoral dissertations.
11.	Notes on a thesis	Notes on the thesis: Structure and coherence of presentation. Overall, the structure of the dissertation is logically organized; however, in certain sections there is either excessive detail or, conversely, insufficient coherence between subsections. Terminological consistency. In some cases, synonymous terms are used to denote the same concepts. There are also occasional inconsistencies in the use and interpretation of key terms across different sections of the work, which may lead to ambiguity in understanding the presented results. The above comments are of an advisory nature and do not affect the overall positive evaluation of the dissertation research.	

12.	Scientific level of the doctoral student's articles on the topic of research (in case of defense of the dissertation in the form of a series of articles, the official reviewers comment on the scientific level of each article of the doctoral student on the topic of research)	The scientific level of the doctoral candidate's articles on the research topic meets the requirements set for publications in the profile of the dissertation work.
13.	Decision of the official reviewer (pursuant to paragraph 28 of the present Model Regulations)	I consider Mukhit Zhanuzakov to be worthy of the degree of Doctor of Philosophy (PhD) in the specialty «8D06103 – Computer Science»

Official Reviewer:
International Information Technologies University
Department of Information Systems
Doctor of Technical Sciences,
Research Professor **Naizabayeva L.**

Подпись указанного лица удостоверяю