MEDICAL ASPECTS OF EXTREME ENVIRONMENTS: SPACE EXPLORATION AS A MODEL FOR OTHER EXTREME ENVIRONMENTS

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ENVIRONMENTAL AND TECHNOLOGICAL HEALTH AND SAFETY INDUCED RISKS

(MEDICAL APPROACHES TO MODERAION OF ENVIRONMENTAL INDUCED RISKS)

- **Extreme environments are a factor in the risk of destabilization of human state, deterioration of health, wellbeing and ability to work, and degradation of reliability within the control systems.**
- **In the process of evolution, natural protective-adaptive reactions to extremities of the outer world have been developed.**
- **In relation to some of the technological induced risks (ionizing radiation, noise, dynamic flight factors), the human organism lacks natural mechanisms of adaptation. Medical approach to reduction of this type of risks has been formulated on the basis of the anthropocentric concept (equipment must serve and not do harm to humans). Technical approach sometimes opts for using less effective but then cheaper technical means of protection, as for instance, to abate noise. The outcome can be the risk of impairment of hearing.**
- **Hence, risk as a probability of hazardous consequences can stem either from absence of appropriate protection measures or their expensiveness. From the medical standpoint, risk should be kept as low as possible by way of using engineering solutions which will be best in the context of both effectiveness and costs.**
- **Medical approaches to technological induced risks can be illustrated with the case of space flight.**

EVIDENCE-BASED POLICY FORMULATION

(MEDICAL APPROACHES TO THE INVESTIGATIONS OF SPACFLIGHT EXTREMITIES)

Theoretic base for investigations: ***Classical physiology, biology, psychology, hygiene, clinical disciplines; concept of the organism-environment interaction; homeostasis and adaptation doctrines; modeling, prediction and control theories.***

Adoption of experience ***gained by aviation, marine and sports medicine in crew selection and training, and protection against stresses.***

Construction of the hypothesis: ***Prognosis by E.K. Tsiolkovsky of changes in behavior, structure and functions of living organisms in microgravity and coping methods.***

Investigations with animals: ***50s of the past century marked the beginning of a series of experimental studies with animals during vertical launches of geophysical rockets, and flown aboard artificial Earth's satellites and then biosatellites (V. Yazdovsky, O.Gazenko, A.Genin, Eu. Ilyin et al.).***

Ground-based investigations with volunteered subjects: ***Since 60s, human subjects have been routinely investigated for reactions to g-loads (P.Suvorov, A.Kotovskaya, A.Barer), simulated microgravity (L.Kakurin, A.Genin, I.Pestov, V.Mikhailov et al.), isolation and confinement of space vehicle mockups (L.Khachaturiants, V.Smirnov, V.Baranov et sl.) and other factors.***

Investigations in piloted space flights: ***Starting with Gagarin's flight, these investigations have always been part and parcel of flights of varying (up to 438-d mission of V.V.Polyakov) length до 438-суточного полета В.В.Полякова) within the national and cooperative with international partners programs (leads: V.I. Yazdovsky, A.M. Genin, V.V. Parin, O.G. Gazenko, A.I. Grigoriev).***

FACILITATORS (INFRASTRUCTURE, ORGANIZATIONS)

(MANAGEMENT OF RESEARCH AND EXPERIMENTAL DEVELOPMENT EFFORTS – ER and RDE)

Leading medical organizations: Till 1964 – Institute of Aviation and Space Medicine, USSR Ministry of Defense; since 1964 – Institute for Biomedical Problems, USSR/ Russian Ministry of Health (at present – Russian Academy of Sciences).

Partners: Gagarin Crew Training Center, plants Zvezda, Biofizpribor, Vympel and others.

Stakeholders (RE and RDE customers and buyers):

- **Rosaviakosmos, RSC-Energia, TsNIIMASh:** ***Development of methods and means for reliable and safe crew functioning in flight (board systems of life support, medical monitoring, countermeasures, rescue in emergency; crew operations planning, telemedicine), and programs of biomedical investigations and associated payloads;***
- **Ministry of Health:** ***Development of a system for crew medical support on the phase of pre-flight training, during and after space flight (crew selection, training, therapeutic and preventive care, sanitary-hygienic standards, in-flight work/rest schedule, and post-flight rehabilitation);***
- **Ministry of Science, Industry and Technologies:** ***Sponsoring new scientific developments applicable to space biology and medicine, biotechnology, diving and caisson works;***
- **Russian Academy of Sciences:** ***Fundamental investigations in the fields of physiology, psychology, biology, ecology, biomedical aspects of the healthy life-style;***
- **International partners:** ***Support to implementation of research programs.***

CLASSIFICATION OF SAFETY AND HEALTH RISKS

(CLASSIFICATION OF EXTREME FACTORS IN THE FOCUS OF THE INSTITUTE FOR BIOMEDICAL PROBLEMS)

- **Factors associated by the spaceflight dynamics:** ***microgravity, g-loads (long-acting and shock loads), accelerations (linear and angular), vibration;***
- **Factors associated with physical characteristics of the space environment:** ***ionizing radiation, space vacuum and temperature gradients, especially topical during extravehicular activity;***
- **Factors linked with the physiological-hygienic and sociopsychological constraints of living in closed space:** ***possible deviations of the environmental parameters (chemical, biological, acoustic) from their normal ranges, stressful agents (isolation, limited social contacts, responsibility for mission success);***
- **Professionally conditioned factors:** ***inadequate crew time planning, violations of the work-rest schedule, professional risks, implementation of physically and mentally demanding operations;***
- **Exposure to changed air composition and barometric pressure** ***during diving and caisson works that may compromise health and performance and give rise to an occupational pathology.***

EMPHASIS ON "HEALTH AND SAFETY"

(RISKS FROM EXPOSURE TO EXTREME FACTORS)

- **Potential hazard to flight safety, crew life and health** ***due to emergency conditions, failure of the orbital life support systems and resultant departure of the physical, chemical and biological parameters of the crew environment from their standard values, and appearance of somatic and mental diseases in the crew;***
- **Hazard to the crew health and wellbeing** ***in consequence of unfavorable changes in their physical and mental state such as symptoms of motion sickness, vestibular dysfunction, shifts in the anti-gravity and gravity-dependent systems, decline of the physical performance, endurance of gravity-related and stressful factors which is particularly pronounced in the post-flight period.***
- **Hazard to the crew professional effectiveness** ***from rearrangement of mechanisms of spatial analysis, motor skills, general aesthenization, and fatigue preconditioning loss of useful skills, slow data processing, erroneous actions and corrosion of reliability of the human as part of the hardware control systems.***
- **Risks of occupational diseases among divers and caisson employees.**
- **Investigations of the effects of extreme environments** ***are setting the stage for successful resolution of the extreme medicine issues; however, they are also a source of risks and require protection of human subjects in accordance with relevant biomedical ethics regulations.***

EXPERIENCE BASED POLICY FORMULATION

(RUSSIAN EXPERIENCE IN PROTECTION AGAINST THE SPACEFLIGHT EXTREMITIES)

Main aspects of the protection policy development were the following: *prevention of the negative effects of microgravity, anti-g protection, psychological support, prophylaxis and treatment during space flight.* Below is a summary of the key principles of preventing the adverse consequences of exposure in microgravity.

- **Based on experimentally proven conclusions that adaptation to microgravity is accompanied by deadaptation to the gravity loads, it was proposed to stabilize cosmonauts' health by means of speeding up adaptive processes at the beginning of space flight, suppressing deadaptive reactions in the middle and stimulating recovery of the anti-gravity functions at the end of space flight, and implementing a readaptation program on return.**
- **The complex of measures executed in the pre-flight period (vestibular and anti-orthostatic desensitization training), during (physical training and wearing the loading suits) and at the end of flight (LBNP training, water-salt supplements to the diet), and use of the anti-g suit on the phase of descent and on return notably dampened effects of microgravity and secured crews in missions with increasing duration. Russian experts made this experience available to the international partners.**

BIOETHICS OF RESEARCHES OF EXTREME EFFECTS

(BIOETHICS OF THE INVESTIGATIONS INTO THE EXTREME EFFECTS)

- **Investigations of the effects of extreme environments must be conducted in compliance with the bioethic regulations.**
- **Before 1993, investigations in the field of space medicine had been planned and made following the basic principles of the Nuremberg Code and the Helsinki Declaration (voluntariness, the right to refuse to participate in an experiment or terminate ahead of time etc.); however, there was no requirement of an independent bioethic review.**
- **Enactment of the Basics of the Russian Federation Health Protection Legislation in 1983 and the necessity to unify national and international policy of biomedical investigations in space flights led to establishment of the independent Biomedical Ethics Committee (BMEC) at the Institute of Biomedical Problems (IBMP). Professor A.M. Genin, the outstanding figure in space medicine, was the first BMEC chairman.**
- **BMEC has been entrusted to review protocols of laboratory and in-flight biomedical investigations with human subjects and animals and to give the opinion regarding compliance of proposed investigations with the biomedical ethics standards and regulations.**
- **In connection with expansion of the international cooperation in space biomedicine, the Charter of Human Research Multilateral Review Board (HRMRB) was developed and concurred by all ISS partners at the end of 90s which establishes the procedures of reviewing experiments proposed to fly on the ISS. These procedures have proven their effeciency in 7 ISS increments.**

DESIRED OUTCOMES AND IMPACTS

By the example of the medical approaches to protection against extreme factors of space flight, there is good reason to derive the following general CONCLUSIONS**:**

- **Extreme natural and technical environments cause risks of human state destabilization, debilitation of health, wellbeing and performance and, therefore, degradation of equally human reliability and efficiency within the hardware control systems and safety of a particular operator or a whole crew.**
- **Investigations aimed at minimization of the risks from extreme effects are morally justified and eligible investments as they make for enhancing human-operated equipment, ensuring safety, health and professional longevity of employees working in extreme conditions.**
- **Medical approaches to protection against extreme factors should account for medical requirements and guidelines concerning the life and work of personnel engaged in extreme occupations, convincing substantiation of preventive strategy, development of adequate methods and means and associated regimens, verification of countermeasures during simulation of extreme factors with observation of the principles and standards of the biomedical ethics.**