

**МЕДИКО-БИОЛОГИЧЕСКИЕ ПРОБЛЕМЫ.
ЭРГОНОМИКА И ЧЕЛОВЕЧЕСКИЙ ФАКТОР**

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**MEDICAL AND BIOLOGICAL PROBLEMS.
ERGONOMICS AND HUMAN FACTOR**

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12.1. DRUGLESS REHABILITATION USING BIOFEEDBACK METHODS ON THE BASIS OF REHACOR™ SYSTEM

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Early diagnosis of regulatory abnormalities caused by stresses of extreme situations, informational overload or social conditions and their correction, where possible, by non-medicamentous methods present an actual task of today's health care. An efficient solution to this task may be provided with "REHACOR" Rehabilitative Biofeedback System produced by Medicom-MTD, Ltd. and intended for conducting Functional Bio-Control (FBC) procedures based on Biofeedback (BFB) principle. FBC methods are efficient in the body control and homeostatic dysfunctions due to overstrain and fatigue or in various functional and organic abnormalities. The provided biofeedback sessions can be indicated for correcting first manifestations of arterial hypertension, for improving the autonomic dysfunctions, in treatment of vision, locomotor disorders, etc. The computer multimedia used in biofeedback procedures provide flexible representation both of original physiological signals and biofeedback results and of biofeedback targets in the form of histograms, plots, images, sounds and games delivered by computer graphic and sound synthesis tools. Efficient biofeedback software allows to choose an optimal set of physiological parameters and visualization forms when arranging a biofeedback loop and to select an individual biofeedback strategy for each patient,

The convenience of using the biofeedback procedures is additionally enhanced due to automatic adaptation of the procedures to every individual patient. The instructor can easily change the content of biofeedback procedures depending on age, intellect and preferences of the patient. These features are aimed at increasing the patient's motivation to biofeedback training, towards achievement of maximal results using a minimal number of procedures. There are tools to monitor the success of a single session or the entire rehabilitative course based on dynamics of physiologic indices and various success factors displayed as tables and plots.

REHACOR software can also be used with other systems produced by Medicom-MTD, Ltd. company (such as "Rehacor" patient module, electroencephalographs, rheographs, etc.). Thus, REHACOR enables the full cycle "Diagnosis-Treatment-Monitoring", allowing for wider and deeper use of advanced biofeedback methods for drugless correction and rehabilitation of a variety of conditions in a wide clinical practice.

12.2. ADAPTIVE MODEL OF OPERATOR'S ACTIVITY IN CONSISTENCE OF REHABILITATIVE PSYCHOPHYSIOLOGICAL SYSTEM "REHACOR" AS THE TOOL OF ESTIMATION OF OPERATOR'S PSYCHOPHYSIOLOGICAL STATE

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In this paper depicted complex designed for studying of psychophysiological state of the person while performing combined operator's activity. This complex was designed in cooperation by ergonomics chair of Moscow State Aviation Technological University and Medicom-MTD Ltd. (Russia, Taganrog) using combined operator's activity model. This model implies the whole of two tasks: logical task that is connected with solving mathematical problem in determined time range and motor activity task – keeping viewfinder in required region. Adaptability of this tasks is consist in the increasing of complexity of tasks in case of successful execution, and decreasing in other case – this allows to make operator work at the peak of his functional abilities by each informational channel. Model allows monitoring of a number of indices which can illustrate quality of work. This instrument was developed in addition for mainstream device “REHACOR”. This complex was designed for functional biocontrol based on biofeedback method, and it allows monitoring of huge amount of physiological signals. Experiments that were hold have shown wide range of abilities of this complex in studying operator's activity, processes of adaptation and for training purposes.

12.3. 24-HOUR MONITORING OF EEG AND OTHER POLYGRAPHIC SIGNALS WITH "ENCEPHALAN-RM" MOBILE WIRELESS EEG-RECORDER

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Long-term recording of EEG, ECG, and other polygraphic signals either from working human operators or from astronauts and aircraft pilots in flight conditions allows to reveal specific interactions among different body systems and to study adaptive processes in a human body. Mobile EEG recorders, capable to accumulate the human polygraphic data in internal memory and wirelessly transfer the collected data to computer, can be effectively used for these purposes. The paper presents the new developments in this field made by our company.

"ENCEPHALAN-RM" Mobile EEG Recorder (produced by Medicom-MTD, Ltd., Taganrog, Russia) allows to collect data of long-term EEG studies into its internal memory and to transfer the accumulated data to a computer via a Flash card or over a wireless connection.

The mobile EEG recorder offers the patient full freedom of movement owing to battery power supply, low weight (up to 400 g), internal data storage and a wireless connection with a Workstation computer. The device allows recording of 19 standard EEG inputs, A1-A2 reference potential difference, 2 polygraphic (e.g. EMG, EOG, etc.) inputs, and signals from a respiration gauge and a two-coordinate body position sensor. The device also allows continuous recording of EEG electrode impedances and offset potentials used to study ultra-slow electric activity of the brain. The mobile EEG recorder includes EEG caps of different sizes (of Quik-Cap type) for comfortable long-term EEG recording.

The device records EEG and polygraphic data onto internal Flash-card memory (of up to 1GB). can be easily removed out of the patient module and connected to the electroencephalograph workstation via the convenient interface. After the study, the Flash Card can be easily removed out of the device and connected to the electroencephalograph workstation via a convenient interface.

The wireless connection between the mobile EEG recorder and the computer allows remotely to initialize the device operation (by setting inputs and filter cut-off frequencies) or to check electrode-skin contacts, with the patient connected to EEG recorder being at a distance of up to 10 m away from the PC. Portable recording begins immediately after the initialization and electrode check. After initial DSP processing, the signals acquired from electrodes and sensors are stored in the internal memory during an EEG study. The DSP processor automatically tracks the signal quality and warns the patient/doctor of such problems as low battery power, bad signal quality during a long time, etc. After the EEG study, all accumulated data is copied to the hard disk of EEG workstation for further analysis with Encephalan-131-03 EEG Analyser software.

12.4. GENERAL RULES OF LIVING SYSTEMS FUNCTIONING: SYSTEMS APPROACH IN BIOLOGY AND MEDICINE

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As a line of research systems biology arose in the middle of XX-th century after the general theory of systems was created. Despite of great achievements in the field of theory its practical outcome was negligible. Only now after deciphering of the human genome and with the emergence of powerful computers the understanding of the living system functioning as a system gets its material basis and becomes feasible. From the beginning of XXI-th century number of publications, journals, institutes and scientific groups connected with research in the field of systems biology is growing almost exponentially.

The most general principles of functioning of all complex systems are similar and are defined by the solutions of corresponding systems of equations. This constitutes the methodological basis for the use of analogies between living and non-living complex systems.

The number of possible external stimuli of a biosystem greatly exceeds the number of its possible immediate adaptation reactions, therefore the choice of the type of adaptation response depends on a limited number of control parameters. Description of any specific state of the system consists not in the listing of the states of all its elements but in the specifying values of a few integrative characteristics which are the state parameters of the system. Such parameters are commonly used in medicine and include body temperature, blood pressure, pulse frequency, etc. However they usually do not give the complete description of the system's state. Distributions of the parameters over the surface and volume of the system are much more informative.

The possibility of a detailed description of the system by means of a set of the state parameters allows for introduction of accurate quantitative characteristics of different states and such concepts as illness, homeostasis, adaptation, etc. The state parameters of an organism are defined to a great extent by its genome. However the genes expression depends on internal factors that are influenced by various and numerous external factors. Therefore the organisms with identical genomes under identical external conditions may be in different states, their state parameters depending on their life histories.

The state parameters are not independent. They change with time under constant external conditions and any change in the external conditions results in the changes of that process. The system travels over a landscape in the multidimensional space of its state parameters, the specific trajectory being dependent on the feasibility of various compensatory processes and accessible energy first of all. The accessible energy includes not merely energy sources but also effective mechanisms of its use and depends therefore on the characteristics of information processing (transfer, reception, generation, elimination) and the priority of physiological functions at the moment.

A complete description of a complex system like an organism requires a set of nonlinear differential equations. Its steady-state solutions usually possess regularity to a certain extent which is ascribed to some kind of a dissipative structure. Transitions between the stationary states go through chaotic states. Theoretical methods are developed that allow for prediction of the changes in the system state on the basis of fluctuation analysis of the state parameters.

Interactions of an organism with its environment are determined by its phenotype, not the genotype. As identical genotypes may produce quite different phenotypes, the knowledge of the genetic information is insufficient for prediction of the system changes. It is necessary to know to what specific class of phenotypes the organism belongs. Therefore the phenotype classification is essential. It may be carried out with the use of quantitative characteristics of phenotypes, i.e. the systems state parameters. The systems classification implies partitioning of the whole set of the systems into subsets or groups of systems with similar behavior and reactions to external stimuli. Such classification would allow for development of group-specific methods of diagnostics and behavior control.

The systems biology is based on the concepts borrowed from the general systems theory. In systems biology an organism is considered as one and indivisible system of such elements as genes, proteins, biochemical reactions. Interactions between these elements make the system live and define morphology and physiology of the organism.

It is hoped that the systems approach may greatly contribute to optimization of research in various fields of biology and medicine like genomics, bioinformatics, diagnostics, rational design of new more effective and less harmful drugs, aetiology of illnesses. The research work must be carried out taking into consideration general principles of emergence, development, and adaptation of functions in the evolution of living systems including man. Simplified set of those principles may include: limited resources (especially energy), homeostasis maintenance, functional limitations, interdependency of functions and structure, memory, selection of priority forms of activity, expediency of specific forms of activity, induction of compensatory-adaptive reactions by environment, tendency to increase pleasant sensations and decrease unpleasant ones, tendency to increase the system longevity, tendency to decrease the information losses and to improve the regulation quality.

Methods of the systems biology seem to promise to speed up and reduce price of preclinical as well as clinical trials of pharmaceutical products. In preclinical studies it is due to the use of general principles of the systems functioning and corresponding new instrumentation. At the stage of clinical trials classification of the participants into different classes will reduce unnecessary expenses connected with the use of large random groups of genetically and phenotypically different people.

The systems approach makes feasible development of new means of diagnostics and treatment of illnesses. It is well known that systems in the states close to a bifurcation may become extremely susceptible to little perturbations of the state parameters. Finding the critical parameters in different functioning modes of specific living systems would allow for development of new and fast methods of diagnostics and drug-free medical treatment.

In space flights it not always possible to use pharmacotherapy if it is necessary to correct an astronaut's psycho-physiological state. In this situation a drug-free medical treatment may become preferable solution. The proposed approaches allow for increasing safety as well as duration of work under extreme conditions including space flights.

In general, the systems approach promises development of preventive, prognostic and personalized medicine. It also allows for more precise definitions of such concepts as pathological states of an organism, illness, psychic activity in terms of the system state parameters which can be measured and expressed in numbers. For example, the adaptation responses of an organism may be classified into four subsets with different properties, and these subsets change in turn cyclically depending on the specific state of the organism.

The processes of energy transformation and information processing in an organism are interrelated. Normally, an organism maintains optimal values of parameters of these processes by means of various compensatory mechanisms. These compensatory reactions are responsible for the organism adaptation to changes in the environmental conditions. If the changes are too large or too long-lasting the adaptation may be achieved only with the changes of the processes of energy transformation and information processing. Changes of the system state parameters in certain limits do not influence substantially on the system's functionality and does not entail any deficit of resources. Periodical changes of the homeostasis related to individual characteristics of the organism development, biorythms, life style, with natural phenomena, etc. are not anomalous. The organism's adaptation faculties are also subject to natural variations and in some cases come down to the level characteristic of an illness. One of examples is extreme fatigue.

Deficit of energy, substance, information, or a defect in the structure impose limitations on possible types of the organism's activities. This results in compensatory processes and in case when the compensation is impossible the state of illness may rise with concurrent redistribution of hierarchical levels and resources accessibility at each level.

The abovementioned discreet levels of adaptation of an organism characterize indirectly the energy resources available for compensatory processes. Normally, an organism chooses an adaptation level according to the situation and resources available. In illness an organism switches to a state in which

energy consumption is usually higher than in the normal state and with it drifts to another, decompensated, state because of limited resources and may come to a state of stress. In this case the clinical course may become complicated.

In all cases choice of priority types of activity is determined by environmental conditions, by the state of the organism and processes in it. The illness symptoms allow for establishing the priority functions at the moment and vice versa establishing the currently priority functions may help to determine the nature of the illness. The rise of the system of priorities with corresponding compensatory mechanisms in the course of the species evolution was determined by their expediency. Derangements of information processing, e.g. as a side effect of pharmacotherapy, may cause distortion of the scale of the priority activities of the organism. Then the resources would be wasted on currently not very important activities. Subjectively, the patient may feel better but in a time the lack of resources would result in a drastic deterioration of the clinical course.

The choice of priority forms of activity at the moment governed by the genetic information, information received by the system from the outside during its lifespan, information being received and generated in the system at the moment constitutes the psychic activity. In other words the psyche is a set of adaptive reactions of a living system determined by the genetic information as well as all kinds of information available (both at the conscious and unconscious levels) including information contained in all sorts of memory of the system, information corresponding to the current physiological state, information being received from the outside the system, and information generated by the system (results of calculations, imagination, intuition, etc.). Actually, it is the interference of information fluxes from different sources that determines the choice of the specific activity form. Psychic activity provides not only for better adaptation to the current environment but for the adaptation in advance, i.e. to the virtual environment corresponding to the calculated or imagined prognosis of the situation.

The systems of energy supply and of functional control in an organism are linked to each other because in the course of evolution they originated from the non-equilibrium distribution of ions between the cell and the environment that gave rise to the membrane potential. Membrane potential depends on the metabolism of the cell but it itself affects the metabolism and other intracellular processes. In multicellular organisms similar role plays the potential difference on the tonoplast or the basal membrane. The system of electrical signaling and control in an organism is quite universal but not unique: temperature and mechanical stimuli may play similar roles.

At the Chair of Biophysics, Faculty of Physics, Moscow State University, during the last few decades a research work was being carried out on the possibility of electrically controlled regeneration of tissues and especially bones. A technique was developed that allowed for not only to speed up substantially regeneration of fractured bones but also to stop bone destruction in such illness as spontaneous bone resorption. It is interesting that the change of the current direction to the opposite one resulted in bone destruction.

Most obvious are the following directions of experimental research in this field. First, measurement of the electric potential, temperature, and their fluctuations distributions over the body surface in organisms with different phenotypes. Second, establishing of correlations between the parameters of those distributions and the organism states. Third, use of the data obtained for determination of efficiency of drugs and other external influences in purposeful change of the organism state.

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12.5. A MAGNETIC STORM DECREASES THE COHERENCE FUNCTION OF TIME SERIES OF OSCILLATIONS OF ELECTRIC POTENTIALS OF THE CEREBRAL CORTEX DURING IMPLEMENTATION A PROOF - READING TEST

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During last decades, the scientific interest to influence of sun-terrestrial physical events on the earth biosphere (sun-terrestrial biophysics), including men and their functional systems, is increasing permanently. On the other hand, quantitative neuro-physiological investigations by physical experimental methods and by mathematical ones, is being developed intensively as well. This paper belongs to these directions. (Бреус and Раппопорт, 2003; Kopel, 2000; Красногоская (Ed.), 1992; Кузнецов, 1994; Тамбиев et al., 1995; Темуриянц et al., 1992; Черноух et al., 1981).

Characteristics of the group under test, the experimental device, and the proof-test.

Below, the effect formulated in the title is described for a group of 10 students (practically healthy girls and boys from 18 до 23 years old). Their electroencephalograms (EEG) were being registered during a year beginning from May 2004, as a rule, 2 times per week. Duration of every EEG investigation by the open eyes and by closed ones was 2 minutes, whereas duration of every investigation by the implementation of the proof-reading test in absence of a magnetic storm or under its influence supposed was 15 to 30 minutes.

The electroencephalograph «Нейрон спектр» with eight channels was used. The left group of four active electrodes were measuring the electric potentials (in regard to the lobe of the left ear were a passive electrode was located) of four points of the left part of the head: the first point was at the forehead, the second one at the sinciput, the third at the temple, and the fourth at the back of the head (occiput). The right group of four electrodes was measuring the electric potentials (in regard to the lobe of the right ear) of the symmetric points at the same parts of the head but above the right cerebral semi-sphere. The earth electrode was at the sinciput, namely at the point of intersection of two imagined lines: the line going from the bottom of the nose to the ridge of the occiput bone and the line from left ear to the right one. The electric sensors with sensitivity of $0.01 \mu\text{V}$ were applied and 600 values of the electric potential of every point mentioned were recorded during a second at the hard disk of a computer. The data of IZMIRAN about dynamics of the geomagnetic field were used. To control the functional state of the men under test, the respiratory rhythms, arterial blood pressure and other characteristics, along with electrocardiograms, were registered and any considerable deflections were not observed.

As the proof-test, everyone from the group tested was given a line of random symbols at the monitor of a computer and an unlimited time interval to find two prescribed symbols from this line. Everybody was known that the time interval for searching is unlimited. The computer registered the number of true and wrong determinations. During showing (typically 15 to 30 min) forty lines of random symbols were demonstrated for everyone tested and there were 1024 true pairs.

The coherence function.

We considered the brain electric potential oscillations combining two points, the first one was chosen at one of the parts of the head (mentioned in the previous Section) and the second point of the pair was chosen at one of the other parts. So, we choose two time series of oscillations of electric potentials: a) for the forehead point and b) for the occiput point (the point at the back part of the head, see above), both of the points being located above the left cerebral semi-sphere. Another pair of points for this semi-sphere was chosen from another pair of the parts of the head mentioned. The choice of the pairs of points for investigation of the electric potential oscillations for the case of the right semi-sphere was the same as for the left one (let us remember we were able to use eight channels only). For this preliminary stage, we are trying to find out a characteristic of bioelectric activity of the brain with the most distinctive response to magnetic storms, which may be discovered, in particular, without advanced mathematical tools. Surely, we recognized that this problem may occur to be unsolvable by experimental methods (see above) we

were able to apply. Indeed, we failed trying to discover the most distinctive changes of the bioelectric activity of the brain in terms of the index of bioelectric activity estimating the time interval of presence of different known rhythms (see below) in resulting electric potential oscillations. Now we are going to show that the distinctive response may be obtained in terms of the coherence function which is well-known in the mathematical statistics of time series and in practical analysis of EEGs. Generally speaking, the coherence function determines co-ordination (concordance) of two random processes, e.g. the co-ordination of the electric potential oscillations of the forehead and occipital points of one of the semi-spheres, in our case. So we are trying to trace influence of a magnetic storm as a change of co-ordination of the oscillatory random processes in a few chosen pairs of point of the head above the left and right semi-spheres. But to remember the definitions needed for the corresponding numerical analysis, some notations are needed.

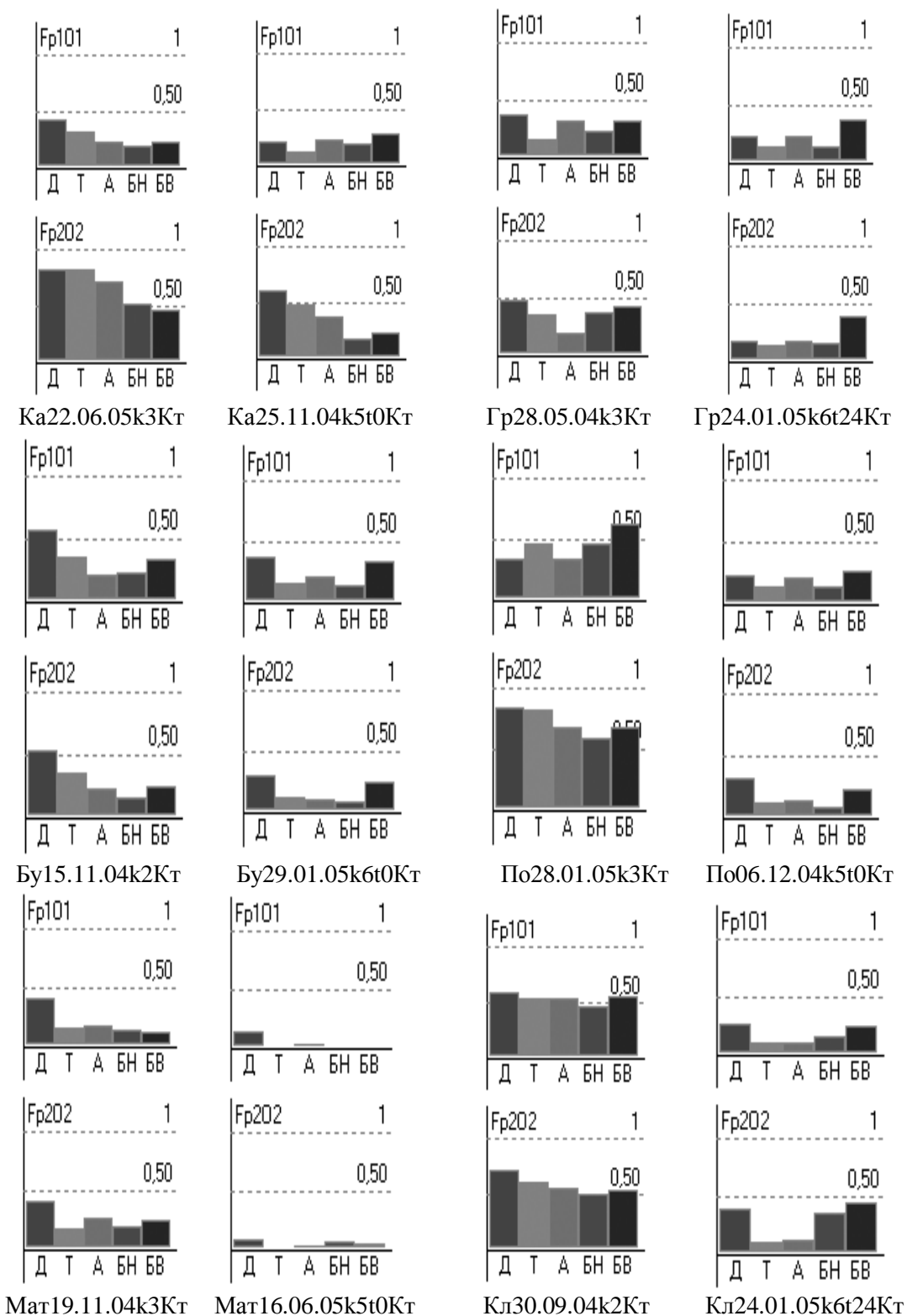
Let us denote the random process of oscillations of the electric potential of the forehead point by X_t and the similar process for the occipital point by Y_t , t is the time. The coherence function of the random processes (time series) X_t and Y_t is determined as a fraction with the module of the cross-spectral density of these processes as the numerator and the square root of the production of their spectral densities as the denominator. The spectral density of a process X_t is determined as the Fourier transformation of its auto-covariance function $E[(X_{t+m}-EX_{t+m})(X_t-EX_t)]$, where E denotes a mathematical expectation and m is an arbitrary time shift. The same definition with replacing of X by Y is valid for the process Y_t . At last, the cross-spectral density of the processes X_t and Y_t is determined as the Fourier transformation of their cross-covariance function $E[(X_{t+m}-EX_{t+m})(Y_t-EY_t)]$. The values of the coherence function belong to the interval $[0,1]$. If one of the processes is a transformation of the another one then the coherence function is 1, identically. Surely, the forehead and occipital points and the corresponding electric oscillatory processes were considered as an example and the same definitions are valid for pairs of point from other parts of the head.

The coherence function of the measured time series of oscillations of electric potentials of the cerebral cortex.

An analysis of the EEG electric potential recordings includes usually extracting of the following five modes of electric oscillations, typical for bioelectrical activity of a brain and known in neurophysiology as rhythms: δ -rhythm ($f = 0.5 - 3.9$ Hz, $A = 20$ μ V), denoted by Δ at the diagrams below; θ -rhythm ($f = 4 - 7.9$ Hz, $A = 20$ μ V), denoted by T ; α -rhythm ($f = 8 - 13$ Hz, $A = 15$ μ V), denoted by A ; β -low-rhythm $f = 14 - 19.9$ Hz, $A = 5$ μ V), denoted by BH ; β -high-rhythm ($f = 20 - 35$ Hz, $A = 5$ μ V), denoted by BB ; here f is the frequency and A is the amplitude.

As usually, to characterize the co-ordination of the electric potential oscillations of the forehead (Fp) and occipital (O) points of the left (1) cerebral semi-sphere (resulting notation is Fp1O1 at the diagrams below), we calculated the coherence function for oscillations in every of the frequency ranges, i.e. for every oscillatory rhythm mentioned. The height of a rectangle at a diagram is equal to the value of the coherence function of the time series of oscillations in the rhythm shown at the bottom of a rectangle. In other words, we characterize the co-ordination of the electric potential oscillations of a pair of points of the head by five coherence functions, according to five basic rhythms, and visualize the numerical result using five rectangles at the diagram for the pair of points under consideration. At the diagrams, the abbreviation Fp2O2 denotes the same as Fp1O1 but for the right semi-sphere. In the case of absence of a magnetic storm, the diagrams (and the EEG investigations at whole) are numbered by the following manner: the first letters denote the abbreviation of the family name of somebody under test, then

we show the data of the EEG measurements and the value of the ionosphere activity index k (k_2 , k_3 corresponds to the quiet state of the ionosphere, k_5 and more – to the magnetic storms) during the EEG measurement concerned; the abbreviation K_T denotes a EEG measurement during the proof-test implementation. In the case of the magnetic storm, the notations are the same save for the time delay of the beginning of the EEG measurements in regard to the nearest preceding magnetic storm, say, t_{24} denotes a measurement 24 hours after the storm and t_0 denotes a measurement during a magnetic storm.



So, the coherence function values for every rhythm without storm are shown in the left column for the left (the upper diagram Fp101) and for the right (lower diagram Fp202) semi-spheres, whereas the same results but under a storm influence are shown in the right column. In other words, for everyone under test (Ka, Gr,, Кл) we show four diagrams: two diagrams (left without storm and right with it) for the left semi-sphere shown in the upper line above the number of the investigation and two diagrams (left one - without storm and right one - with it) for the right semi-sphere, shown at the lower line.

Conclusion.

At the diagrams, according to the notations explained, the values of the coherent function for the low-frequency rhythms Д and Т are decreased considerably (rather approximately, half as many, in most

of the computed cases, both shown and omitted here) after or during magnetic storms, both for the left and right forehead-occipital pairs. Also, one can see, as the result of comparison of the left and right (storm) parts of diagrams for left (1) and right (2) semisphere that a distinctive decrease or increase of the forehead-occipital coherence function for all of the higher frequency rhythms А, Бн, Бв is absent.

Due to limited size of the paper, we demonstrated above only 6 (from 10 EEG investigations processed, with similar results) examples of attenuation of co-ordination of bioelectrical activity of the brain observed after or during magnetic storms. Computed diagrams for the case of the open or closed eyes, i.e. without the proof-test implementations, in the case of considered pair of points Fp1O1 and Fp2O2 are omitted here as well as computed diagrams for pairs of points from all other parts of the head included in the EEG measurements (see above) because we did not observe a distinctive coherence function decrease or increase for any rhythm in these cases. Moreover, analysis of a wider sample of the EEGs then we were able to demonstrate here shows that the decrease of the forehead-occipital coherence function for the δ -rhythm (Д) is not so typical as for the θ -rhythm (Т). Besides, we omit the diagrams showing that the changes of the coherent function disappear 48 hours after the magnetic storm.

We noticed the decrease of the forehead-occipital θ -rhythm coherence function as a general response to a magnetic storm but, surely, there are particularities of the separate tested ones, e.g.: in the case of Гр this decrease is observed for the right semi-sphere only (may be, because of 24 hours passed after the storm); in the case of Мар, the decrease is up to the zero. Besides, particularities of a separate (personal) response to the magnetic storm may be caused by particularities of the magnetic storm (storms) developed during or before the EEG measurement of the person concerned. Possibly, some of the magnetic storm particularities, which are of importance for the brain bio-electric processes, are not reflected by the ionosphere k index dynamics. We considered here the simplest approach from the geophysical, neuro-physiological and mathematical viewpoints.

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12.6. TERRAIN AVOIDING WARNING SYSTEM FOR HELICOPTERS

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Safety of the helicopter flight depends on work quality of measuring sensor equipment, processing systems, indicating systems and pilot, who takes the control action. In some situations, the probability of human mistake rises, that can lead to air crash. There is no claim to measuring system with it, all the problem is an interface between pilot and measuring system. Such situations are low altitude flight, low vision and so on. It's most important within flights to sea oil-rigs that placed in northern seas. Difficultness caused by polar night, bad weather, absent reference points on the ground, and need to landing on the small, high placed pad. Quality of pilot work within deficiency of time for decision depends, at first, on the right ergonomic designing of "pilot – helicopter measuring system" interface. In Science and Research Institute of Avionics developed terrain avoiding warning system, than consists of software than processes incoming flight information, and presents it in more suitable for pilots perception form. Base measuring and indicating equipments of helicopter are not changing, only form of information changes. General measuring parameters are:

- bar- and radio-altitude,
- vertical and horizontal speed,
- navigation parameters,
- oil-rig landing pad approach parameters.

Messages displayed in different colors and followed with sound alarm. Text and sound of message are changes with evolution of situation. At fist, pilot gets information of unconditional flight parameters, then with close to decision point he gets a demand to take an action to avoid the crash forecasted.

When algorithm of system been developed, results of 35 helicopter pilots interview had been analyzed, cases of last years helicopter crashes that had a human factor as a reason had been analyzed too. It helped to define flight parameters and their complexes that are difficult to be controlled specially in complex with other flight information. Algorithm helps to control these parameters and lets to consider on primary flight tasks. With it, reserve of time for decision is provided to avoid extraordinary maneuverings. Also protection of wrong signaling is provided, that reached by filtering and logical processing and control of incoming flight data.

Software been tested on labor-stand, with specially designed program, that simulate helicopter flights in according to test plan profiles. Algorithm parameters and indicating signalization parameters complains to ergonomic standards, Federal Aviation Rules and Helicopter Ka-226AG Flight Rules. System is recommended by Science and Research Institute of Avionics to be installed on Ka-226AG as base variant.

12.7. TAKE CARE OF YOURSELF!

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Non-acceptance of the theory by academician Abdullaev Farkhat Mukhamedovich in the direction of genetic medicine, based on insufficient understanding and sometimes on a groundless criticism, does not mean that one should deny the newest theory that by its means correlates with traditional folk medicine. The method evolved by FARKHAT ata and NINA ana does not set any strict limits to application and is aimed at all existent human diseases by restoration of healthy consciousness and conscientiousness of people to the level of total recognition and cultivating within oneself love, kindness and belief.

Having an experience (1995 – 1999) in healing by the method of famous Dzhuna and as a follower of FARKHAT ata and NINA ana (from the 29-th of May, 2006) and comparing these two directions with one another and a series of the others, I can sum up adequately:

FARKHAT ata and NINA ana represent a unique phenomenon. Their method and theory are directed on recovery of everyone on Earth and in Space. Moreover they are aimed at consciousness and rising it to the highest level.

FARKHAT ata provides an opportunity of mastering the method (to some or other extent for curing family members or other people) not for everyone but selectively since it's connected with the healer's personality, his (her) possibilities.

Another unicity of FARKHAT ata and NINA ana is that they completely deny advertisement, much less self advertisement. Therefore, my report comprises information for you who are in the most advanced (cosmic) positions of international medicine whose aim is to improve health of people, to preserve health, working efficiency of cosmonauts and all whose life is connected with aviation and outer space.

Regarding the above I ask to enter the following item in the section solution and as a whole in the Congress Declaration: "For absolute curing people injured during tests and at the time of mastering aviation and space technology it is recommended to apply the method by FARKHAT ata and NINA ana internationally".

Thank you for attention!

12.8. EGOSCOPY -- NEW PSYCHODIAGNOSIS APPROACH USING PICTO-POLYGRAPHIC METHOD

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Screening candidates to be trained for operation in hard conditions of space or air flights follows a system of diverse studies based on separate methods of mental, psychophysiological, and medical testing. Such a traditional approach implements the diagnosis of integrated personality (IP) of an individual. However, there is a scientifically substantiated and empirically known concept of a unique pattern of ethico-somatic correlates of individual personality as synchronic functional structures of IP.

To improve validity of the personality framework studies and make them more objective, we suggested the Egoscopy Method providing a synthesis of a self-documenting version of projective techniques and psycho-physiological testing of mental responses during task solving, e.g. with polygraph (lie detector).

In order to objectify the projective techniques of personality testing by multivariate analysis of senso-physiological patterns of personality, we designed "EGOSCOPE" Projective Analysis System, developed on the basis of "REHACOR" Rehabilitative Psychophysiological Biofeedback System. Egoscopy (from latin "ego" (me) + greek "skopeo" (to study)) is a fundamentally new approach to personality diagnosis based on integral trend analysis of multiple indices of EEG, photoplethysmogram, pneumogram, galvanic skin response, EMG, etc. and behavioural activity of a person solving the diagnostic tasks with a special pen on paper placed on a digitizing pad connected to the computer. A diagnostic session includes a series of projective stimuli or tasks (i.e. questions, statements, instructions), which is presented to the tested person on the monitor screen. Trends of the pen's movement and its pressure on the digitizing pad (in 256 degrees of pressure) are analyzed.

The results are represented as profiles of senso-physiological significance grouped in clusters of different personal significance (with indication of statistic validity) displayed on plots, tables or 3D views. Problems significance is appraised using statistic tests of agreement between pictographic, polygraphic and EEG indices. Egoscopy helps professional psychologists formulate a personal diagnosis taking into account ethico-somatic inter-relationships of the ego, obtain an individual ethico-somatic profile (virtually undistorted by psychological defense mechanisms) and reveal unrecognized pre-clinical states or problems in social, professional and private life of the tested person.

12.9. VALIDATION OF MODERN HUMAN THERMAL MODELS FOR EVA APPLICATIONS

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The human thermal models are actually being applied for extra - vehicular activity (EVA). The mathematical models first successfully developed to provide thermal comfort for an EVA in space suit of Apollo program (J. Stolwijk, 1971; P. Webb, 1975; J. Waligora, 1977-1994), and in using thermal control during physiological tests of portable life support system (PLSS) for Orlan type space suits (Yu.G. Konahevitch, 1972; A.S. Barer et al, 1979-1987) or for different types of individual equipment (V.S. Koscheyev et al, 1980-2005).

A review has begun of Russian models for thermoregulation (I.I. Ermakova, 1987-1990); for human diving in cold water (L.M. Savelieva et al, 1987); for individual equipment (A.A. Glushko, 1986); for a suited mode with ventilation and liquid cooling garment capabilities (I.K. Zaratuitcenko et al, 1997; S.N. Filipenkov et al, 1998-1999); for human thermoregulation in isolated volume (N.N. Khabarovski et al, 2002; T.V. Matushev, N.N. Khabarovski, 2001). A detailed comparison has performed of the structure and function for the models, described by differential and/or algebraic equations for cylindrical compartments of human body (with total number from 1 to 17 segments).

The evaluations being carried out to establish the current state of the art in human thermal modeling have implications, particularly for the 41-node NASA model (J. Stolwijk, 1971), ESA human physiological model (F. Monchoux, F. Thellier, F. Bagiana et al., 1994); and the 255-node Wissler model with 15 compartments (L.F. Smith et al., 1994-1996; J.D. French et al., 1998; K. L. Nyberg et al., 1997-2000; V.L. Pisacane, L.H. Kuznetz, J.S. Logan, J.B. Clark, E.H. Wissler, 2005).

The main goal of this research is the mathematical base for the software development in light of the proposed use of computerized complex in EVA operative physiological and medical control.

In this way validity assessment can determinate coincidence between the model mathematical description and human thermal reactions, being considered for use in proposed simulation test bed to model the fully transient EVA especially in specific conditions. It needs for the human thermal status prognosis. An accuracy of the prognosis is a critical problem in the computation of operative assessments for cosmonaut's thermal status during actual EVA sorties. The mentioned above models have low accuracy for mean body temperature computation (above ± 1.0 °C) during steady - state modes of heat exchange between human body and PLSS of space suit. There is no biophysical adequacy in description of transient states during exchange of physical activity with transition from the lower part of the body or leg's workloads (lunar EVA simulation) to the upper body or the arm's workloads (orbital EVA simulation). There is no any biophysical and mathematical description for combine effects of conductive and convective heat exchange in the transient modes with vapor condensation on the tubes of liquid cooling garment.

The most complicated Wissler model has the best accuracy approximately ± 0.5 °C for prognosis of core body temperature and approximately ± 2.0 °C for the mean skin temperature (Piscane V.L. et al., 2005). However, all these errors are very high for operative medical assessment of the human body heat storage. It will be better to use thermal sensor with registration of exact value of human body temperature during actual EVA sorties (with accuracy ± 0.2 °C), especially, for prognosis of cosmonauts thermal status in real time of EVA sorties (A.A. Sheikin, B.A. Utehin, 2002; B.A. Utehin, 2002).

A need has been identified for accurate transient human thermal modeling for use in the EVA simulation. Continued detailed evaluations of the model's performance and mathematical formulations are planned during different EVA conditions. They include further analyses of accuracy already discussed (S.M. Gorodinsky et al., 1976; A.A. Glushko, 1986; I.K. Zaratuitcenko et al, 1996; N.N. Khabarovski et al, 2002) as well as issues not addressed, such as transient biophysical and physiological mechanisms in the closed 'space suit-human' system. For prognosis value it is also desired to assess known characters of this system or to tabulate the parameters.

Determination of the crucial limiting factors can provide guidelines to the thermal modeling of the 'space suit- human' system. All these measures will provide a solid basis for selecting and improving the

best thermoregulation model for inclusion in the proposed overall test bed for EVA simulation during orbital flight and sorties on the Lunar or Martian surfaces, and for description of human thermal status in the other types of extreme conditions on Earth.

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12.11. A UNIVERSAL SPACE SUIT CONCEPT FOR LUNAR AND MARS MISSIONS

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Abstract

This paper presents a conceptual study of a universal space suit (SS) applicable for Lunar/Mars manned missions. The following scenario of extravehicular activity (EVA) with the suit application is reviewed:

- EVA capabilities in the interplanetary flight phase and in the orbital phase;
- EVA on the Lunar/Martian surface;
- suited mode during descent/ascent and rendezvous;
- manned aspects on Lunar and Mars exploration.

The paper reviews various cases and conditions for EVA periods and requirements they impose on the suit design. Design concepts are selected with high reliability, availability, safety, maintainability and adaptability as principal considerations.

The purposes of this report are following: the consideration of biomedical problems and technical issues of complex systems creation for EVA during the interplanetary flight and for the sorties on a surface of a Mars, definition of situations requiring space suits application and possible cases of EVA operation, definition of space suit types and their quantity (amount), definition of the general (common) requirements to universal suit.

INTRODUCTION

Alexey Leonov, who made first in spacewalk in 1965, responded novel "Outside the Earth" by K.E.Tsiolkovsky, as the exact scientific prognosis. Many issues from the Tsiolkovski's recommendations are realized in Russian EVA systems [1]. Manned interplanetary missions are realistic in the coming century. However the large part of his forecasts about planning in 2017 of interplanetary expedition to Mars with international crew from 6 persons still only now is put in the summons scientific and experimental researches. Both Russia and United States have gained a considerable experience in the development and operation of EVA suits for near earth and Lunar missions. The experience gained must be used for development of new generation suits for Universe missions.

The universal SS must protect the crewmember from the natural space environment, a suitable operating pressure mode, temperature control, and breathable atmosphere. That environment consists of vacuum, radiation, thermal gradients, hazard of and micrometeoroids or debris impact. There are two basic phases of the mission as far as the EVA is concerned, the first is the transplanetary cruise and second is the sorties on the surface. The transplanetary phase includes all EVA performed in microgravity environment including any activity associated with departure or arrival of the surface excursion spacecraft (Lander). The surface phase included all EVA performed on the Lunar/Martian surface. Currently, a big number of problems related to extended Lunar/Mars expeditions are under consideration, and issues of EVA suits to be used to support manned missions are among them.

The paper addresses such problems as radiation protection of the suited crew member, locomotion limitations imposed by velocity and mass under microgravity conditions and in the hypogravitational Lunar/Martian environment, and safety of EVA decompression protocols. Objectives of this paper are to review certain issues associated with EVA support in the cruise phase and during sorties on the surface, identify situations calling for the use of SS and intravehicular (IVA)/extra vehicular (EVA) modes, and identify types of suits and their quantity for Lunar/Martian expeditions.

Manned mission: analysis of conditions, time and scenario for suit utilization

Utilization of SS is reviewed on the experience already gained in operation of existing suits with specific features of Lunar/Martian missions taken into account [1-5,21]. An additional requirements to EVA should be formed on a basis of already saved experience of modern EVA operation in view of specificity of expedition [1-5,6].

Ionizing Radiation. For manned missions to Moon or to Mars, the major radiation component is exposure to the highly damaging Galactic Cosmic Rays (GCR) and Solar Particle Events (SPEs) also pose a threat beyond the geomagnetosphere [6-8]. SPEs are protons with average energy about 100 MeV. SPEs may occur as often as once every two month or as rarely as once every two years. Very large SPEs capable of causing lethal damage to humans occur as infrequently as once every 7 to 10 years. To avoid a hazard of gigantic solar flares, EVA sorties on the Moon/Mars surface can be performed in night time of a day and in light time of a day crew members will stay in the shelter of landing module or ride a rover vehicle with passive protection of the habitable module (in airlock and in pressurized cabin). The effects of GCR are caused by nuclei of all elements traveling at high velocities. These particles have an average energy of 1 GeV with flux on surface of the Moon between 1 and 2.5 particles/cm² – sec. This is roughly only one-half that of free space, because particles are blocked below Lunar horizon. Even so, they are still of concern to humans on the surface, considering the annual dose –equivalent is above 0.25 Sv.

The carbon dioxide in the Martian atmosphere provides approximately 27 g/cm² of shielding from harmful radiation sources from SEPs and GCRs. Average GCR amounts to approximately 0.3 Sv per year, but higher doses are due to combination with solar-flare particles, most of which stem from gigantic flares each lasting a few days. The depth-dose equivalent of 0.5 Sv per year will be possible for expedition to Moon and 0.5-1.0 Sv per year will be possible for expedition Mars. This may be within the allowable ionizing radiation exposure limit recommended for 7-30 days surface stay time. The Martian surface is exposed a continuous flux of GCR. This flux is between 1 to 10⁻⁵ particles/cm² – sec, depending on the solar activity. The interaction of GCR particles (mainly protons with about 10% alpha-particles and 1% heavier nuclei) produces secondary particles, of which neutrons and heavy charged particles are of special importance. SPEs and GCR heavy particles can represent a lethal threat to crew during interplanetary mission or during EVA sortie on the planetar surface. To some degree, the Martian carbon dioxide also attenuates the SEPs and GCRs reaching the surface (it provides 27 g/ cm² of shielding, although it don't protect against extraordinary large SPEs). Exposure to SEPs can be very damaging to humans without adequate shielding. The amount of shielding required, about 400 g/ cm², will have to be provided by a storm shelter of Lander or Habitat [13,17,18]. This is the reason, why short-term forecasts of SPEs are necessary for all Lunar and Martian EVA tasks. Methods for predicting SPEs are still in a primitive state, although the increased usage of solar X-ray detectors the forecasting is expected to improve. Flare protons are usually scattered by the interplanetary medium, resulting in quasi-isotropic fluxes, thus requiring an all round shielding. However, large-scale features of magnetic field, can cause charged particles to temporary adopt highly anisotropic distributions.

Lighting Conditions. Both Moon and Mars have a night and day cycle (28 days on the Moon and 24.5 hours on Mars). The illumination provided by the Sun to the Moon surface is approximately 10000 foot candles. Owing to the absence of atmosphere on the Moon, the sunlight reaching the surface is not diffused. The shadowed areas are very dark and may conceal boulders or depressions, while adjacent light areas can be very bright. The solar illumination does get backscattered into the dark areas enough to allow the crew to see and work in those spots. During 'Apollo' program astronauts had difficulty distinguishing between near and far objects, because the shading of light and dark areas has tendency to mask surface terrain features, thus affecting judgment of range and distances [6,7]. The flux incident of solar thermal radiation on the Lunar surface is 0.14 W/cm². Most of this radiation reaching the surface is in spectral region 3000-10000 A. The ultra-violet (UV) radiation portion of this spectra is important because it strongly degrades the polymeric materials used in SS construction. Similar types of solar thermal radiation affect the Martian surface. The mean flux incident on the Martian surface is 0.06 W/cm². Wavelengths below 2000 A are absorbed by

carbon dioxide in the atmosphere [6]. The partial atmosphere of Mars, combined with presence of suspended dust and clouds, results in scattering or diffusion of light on the Martian surface. Therefore, the sharp contrast between shadow and light areas that occurs on the surface of Moon does not exist on Mars.

Protection of crew member's eyes from solar radiation is not a problem since the existing visors and light filters do their work perfectly [1,21]. A gold coated visor with high reflectivity are attached for daylight operations and only protective scratch outer - visor is used during a night EVA. Cosmonauts can adjust two outer sunlight-visors individually depending upon the sun angle, shadow/darkness, and desired visibility. On the Moon the sun will move only a little over four degrees during 5-10 hour EVA. With this stability in sun angle, visors can be predictably tailored to the EVA sortie. However, it is necessary to improve visibility of the area under crew member's feet, develop helmet located data indication means and evaluate psychosensory reactions under varying lighting conditions on Lunar/Martian terrain [8].

Manual operations and locomotion. Modern scenarios of exploration missions include significant automation and self-deployment of initial habitats on the Moon and Mars [9,12,15,23]. However, the first crew will have to check out and verify the system and perform some tasks upon arrival. Although some activities will be accomplished with robotics and teleoperations, the adaptable human capability will be required outside the habitable cabin to explore the surface, construct base structures, perform science experiments, and mine for in - situ resources [6,23]. Additional base facilities are likely to include some form of constructible habitats such as inflatables. Complex exploration tasks will require interactive coordination between the humans and automates. These types of EVA are not heavily demanding physically but do require manual, mental and visual acuity. If manual drilling and sampling are necessary, this will require much greater physical activity level. Expected EVA operations will include inspection, servicing, maintenance, observation, procedure verification, calibration, data collection, gathering information about natural resources, learning how to utilize those resources, and studying long - term effects of low-gravity environment on humans. These tasks might include unloading cargo from Lander vehicle, making utility connections setting interfaces and etc. [6,23]. The reduced gravitational forces on both the Moon and Mars are advantageous because objects on these surfaces weigh less than they do on Earth. This does help make handling of large objects easier while using less energy. A reduced gravitation will give cosmonauts a sense of up and down; but when they lose balance they will fall down into the regolith. Reduced gravity affects locomotion by allowing cosmonauts to traverse in a leaping manner.

Gravity conditions. The universal SS is designed to operate both in weightlessness and a partial gravity field. The acceleration due to gravity at the Martian surface is slightly above 3/8 of the Earth's surface gravity. The acceleration due to gravity at the Moon surface is approximately 1/6 of the Earth's surface gravity. Peculiar aspects in the Martian hypogravity include: walking and running gaits, posture, traction [12,19,23]. Less muscular forces and energy are required to walk. The optimal speed at which walking shifts to running become lower on Mars than on Earth [6,8,19].

Without EVA suit running and jumping are favored, because the low weight reduces the vertical force component of traction producing movement. Backpack PLSS is preferably in Martian gravity, as locomotion speed is increased, the forward body inclination gets progressively larger [6,8]. A reduction of gravity implies a reduction in the friction between the foot and the Martian surface, making human body balance and locomotion hazardous. It need to reduce, as much, as possible height of suited cosmonaut center of gravity position during development of EVA suit design [8]. Issue is design human-machine systems that optimize productivity and reliability of EVA sorties. Work will be shared between humans and robots, either automated or remotely controlled [8,12,23].

Tsiolkovsky established a load of 10 kg Earth weight as a comfortable value of space suit mass [8]. The USA Occupational Safety and Health Administration has established a load of 20 kg Earth weight as a comfortable additional weight to be carried on the person's back [6]. The Health Ministry of former USSR established higher load in range between 20-30 kg as acceptable for trained male subjects with body mass in range between 60-120 kg [5,8]. Therefore this range has been established

as design goal for planetary surface portable life support systems (PLSS). This means the Lunar SS with PLSS can weigh 120 kg on Earth and still meet the EVA requirement. The Martian SS with PLSS weighing 55-80 kg on Earth would also meet the planetary surface weight goal. From point of view of cosmonaut Dr. Valery Polyakov (who performed super-extended space flight during 437-day) the total weight of cosmonaut wearing Martian SS "will be in the region of his own weight on the Earth and his functioning under the Martian environments will also require approximately on Earth level of performance, which will depend on his physical state at the instant a cosmonaut sets foot on Mars and performs some kinds of work on this planet" [19].

Looking at current trends in microgravity EVA systems, however, mass of the systems have increased as technology advancements are made (both in Russian 'Orlan' SS - from 56 to 112 kg, and in American SS – from 89 to 285 kg) [1,6,14,25]. These mass increases are a result of added structural and resource support required to use EVA systems at an increased operating pressure during extended life time [5,16,21,24,25]. By using a lower operating pressure, lightweight materials and close loop of regeneration can be incorporated into primary structure of the suit and PLSS, thereby achieving a EVA system with reduced overall weight [1,5,8,21,25].

Dust/Contaminant Isolation. Planetary surface dust is important environmental factor to consider [6,8,14]. Lunar soil has limited bearing strength and loses its cohesiveness after repeated travel. Therefore greater concentrations of dust particles will exist along well traveled routes. Lunar dust has electrostatic properties and adheres to the suit. The leaping and bounding locomotion across the Lunar surface will kick up dust particles that may take on a long trajectory or may settle on the suit, tools, equipment, and test articles. The dust particles are very fine (40-130 microns with an average of 70 microns), irregular in shape, and adhere strongly to exposed surfaces. Removal is difficult and when brushed away usually scratches the surface. During the 'Apollo' missions the visibility of displays and performance of thermal coatings was impaired because of dust buildup. The dust particles also can penetrate SS bearings, reducing their mobility; coat thermal control surfaces, reducing heat exchanger's performance; and abrade suit materials and optical surfaces, especially as attempts are made to wipe off the surfaces. Furthermore the process of getting in and out of the suit brings the risk of contaminating both breathable atmosphere and pressure seals to the suit, airlock and habitat. These fine particles have infiltrated the habitation of Lunar module (causing skin, eye, throat, and lung irritations which could lead to greater health concerns) [6].

Not as much is known about the physical properties of Martian soil, because no samples were ever returned to Earth for analysis. It has been determined from US Viking Lander data that Martian particles range in size from 100 to 1000 microns and Martian soil may have a shear strength slightly greater than that of the Moon [6]. Mars also has an active atmosphere that will have a tendency to blow dust particles on EVA suit. These exposed surfaces will need to be protected from the blowing dust and other contaminations. It is important that the dust surfaces can be easily cleaned in airlock module before the habitat is entered; otherwise, there is a high risk of contaminating the entire cabin with dust particles. Martian dust sticks tenaciously to equipment surfaces and removal efforts are futile. A deposited dust layer can decrease performance of radiators, solar arrays, optical sensors, visor assembly and space suit enclosure. Dust pollution of habitats may occur when EVA suits and tools, soiled with dust, are introduced into airlock. However contamination of habitable cabin by dust entails a toxicological hazard for crew. Dust avoidance or limitation is a crucial EVA issue, acting the design of EVA suits and systems, include airlock for bioisolation. Potential solution of the problem is 'no waste'. While the probability of life of any kind existing on Mars is extremely small, the design of the SS enclosure, at least initially, will have to provide some measure of quarantine from microorganisms or contaminant exposure. Although the existence of even single-celled organisms is not likely, the probability of irritating or threatening contaminants in the soil or atmosphere is considerably greater. Consequently, unless robotic sample return missions demonstrate otherwise, the Martian SS enclosure must provide isolation from these factors, perhaps by use of a low porosity bladder layer against the skin that acts as a filter [8, 14].

Extreme environmental conditions. The Moon lacks any substantial atmosphere, although measurements of surface gas molecules show a density of $2 * 10^5$ molecules/cm³. The conditions on

the Lunar surface are: vacuum, surface temperature from minus - 170°C to +120°C, dust, abrasive effects of regolith. During the Lunar noon, objects in direct sunlight have reached 111 °C. The surface temperatures of minus - 170°C have been recorded for objects exposed to the cold temperatures of the Lunar night [6,7].

Mars has an atmosphere, however, that varies from day to day much like that of Earth. It is composed of about 95% carbon dioxide with trace gases of nitrogen, argon, and oxygen. The surface pressure range from 6 to 15 mbar, varying relief, abrasive and corrosive effects of environments and probability of sand storms with wind velocity 50 - 100 m/s (but because of the reduced pressure on the Martian surface, these winds are comparable to light breezes on Earth) [6,8,14,23]. In general, Martian surface temperatures may be colder than those on the Moon, because they follow a seasonal cycle with summer temperatures varying from -83°C to +22°C and winter stabilizes at -123°C, the frost point of CO₂. The Martian surface temperature varies enormously during day/night cycle showing extremes of -143 and +22 °C with a mean surface temperature of -55 °C. The EVA work period within particular cycle must be determined to minimize thermal loads on the PLSS. The large variations in daily temperatures on Mars, though ranging on the cold side, require that automatic thermal control system be designed to maintain a comfortable environment over a large range. Main components of the Lunar environments (vacuum) and Martian atmosphere (CO₂, Nitrogen, Argon, etc.) are chemically inert that are not detrimental for SS materials, but coil components may be corrosive and toxic [8,15].

Cruise phase: The level of ionizing radiation in the deep space is relatively high and, thus, radiation protection of crew members is one of the most critical problems. Therefore, it is necessary to exclude scheduled EVA in the cruise and Lunar or Mars orbital phases [8,13]. The existing EVA suits do not offer the proper radiation protection. For instance, the Russian Orlan type suit ensures an aluminum equivalent protection in range between 0.5; 1.0; and 1.5 g/cm² for limbs, cirase (with helmet visor assembly), and backpack, respectively [1]. The NASA Extravehicular Mobility Unit (EMU) features are 0.2, 0.5 and 0.9 g/cm² for arms, Hard Upper Torso (HUT) and helmet components, respectively [25]. The thicker enclosure for improved protection will result in increased envelope dimensions of the suit and a considerable weight (See Fig 1).

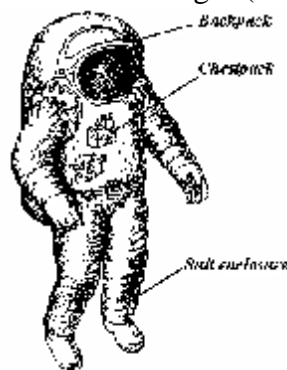


Fig 1. Architecture of the universal Space Suit

The cruise phase scenario may include only unscheduled EVA periods performed in cases when an emergency situation develops in such a way that an EVA becomes the must. It is hardly reasonable to have a suit specially designed for EVA periods in the cruise phase since its radiation protection capability has to be improved by orders of magnitude (about 20-30 g/cm² of aluminum equivalent) [8,13]. The introduction of active radiation protection implies a very high energy consumption for the generation of electromagnetic fields around crew members. In case of emergency EVA tasks shall be accomplished by robotics means or with a re-equipped suit for operations on the surface. A list of special features/components to support EVA in vacuum and under weightlessness is given in Table 1.

Table 1. An approximate list of equipment for Lunar and Lunar/Martian space suit [8]

	Equipment	Purpose
1	Additional protection	To protect from radiation
2	Garment with multi-layer shield vacuum thermal insulation	Thermal insulation
3	Tethers (safety, electrical, and etc.)	To support EVA on the surface of the main cruise module
4	Gloves (for specific tasks)	To support EVA periods in vacuum
5	Portable Life Support System components	To support EVA periods in vacuum

Items 2 and 5 for the SS for operations on the surface and the SS for EVA in free space may have different design features. Additional equipment designed to enhance suit capabilities can be made as a separate storable set used in case of emergency. One can assume situations when only EVAs will enable crew members to restore spacecraft vital functions. As the Lunar or Mars exploration program evolves, it may include scheduled EVAs on the surface of a module continuously orbiting around Moon or Mars [1,8]. It is appropriate to investigate SS fitted with a passive protection system that uses water in the gap between the SS enclosure and the crew member body. Water can improve radiation protection by 2...3 g/cm² [8].

Docking/undocking, descent and ascent: Crewmembers must wear SS to ensure the proper safety during docking/undocking with the orbiting module, landing and ascent [1,23]. Currently, in such critical phases of a mission crew members wear IVA suits [1]. Crew members staying in the landing module must be protected by a SS in case of emergency that may call for EVA if the module becomes depressurized. In this case, an EVA suit designed for operations on the Lunar/Martian surface must be used as an emergency IVA suit, the way it was planned in the Soviet Lunar-3 program and practically done in the NASA Apollo program [1,6,8]. In the descent and ascent phases, crew members may experience considerable accelerations and, therefore, SS must be compatible with a shock absorbing system [1,22]. Moreover, the idea of a water filled enclosure can be used to counteract G-loads [8].

During descent/ascent, crew members can be in standing or lying position. For the lying position, an individually tailored profiled insert supporting the crew member's back can be used [8]. As to the standing position, G-loads will be absorbed through squatting and moving the body inside the suit. SS has to be suspended in a special system featuring shock/load absorbing capabilities [1,8]. In the both cases, the suit must be properly fixed at suspension points. For the vertically fixed SS, the suspension system will facilitate suit donning/doffing, maintenance and storage [1,8,21]. Selection of the specific position of the crewmember in descent/ascent phases of the mission will depend on the designed acceleration level accepted for the specific type of a landing module.

Eva on the lunar/martian surface: After a durable flight to Mars under weightlessness conditions, crew members will perform EVAs on the Lunar/Martian surface with the surface hypogravity about 0.17 / 0.38 of that on the Earth surface. Two extreme scenarios must be envisaged: extensively robotics-based (tele-operator on site, for unplanned or planned or off-nominal intervention in exploration); extensively EVA-based (EVA operations in emergency situation).

In EVA-based scenario, extended (in excess of 5 hours), repeated EVAs may be expected to take place [8,23]. Repeated, productive surface activity for 5-10 hours each day for up to 6 days a week will be a requirement [6,8]. The interaction of the mental, physical, and emotional load in EVA crew members may then become a serious problem. In physical terms the mass of EVA suit is crucial issue in determining the workload, due to Martian hypogravity [8,19]. Distance covered during EVA is also crucial parameter in emergency situations. Studies would be conducted with aim of determining the speed with which crew would be able to walk back to the habitat, e.g. in case of contingency or emergency. For average workload, terrain and lighting conditions, a walking speed of 1 km/h at the distance 5-10 km may be expected with modern EVA suits [8,12]. In an intensive EVA, crew member workload shall be assessed by conduct a task analysis, and estimating the expected physical load, EVA suit mobility and dexterity, as well as mental loads and emotional stress, and

humans reciprocal interaction [8]. The effects of skill training by EVA repetitions and crew preparation for emotional stress shall be measured. Design of EVA system and establishment of Martian EVA schedule shall be supported by simulation, carried out with a human physiological mathematical model developed in Europe or with model of human thermal control developed in USA and Russia. Validation of these human models shall be achieved by comparison between predicted and actual values measured by human rated tests [8]. Data acquisition should be carried out by underwater simulation with neutral buoyancy, tests by thermal vacuum chamber with suspension for EVA system. After that models will need an upgrade to extend its applicability to hypogravity conditions.

Therefore it will be necessary to find a reliable and valuable way of simulating on Earth all kinds of EVA operations (not only hydrolaboratory and aircraft flight as simulator of microgravity conditions, but aircraft laboratory as a simulator of hypogravity 0.17g and 0.38g). Mobility of the suit and capacities of the PLSS with certain weight limitations will determine EVA on the Lunar/Martian surface. Umbilical connection of the suit to the PLSS located in a rover offers evident advantages [3,8,12]. The PLSS will be used solely in cases when EVAs have to be performed at a long distance from the rover. The utilization of modular PLSS for the suit and the rover fitted with certain interchangeable components will simplify recharging operations and flexibility [3,8,16,20]. The mobility range (within the 5-kilometer radius of landing module) will be limited by life support capability of the universal SS combined with unpressurized rover, and warning system for SPEs detection. The crewmembers seated inside cabin (in Lander or in habitats of Outpost) will also conduct exploration and sample collection to within a 10-100-km region using unmanned radio-teleoperated rovers to study the planetologic and climatic environment without any risk of their health and SS damage. Human activity on the planetary surfaces, the construction and maintenance of Lunar/Martian Outposts and emplacement of a surface habitat with automotive surface vehicles will depend on a range of EVA system capabilities, including complex of Universal SS and Rovers (USSR). The design of the Lunar/Martian SS shall be optimized to provide the proper interaction of crew members with robotics and telecontrolled systems, and rover vehicles (See Fig. 2 and Fig.3). Fig.3 presents that the umbilical is coiled up under the lower left and right sides of the cirase and connects to the both suit's emergency oxygen subsystem and to the rover onboard life support system. This offers ready access to the umbilical with an easy connection to the rover or to the second suit and allows side by side walking behind the rover during the emergency situations.

In Soviet/Russian space programs, EVAs were performed in various periods of durable manned space missions: from the one day of staying aboard up to the one year of a mission [1,21]. The experience shows that the crewmember performance capability level required for an EVA period can be maintained for a year if the proper means counteracting detrimental effects of microgravitation are used [10]. A repeated EVA can be performed with an interval of one-two days or with no interval [1,8,11]. As crewmember gain experience in EVAs, subsequent EVAs are usually performed with lower metabolic rates, and physical and emotional stress, more efficiently and, thus, within shorter time [8,10]. An optimal scenario for EVA on the Lunar/Martian surface may include two EVA periods each lasting 4...5 hours with a break for eating and hygienic operations [8]. An offnominal or emergency scenario for EVA on the Lunar/Martian surface may include only one sortie with extended EVA period lasting 8-10 hours without any break for eating and hygienic operations [1,4,8].

The Lunar/Martian surface gravity calls for studies covering such issues as a posture of the suited crewmember, and biomechanics and metabolic rate while traversing an uneven surface while carrying a backpack. The Fig. 4 shows a range of optimal postures and accelerations, that has been considered, especially for descent/ascent, and EVA sortie from 'LK' Lander of Lunar -3 program [20]. There are following interesting observations surfaced: leg soft enclosure of semi - rigid suit design should work like an inflatable spring column, and the standing position is the best for landing/ascent and for automotive vehicle operations. Using the legs as the columns violates measures of a precise soft limbs design.

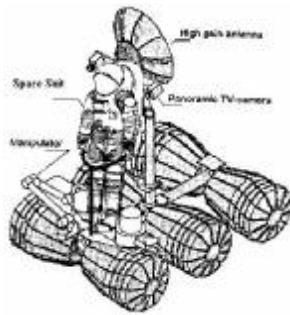


Fig.2. The simplest USSR is individual automotive rover for suited cosmonaut

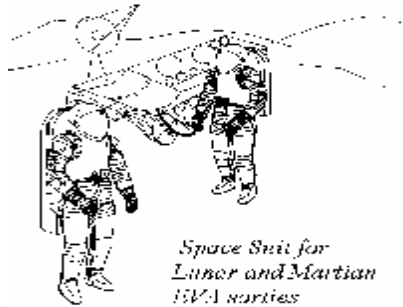


Fig 3. The expedition complex configuration is following: automotive USSR for extended exploration with satellite communication system, onboard life support system, two seats for crewmembers, two versions of Space Suits PLSS (left – autonomous; right – with umbilical and combined connector to rover support).

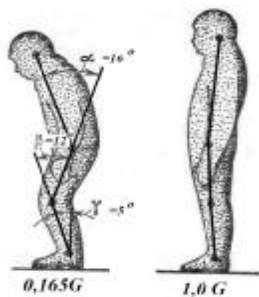


Fig. 4. The optimal standing postures during different G-loads (in range from 0.165 G to 1.0 G) [20].

Taking into account that flight to Mars is longer than to Moon and Lunar gravity is lower than Martian gravity or Earth gravity it is appropriate to simulate EVAs on the Martian surface at ground facilities with crew members of an orbital space station just after their return to Earth after an extended space missions [8].

Moreover, the suit design shall offer the capability of independent return of the crew member to the landing module in case a rover vehicle fails [2-4]. Therefore, it is necessary to define the maximum safe walking distance from the landing module to the Outpost without rover assistance no more than 5 km [8]. This limitation is imposed by metabolic rates expected during walks across a Lunar/Martian terrain rather than PLSS capacities.

Thus, the task is to exclude heavy walking, manual or postural operations and rely on automated tools used in exploratory activities (for example, manipulator, end-effector, exoskeleton, crane and rover).

Improved mobility of suit joints is another critical consideration. However the use of metal interfaces and bearings shall be limited due to weight constraints [1,2,4]. It will be necessary to study and introduce more effective and sophisticated joints such as glove metacarpal joints, bi-axial hip joints, and etc.

The proper medical control over the crew member involved in EVAs on the Lunar/Martian surface is crucial issue for safety of expedition [8,11,15]. Table 2 shows the main medical requirements Lunar/Martian suit.

Table 2. Main medical requirements Lunar/Martian suit and the approaches to requirements justification [11]

Main medical requirements	Rationale
Low mass of EVA system	Presence of the gravitation force and weight
High mobility and dexterity of space suit enclosure with optimal design of joints, especially, for locomotion	Need of high performance of EVA-crewmembers
Autonomous life support system must work during 8-10 h. It needs to use water bottle and device for urine collection	Support of extended working capacity during EVA on Lunar/Martian surface
Sun visor assembly	Eyes protection against UV impact
Quick time for evacuation of exhausted cosmonaut during emergency operation	Urgent need for immediately medical care and hyperbaric oxygen treatment of uncapacitant human being
Additional protection against cold environment and abrasive impact of dust particles during wind storm	Support of EVA safety
Automatic system of thermoregulation and conditioning	The concentration of cosmonaut behavior on the productive completion of EVA tasks
Zero prebreathing time for execution of body denitrogenation	Diminish of airlock period of EVA preparation

The existing orbital experience identifies the following problems to be addressed: computerized acquisition and processing of telemetry data with analysis of electrocardiographic, pneumographic, thermometric and metabolic information by an available biomedical control algorithm, development of onboard medical control means operating through an onboard computer system capable to monitor the physiological state of the crew member involved in EVA without assistance from Earth, and development of programs and procedures for training crew members to independently provide medical support of EVA aboard a space vehicles and onboard the Lunar/Martian habitats during surface sorties [8,11].

Suit pressure. The EVA system is designed to operate in a Lunar vacuum or in rarefied Martian atmosphere. Ideally the universal SS would provide the same pressure as the cabin pressure inside spacecraft. However SS operating pressure directly effects the dexterity of the gloves and even at the low 'Apollo' suit operating pressure 25.9 kPa there is considerable stress on the other suit's structural elements and on the human body. The higher suit operating pressure of 30 kPa and 40 kPa used in the USA and Russian suits, respectively, require pre-breathing to prevent decompression sickness (DCS). An important thing to do is to minimize time needed for switch over from IVA mode to EVA mode.

The extended pre-breathing procedure performed to remove nitrogen from the body decreases effectiveness with which crew member working time is used and increases consumption of gases [8]. This is the reason for activities on pre-breathing-free suit with the operating pressure 50 kPa and higher run for the recent 30 years [1,24]. However, this technical challenge has not been met yet [16,25], because zero pre - breathe conditions more than double the operating pressure mode. This is

significant because the repeated mating and de-mating of field-joints, such as the gloves and helmet, can lead to wear and leakage.

A protocol that involves staying in an artificial hypobaric atmosphere under 70 kPa pressure is effective. It was proposed for the 'Luna-3' program [1], materialized in the Apollo-Soyuz Test Project, and used currently in the Shuttle Program [25]. The protocol provides a step-by-step decrease in the spacecraft pressure as a preparation for an EVA period. The use of a reduced pressure (within the 20...30 kPa range) in a space suit after a long staying in a hypobaric atmosphere is also possible but only in emergency situations since there is a certain risk for DCS incidence [8]. However the use of such a protocol will enable crew members to immediately perform EVA during offnominal or emergency situations without wasting any time for pre-breathing and without a high risk of DCS incidence [8]. A switch over to a higher suit operating pressure mode will depend on the progress made in the development of enclosure joints improving mobility. Any sophistication in EVA support systems must be aimed at improved safety and decreased work loads. Some of the considerations for new EVA systems are minimizing the transition time between IVA and EVA (i.e. different pressures versus DCS and airlock depressurization intervals), maximizing available time for productive EVA (i.e. life support capacity, availability and maintainability), providing minimal restriction of normal human capabilities (both physical, and psychical), minimizing suit mass, numbers of suit sizing adjustments, and mobility aids, increasing communication capacity.

Concept of a universal suit for lunar and mars sorties

The semi-rigid Orlan-D space suit was first worn for a spacewalk on 20 December 1977 by cosmonauts Yuri Romanenko and Georgy Grechko, the crew of the Salyut-6 space station. Ever since, the ever-evolving Orlan family of space suits has invariably been a part of flight hardware on board the Salyut and Mir stations and International Space Station. The Orlan space suit is developed by science and production enterprise "NPP Zvezda" in 1964 -1969, and its origins date back to the 'Luna-3' Program [1]. Apart from moon-walking, the mission program was to include EVA operations to transfer cosmonauts (second pilot) from the lunar orbital spacecraft into the lunar Lander and back [1,21]. The cosmonaut transferring from one module to the other was supported by the mission commander who was also suited up. The commander's attire was a lighter model with fewer life-support system resources. After the benefits of semi-rigid space suits were verified by testing, and on the assumption that EVAs would become common on board an orbital station 'Salyut', the designers at Zvezda produced two options: the lightweight emergency rescue attire and the more refined, reliable and heavy EVA space suit, of the Orlan type [1,21].

The benefits included a shorter unassisted suit-donning/suit-doffing time of no more than 5 minutes and the possibility to adjust the suit in orbit to fit cosmonauts of different size and height [1]. For the Lunar/Martian suit enclosure the following design solutions are feasible: 1) Soft suit – It means the elastic suit from fabric. The enclosure has few layers manufactured from fabric compound with elastic and gasproof materials (native rubber, synthetic polyurethane). 2) Rigid suit - It means that all elements of space suit are rigid, except gloves (the materials are composite or metallic shells with gasproof bearings and joints). 3) Hybrid suit - It means semi-rigid enclosure complex (with soft limbs and hard torso and helmet assembly).

Table 3 shows the comparative mass data for known EVA SSs the design of which may be used as a prototype for a planetary SS. Table 3 shows that a rigid SS is the worst option for Lunar and Mars missions because of weight since this parameter is crucial for the selection process. As shown in Table 4 one suit of an universal 'Orlan' type can adopt to three types of space suits which need for expedition to Mars. Weights of the soft space suit A7LB (or soviet Orel suit) and the semi-rigid Orlan suit do not differ much, however the practice has proved operational advantages of the latter. We are of the opinion that the optimum approach is to develop a baseline semi-rigid suit enclosure to support EVAs both in orbit, and on the Moon or Martian surface.

A semi-rigid EVA suit with a rear entrance through a hinged back-pack and a minimum number of pressure bearings on the lower torso assembly (LTA) looks the most promising for Martian

missions [8]. By reducing the number of pressure connections made for each EVA sorties the rigid upper torso/helmet/backpack assembly minimizes leak paths. This rigid assembly design (called the cirase) avoids a neck ring connection with a seamless union of helmet and upper torso. This configuration integrates external visibility with internal displays offering cosmonauts a portable control center for improved autonomy, safety and productivity. These displays provide direct viewing of the check digits and the diagrams while allowing cosmonauts to keep both hands on the job. The cirase combined with single point rear entry and the maintenance of keeping gloves attached between EVAs minimizes the wear on joints. Long-live pressure integrity is approved by having a single - point connection at the backpack. A major feature of the cirase combined with backpack is a dust - resistant design. All displays are internal avoiding problems of dust buildup and except of the backpack, all pressure joints remain intact until servicing, minimizing exposure to dust. Outer sunlight-visor assembly protect double glasses (polycarbonate) from scratches. The replaceable outer garment inhibits dust from reaching moving parts of the joints and the bearings.

This type has the following advantages: quick donning/doffing; backpack and enclosure form a single pressure tight volume no outside lines/tubes; PLSS maintainability; replaceable arms and LTA; minimum number of type sizes.

The modularity is a key benefit both a semi-rigid EVA suit with a rear entrance, and a backpack with PLSS in its shell [1]. They range from simple pressure suit enclosure with umbilical interface for tethered EVA to an autonomous extended -range PLSS (See Fig. 3). The backpacks are easily removed for transport into clean environment for servicing and maintenance. Modularity concept is extended to the soft gloves, arms, and legs (LTA). For the certain operations where tasks are well understood, repeated clamping may be required. This is fatiguing operation using a pressurized glove and a reason for manipulator or end-effectors to mate to the wrist bearing instead glove. A number of concepts for pressure suit mechanical and automatic end-effectors have been developed. Using these manipulator options, provides the space suit with mechanical advantage and tireless clamping specially useful in construction of Lunar/Martian base habitable modules.

During the decent/accent phases, a suit designed for the EVA on the Lunar/Martian surface must be used as an IVA suit in the landing module. Such an approach will save the total weight [8]. The concept of a universal suit should take into consideration that a crew member will be exposed to descent/ascent induced accelerations ‘wearing’ the suit. It is suggested to use one universal space suit for a Lunar/Martian mission instead of three SS types shown in Table 4. The problem is, that the low friction bearings (that offer effortless mobility in weightlessness) provide no any support in a gravity field. This means that with absence of inflatable spring column entire weight of the suit is carried by cosmonauts. In a gravity field, cosmonauts actually sit within the ballooned suit adjusting the eye point and sometimes compromising visibility. In the pressurized space suit foot control of automotive vehicle would be imprecise and tiring, therefore cosmonauts seated (or stood) in the Lunar/Martian rover urgently used a hand controller (See Fig. 2 and Fig. 3). Another advantage of the standing posture is that the legs serve as natural shock absorbers whereas when seated like in 'Apollo' program, the ride is rough, as confirmed by lunar rover astronauts [6,7].

Table 3. EVA System features since ‘Apollo’ and ‘Lunar-3’ programs: Comparison of operating pressure, oxygen prebreathing modes, EVA suites and Life Support System weights [1,2,4,6,14,25]

	EVA Space Suit	Operating Pressure, kPa	Prebreathe time, hr	SpaceSuit Mass, kg	PLSS Mass, kg	Total Mass, kg	Lunar/ Mars Weight, kg	Enclosure type
USA	Apollo A7LB (1969)	25.8-26.2	N/A	27	50	89	14.8/33.7	soft
USA	Shuttle EMU (1981)	28.3-29.6	2.5-4.0	50	73	123	20.5/46.7	semi-rigid
USA	ISS EMU	29.6	2.5-4.0	80	73	153	25.5/58.1	semi-

	(1998)							rigid
USA	AX – 5 (1990)	57.2	0	77 ... 86	100	177	29.5/67.3	rigid
USA	Mk – III (1990)	57.2	0	73	123- 195	209- 285	34.8/79.4	semi- rigid
USSR	SKV (1962 - 1965)	40	0	85	TBD	TBD	TBD	semi- rigid
USSR	Orel (1966 - 1970)	40	0	20	36	56	9.3/21.3	soft
USSR	Orlan (1967 - 1971)	39.2-40	0	33	26	59	9.8/22.4	semi- rigid
USSR	Orlan-D (1977)	39.2-40	0.5	33	40.5	73.5	12.3/27.9	semi- rigid
USSR	Orlan-DMA (1988)	39.2-40	0.5	33	72	105	17.5/39.9	semi- rigid
Russia	EVA SS – 2000	40-50	0.5	25	75	100	16.7/38	semi- rigid
Russia	Orlan-M (1998)	39.2-40	0.5	30	82	112	18.7/42.6	semi- rigid
Russia	Martian SSprototype	27-40	TBD	30	TBD	TBD	TBD	semi- rigid

Note: Variation of AX-5 mass depends on its size. The weight of EMU and Mk-III enclosures is very high due to a lot of bearings. Variation of Mk – III PLSS mass depends on the changing in requirements of Space Station ‘Freedom’. N/A – not applied; TBD – to be defined.

Table 4. Types of space suits for Lunar/Martian Mission and their application features [8]

Type	Application	Task	Application features
For EVA in free space	On the external surface of the spacecraft during orbital flight or in the Lunar/Martian vicinity	Non-scheduled EVA; off-nominal maintenance or repair operations; and emergency situations	EVA under conditions of vacuum, microgravity, and high level of ionizing radiation. Additional complectation and upgrade
IVA inside spacecraft modules	Active phases of the flight, inside a landing module	Protection against de pressurization of cabin or explosive decompression	Decent/Accent accelerations. SS compatibility with shock absorbing devices
Planetary	Sorties on the Moon, Mars, Phobos and Deimos surfaces	The repeated and productive EVA during Moon and Mars exploration	EVA on Lunar/Martian surface: hypogravity, cosmic, and solar rays. SS high mobility and dexterity. Compatibility with rover and lander.

To assist in operating from the standing position the cirase has two structural attachment points at the mid of rigid torso [3]. Cosmonauts secure suit structure to the 'LK' Lander, automotive vehicle or rover flight deck then lock boots into foot restraints for a rigid, four-point connection. These arrangements in conjunction with column - like legs minimizes the weight carried by the cosmonaut.

The study performed leads to the selection of a semi-rigid suit with the enclosure and backpack of a modular design that offers improved maintainability/serviceability and can become a basis for a flexible concept of a universal space suit. Modularity shall be extended to the hard and soft parts of the suit enclosure (helmet, torso, backpack, arms, gloves, legs and boots). The suit of the proposed type offers EVA capabilities in the cruise phase or operations on the Lunar/Martian surface during sorties. Moreover this suit has intravehicular capabilities with suited mode in cabin during descent/ascent of Lunar/Martian expedition complex.

Conclusion

It is possible to use one universal SS for a Lunar/Martian missions. This is a semi-rigid SS with a rear entrance. For unscheduled EVAs in the cruise phase it is fitted with additional protection layers. In active phases of the mission near Mars or Moon it will be used as an IVA suit in combination with a shock absorbing system. This type of SS calls for highly reliable components and equipment featuring a long operating life. A universal SS with replaceable components will expand human activities in space. Development of universal SS will facilitate a general success of Lunar exploration and first manned mission to Mars.

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