INTERNATIONAL WORKSHOP «REGULATORY FRAMEWORK OF DECOMMISSIONING, LEGACY SITES AND WASTES FROM RECOGNITION TO RESOLUTION: BUILDING OPTIMIZATION INTO THE PROCESS»
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The human factor problem in SNF and RW management: ways to solve the problem and implementation practice

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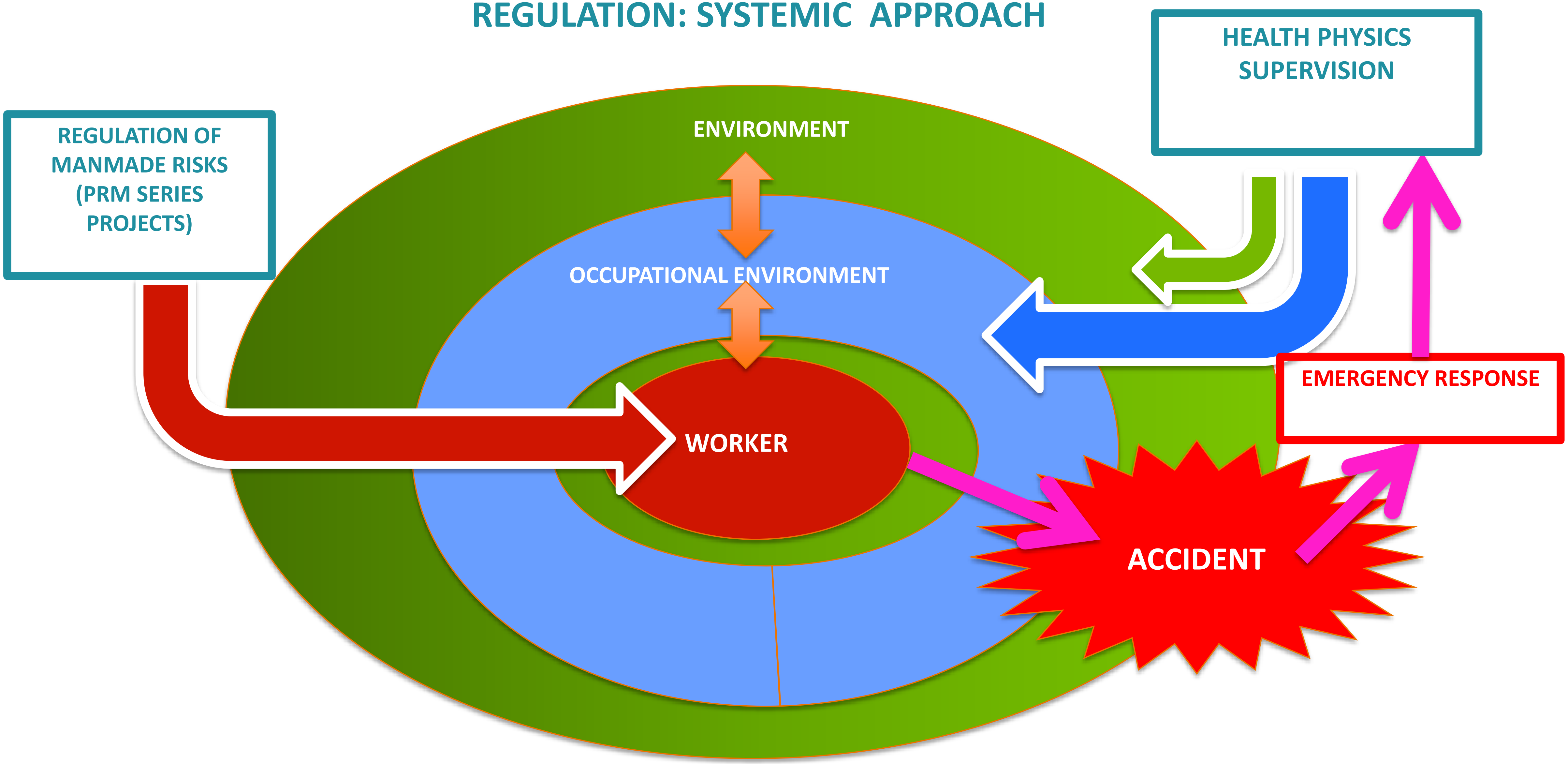
REGULATION: SYSTEMIC APPROACH



Human Factor (HF) - is a complex of psycho-physiological, psychological and physiological characteristics of human behavior in the work environment. (IEA is a federation of 42 individual ergonomics organizations from around the world).

The HF effect is manifested in the following areas:

- reliability of the worker in connection with the requirement to ensure safe and economical work, which leads to the need to identify these features;

- monitoring of human cognitive functions, manifested in the processing of information and decision-making in normal and emergency situations;

- expanding the potential range and increasing the possibilities of improving the human-machine interface, which requires the advanced methods and knowledge that would allow to identify problems and make adequate decisions.

The developments were carried out within the framework of the legal field of the Russian Federation taking into account the existing international experience, most of which is reflected in the documents of the NRC (Nuclear Regulation Comission) and IAEA. High attention was paid to analysis (in relation to the tasks to be solved) of the INSAG (International Nuclear Safety Group) reports, technical reports and documents of the TECDOC and NUREG series, including reports or brochures on regulatory decisions, research results, results of emergency investigations and other technical and administrative information.

In the list of the units of the HF control NRC programme, researchers at this stage focus on expanding the potential range and increasing the possibilities for improving the human-machine interface, which requires the advanced methods and knowledge to identify problems and make adequate decisions. A striking example of the approach is an empirical study of HRA to evaluate the predictions of the HRA method regarding the work of the crew on a simulator of US nuclear power plants (NPP) with the participation of 5 countries.

The goal is to improve the understanding developed on the basis of the international empirical study of HRA conducted previously in Norway at the Halden reactor (IFE) and consider its limitations. The effectiveness of various HRA methods was assessed by comparing forecasts with actual crew performance in simulated accident scenarios conducted in the NPP simulator.

The most used methods of the HF analysis (HFA) are methods and models, which take into account conditions (context) during the task execution to determine the probability of system failure :

THERP, SBDT, HEART, NARA, TRC,CREAM, HDT, SLIM , ATHEANA, and IDHEAS. However, these models do not provide an opportunity to cover all aspects of the operator’s activities that affect the reliability of the human-machine system, and their inconsistent implementation by analysts is the most common source of variable HFA results.

An international empirical study comparing the HFA forecasts of various analysts and methods with observing the performance data of European crews was conducted at the HRP HAMMLAB (Halden Reactor, Norway) in training classes. It revealed the important strengths and weaknesses of the various HFA methods used.

Conclusion: the HFA methods can be enhanced through improvement in terms of the qualitative analysis carried out by these methods.

Like the International Study, the United States evaluated the effectiveness of various HFA methods by comparing the method forecasts with actual crew characteristics in simulated accident scenarios conducted on a NPP simulator.

Outcome: significant agreement was reached in the conclusions and findings drawn in international and American studies in terms of assessing the strengths and weaknesses of HFA methods (**NUREG-2156,** 2016)

A traditional safety analysis is based on the mathematics and principles of the classical theory of reliability. In the theory of reliability, a number of indicators are determined: mean time between failures, average time between failures, failure rate, etc., until recently recognized as sufficient for reliability analysis, and with regard to the HF.

To carry out assessments on the reliability and safety of hazardous nuclear and radiation facilities and technologies of the IAEA, 1993 (INSAG-6), it is recommended to determine the relative failure and accident rates during long-term tests using the same methods, which is the core of the Probabilistic Safety Analysis (PSA) Methodology, which “has acceptable accuracy and practical significance if all its limitations are met”.

Nevertheless: “Failures” in situations involving the HF are far from always linked to the classical theories of reliability and safety, which theoretically mean the inevitability of an accident.

NRC considers HFA as part of a complete probabilistic risk assessment (PRA). HFA seeks to assess the potential and mechanisms of human error, which may affect the safety of a nuclear facility. Activities in the nuclear field are considered safe if the risks arising from this activity are considered acceptable. Hence, there are grounds for "information on the monitored values normalized".

HFA is defined mainly as the use of a synthesis of systems engineering and behavioral sciences by **phenomenological** and **deterministic methods.** This is a serious obstacle to the direct application of PSA to assess the contribution of the HF to the safety of hazardous facilities.

Although the inclusion of HF in risk analysis is an important advantage of PSA, it is necessary to take into account the limitations applicable to the use of this methodology, where all calculations are “based” on an event tree whose sequential chain is valid only if all elements of the tree equally affect safety.

The vulnerability of these representations is shown in the examples of fairly correct models. For example, the most common model with a sequential tree of events, in principle, does not allow optimizing an object, since when additional safety systems with the highest rates are included in such a model, the final reliability will not exceed the lowest reliability of one of the elements.

The human’s reliability is determined by an inverse relationship, thanks to countless compensatory adjustments involving additional elements.

Features of the manifestation of the human factor:

- Individual safety culture level;
- Professional training;
- team psychological incompatibility;
- unsatisfactory current functional state.

All kinds of combinations of these features create an immense count of the many possible actions of the personnel leading to situations of failure.

Conclusion: PSA and proposed models with a sequential tree of events are not suitable today for the correct analysis of the safety of nuclear and radiation hazardous facilities. There are no methods and / or models allowing to obtain reliable results with a fairly narrow range of uncertainties.

In general, the reliability of the human operator in the OTC is due to three main factors (Oak Ridge, USA):

- the correspondence of the psycho-physiological capabilities of the operator to the engineering and psychological requirements imposed by the technical elements of the OTC for a person to solve the problems he faced;
- level of qualification, training and **commitment** of the operator **to safety culture** to perform these tasks;
- his psycho-physiological data, in particular, features of the central and autonomic nervous system, thresholds of sensitivity, health status, psychological characteristics of the operator's personality.

Thus, the reliability of the operator in the OTS should be considered not only as a function of the tasks arising from him and the technical conditions in which they are solved, but also as a function of his individual qualities.

Conclusion: the reliability of the human operator, which depends on many factors, should be determined by the interaction of these three main components.

Reducing manmade risks within the framework of the medical and psycho-physiological support system for the personnel of radiation and nuclear hazardous facilities

Preserving the health and professional longevity of the personnel

↑

Medical and psycho-physiological support for professional reliability of the personnel

↓

Ensuring safe operation of the enterprise by reducing manmade risks

The main results of work on the assessment and control of manmade risks in the framework of completed contracts with the DSA

1. A prototype of an expert diagnostic information system for monitoring the risk of professional reliability violation of workers involved in the management of SNF and RW (PRM project)
2. Methodology for assessing the safety culture of the NWC SevRAO facilities (PRM2)
3. A prototype of a hardware-software training complex based on interactive simulation training games with biological feedback in a virtual environment (PRM3, PRM4).
4. Hardware-software complex and guidelines for pre-shift monitoring of the psycho-physiological state of workers involved in the management of SNF and RW (PRM5)

Ways are proposed to increase the reliability of workers by applying a "proactive" approach and advanced technologies in three directions :

1. Periodic and pre-shift psycho-physiological examination of the personnel in order to find persons with reduced psycho-physiological adaptation;

2. Improving the quality of professional training of operational personnel, using adequate informational training models, which helps to reduce psycho-physiological prices and uncover reserves of the body, increase its stress resistance, maintain and develop professional forms of activity of the worker.

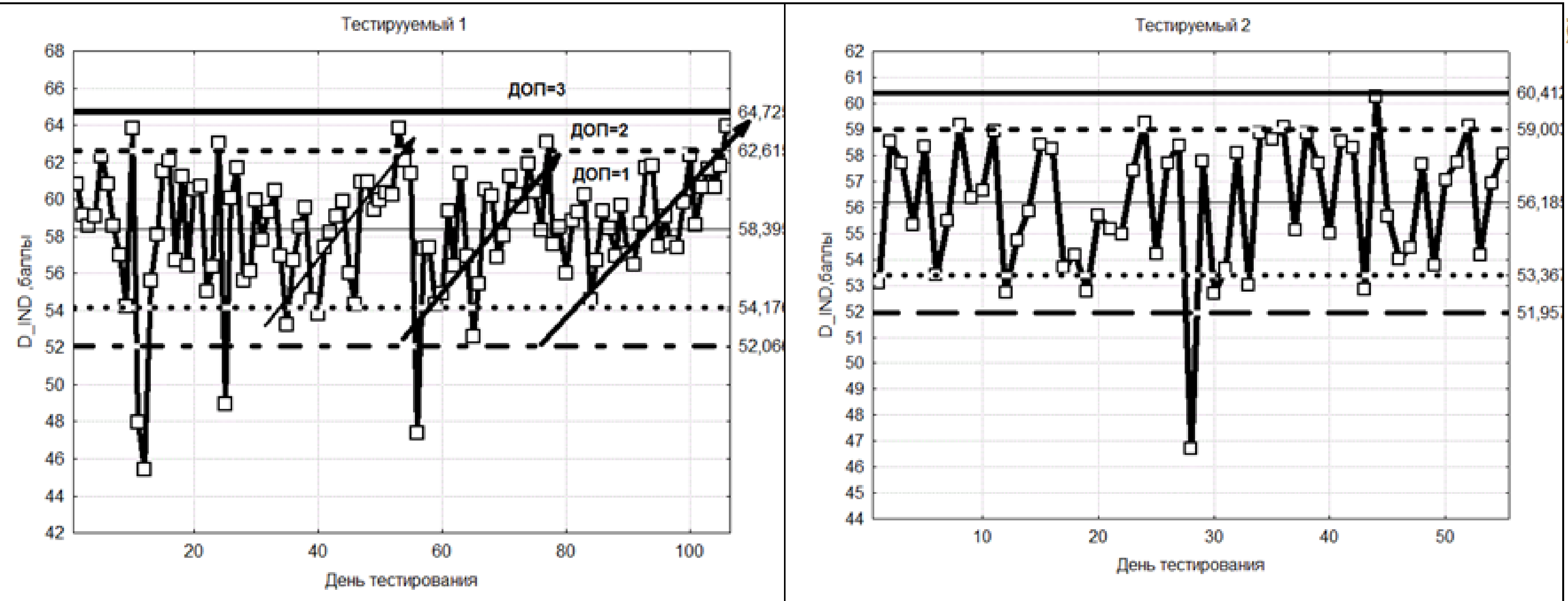
3. The introduction of progressive forms of management through a safety culture, providing for its quantitative assessment at the individual level and the level of management of the facility;

The data on the effective use of "vibra-technology" to solve the main problems in the framework of these areas are obtained.

DEVELOPMENT OF REMOTE MEANS, METHODS AND CRITERIA FOR THE MONITORING OF THE PROFESSIONAL RELIABILITY OF THE PERSONNEL OF FACILITIES FOR THE SPENT NUCLEAR FUEL AND RADIOACTIVE WASTE MANAGEMENT

1 The development of model sample of hardware-software complex for pre-/post-shift monitoring (HSC “SMENA”) and its deployment on the basis of NWC SevRAO

General view of the HSC “SMENA” during the testing


Тестируемый 1
ДОП=3
ДОП=2
ДОП=1
64,72
62,61
58,39
54,17
52,06
D_IND ,баллы
День тестирования
Тестируемый 2
60,41
59,00
56,18
53,36
51,95
D_IND,баллы
День тестирования

а

б

The psycho-physiological simulator SHC “TIBUR_TSP”

Laboratory studies using the psycho-physiological simulator SHC "TIBUR_TSP" to assess behavioral responses on the basis of the vibraimage parameters

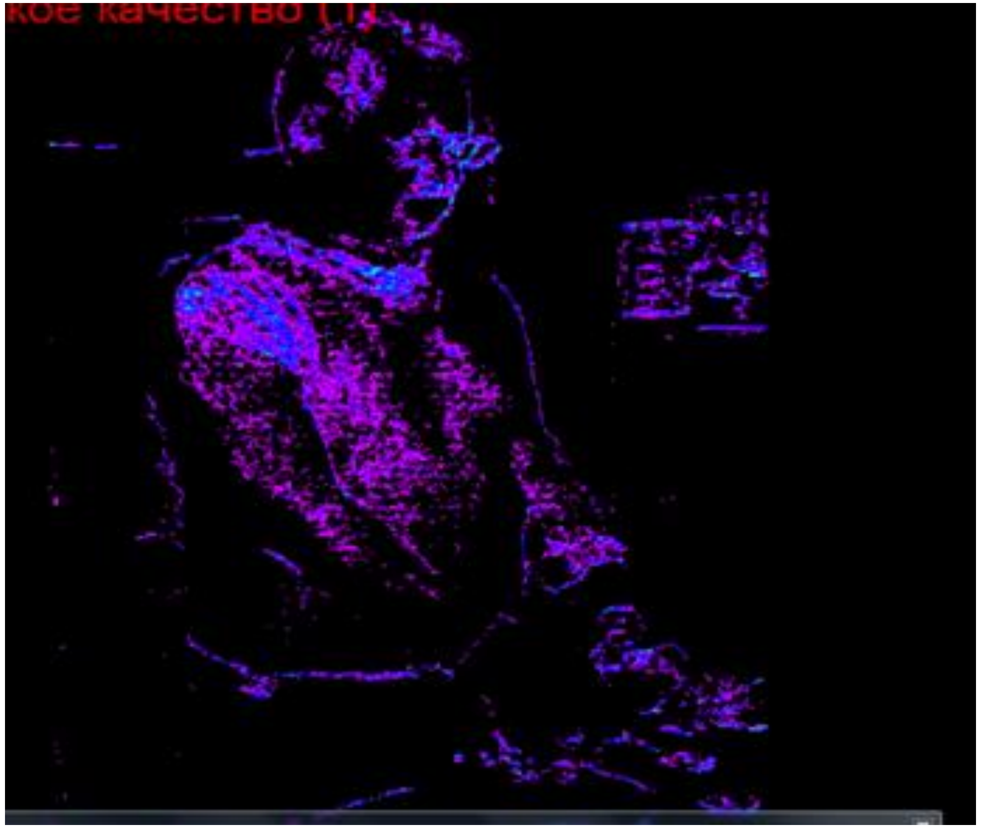
1 – WEB-camera, 2 – camcorder Panasonic HC-V770

OPERATOR'S WORK MODES:

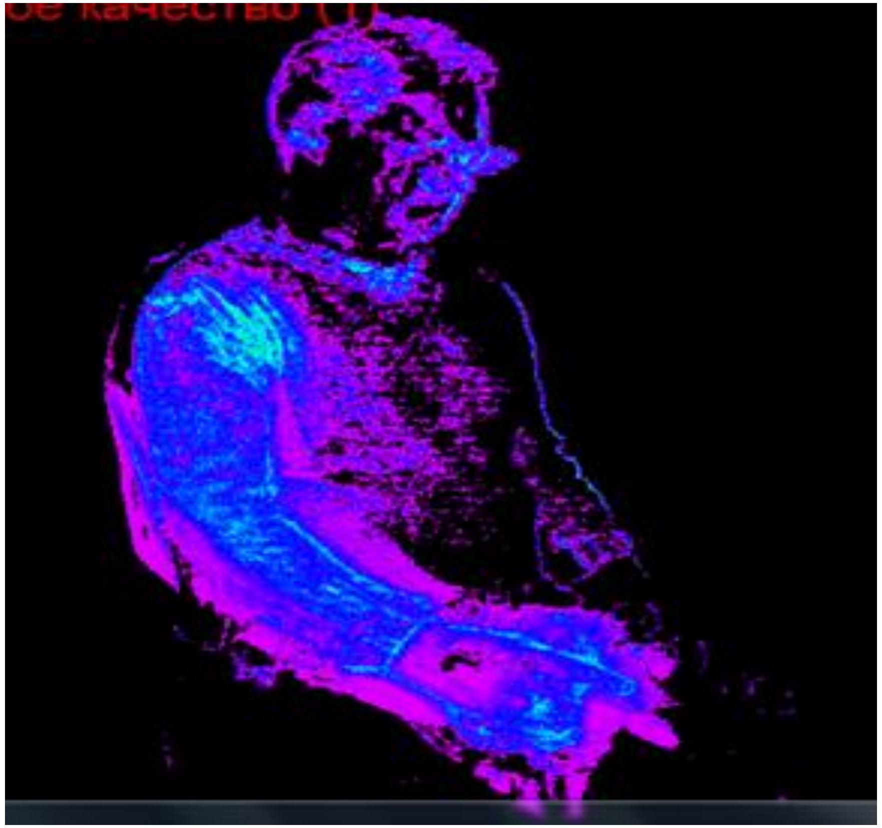
- **BACKGROUND_MODE**
- **STRESS_MODE**

118 Persons / studies

Vibrogram during the motion displaying



Low activity of motions



High activity of motions

Relationship between parameters of macro image of the body and micro image of the face of students / testees

Parameters of the face micro image	Root 1
Stressing level, UR_STRESS, rel.un.	**0.70**
Stability level UR_STAB, rel.un.	-0.45
Activation level UR_ACT, rel.un.	-0.49
Self-regulation level UR_SAM, rel.un.	-0.12

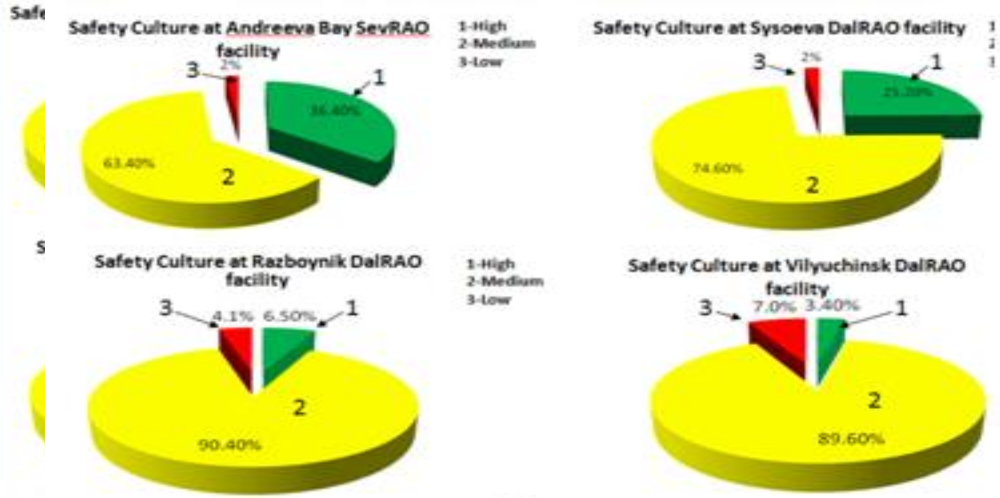
R=0.84 (p=0.00001)

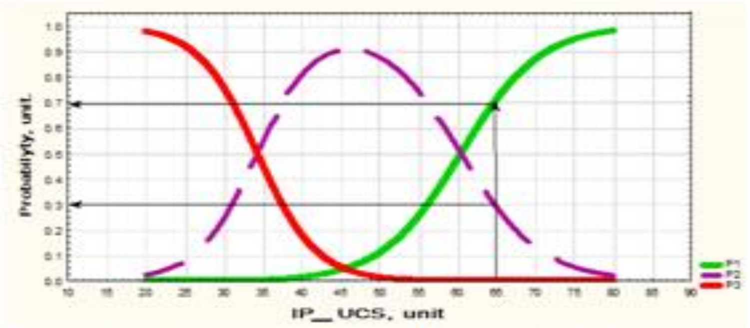
Parameters of the body macro image	Root 1
Integrated amplitude of motions A, rel.un.	**0.77**
Integrated frequency of motions F, rel.un.	0.43
Integrated symmetry of motions S, rel.un.	0.31
Integrated dispersion of motions P, rel.un.	0.31

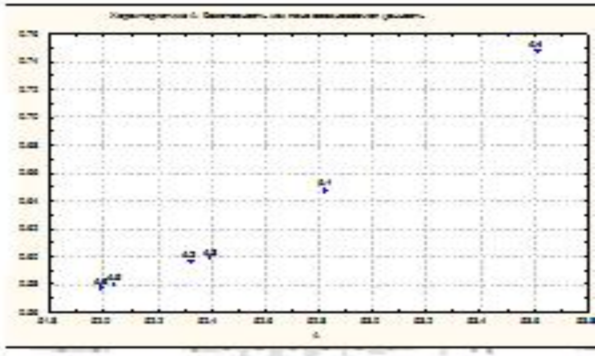
THE FACTOR STRUCTURE OF THE CANONICAL VARIABLES (ROOT 1) OF THE VIBRO-IMAGE PARAMETERS AND THOSE OF ELECTRO-PHYSIOLOGICAL SIGNALS (R=0,85)

Vibro-image parameters	Root 1
UR_STRES, rel. unit	0.984
UR_STAB, rel. unit	0.246
UR_ACT, rel. unit	-0.243
UR_SAM, rel. unit	-0.088
Parameters of electro-physiological signals	Root 1
St Dev RR – Standard Deviation of RR	-0.60
HR – Heart rate	0.33
RSA – Respiratory Sinus Arrhythmia	-0.50
SC – Skin conductivity	0.71
Ln SC – Logarithm Skin conductivity	0.60
GSR – Galvanic skin response /frequency of Galvanic skin responses	0.66
GSR Amplitude – Amplitude of Galvanic skin response	0.10
BrR - Breathing Rate	-0.39
Resp. dur. – Respiration cycle duration	0.23
Rio – inhale/exhale ratio	-0.19
Freq. of BrR - Frequency of Breathing Rate Mode	-0.32
NNbc – Number of cardiac cycles per breath cycle	0.40
IEMG – Integral value of electromiogram (EMGint) 1, μv	-0.11

The pilot version of the software to assess the safety culture
(Project PRM2)







IP_UCS=0.34*A+0.16*B+0.10*C+0.25*D+0.14*E, scores

where A, B, C, D, E – score estimates above the described indicators SCART «Safety is a clearly recognized value», «Leadership for safety is clear», «Accountability for safety is clear», «Safety is learning driven», «Safety is integrated into all activities».

Thank you for your attention!