LIFE SUPPORT SYSTEM FOR AIRCRAFT CREW

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ABSTRACT

The problem of achieving the correct physiological conditions, for maintaining the normal functioning and efficiency of the crew during flight in the civil or high-performances combat aircraft, requires an systemic approach and technique for the concept formulation and design of personal and cockpit protective equipment. Design of the Life Support System for the new aircraft depends on combined technical, physiological and medical requirements, more exactly, on the adoptive criteria. For this reason, the creation must be incorporated to analyze interactions between various parameters in the form of the aircraft performances, the environmental characteristics and analysis of its influencing on the tolerance and possibility to human body adaptation in hostile flight condition. In the case of a multi-purpose combat aircraft, design points, overall requirements of Life Support System and local requirements of subsystems, must be defined so that complete protective functions must be most effective in Central Design Point - Combat conditions. This paper describes one of the modern designed method and an approach for maximal integration of the functions of anti-G requirements, altitude protection and thermal comfort requirements of the Life Support System. It explain essential differences between system' requirements in Central Design Point and subsystem's Local Design Points.

Key words: crew protect equipment, life support, cabin pressurization, breathing system, positive pressure breathing, anti–G, comfort in pilot cabin, seat ejection.

A need for personal protection in aeronautics

Introduction

Impressive achievements of contemporary aeronautics originate from exeptional and creative energy the man has invested in continuos advancement and improvement of the aircraft characteristics. Today, the new technologies, aeronautical materials, modern aerodynamics forms make possible construction of the planes with high mobile and maneuvering performances, but limiting factors in further development become physiological features of a pilot, per se. This particular problem will, probably, be resolved in aircraft without human crew. Nevertheless, the advantage to apply knowledge, experience and intuition simultaneously in unpredictable situation, still keeps the man as an unchangeable subject during flying. It is considered that one needs optimal conditions to be able to make timely and qualitative decisions. That is the problem analyzed in this paper.

Types of the external influences

Man was gifted by nature to adopt to various environments at our Planet. However, intensive and sudden changes of the external world occurring during a flight, overcome physiological tolerance and body reserves. It is inevitable for organism functions to decrease for the existing circumstances over a certain altitude. Because of the,progressive aggravation of vital functions, even an exitus, it is necessary to obtain at least biological environment in cockpit similar to that on earth. Unique combinations of forces, acceleration and visual effects not involved in evolution of the human nervous system point out the need for engaging the experts' teams in researching all preventive medical measures and technical protection so the man's persistence under pressures of flying could be increased.

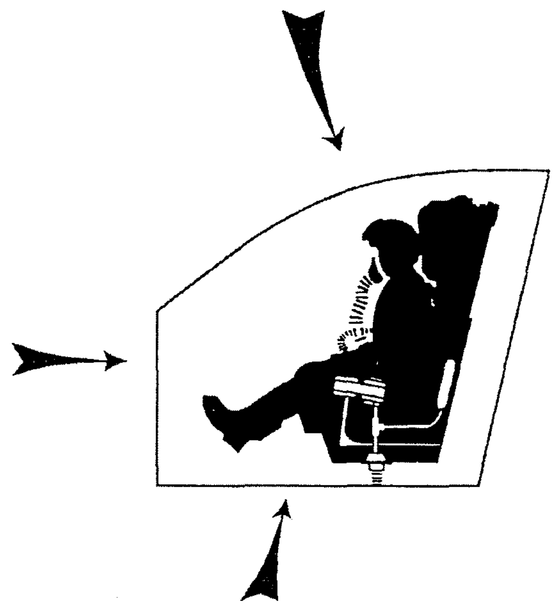
The crew and the passengers in civil aeronautics are, actually, exposed to a limited number of external influencing factors. That includes changes of pressure, temperature, sun radiation, strong vibrations, .oise and permanent incident's risks. For the reason of a relatively modest amount of external factors, protective systems in modern airplanes are being improved technically so much and incorporated in general comfort so discreetly that a large number of passengers don't even notice their true effects.

To protect the personnel or the pilot in a military aircraft becomes a significantly more complexed problem. The reason for it seam to be numerous and various external factors, as the combat performances of the plane, the danger of enemy weapons and the elements consisted in war doctrine (Fig 1). In this particular case, concept and applied protection of the pilot depend on technical purposes and performances of the plane, in the first place. Therefore, significant differences exist in personal protection equipment.

The planes with varied characteristics, high flying and maneuvering possibilities present the biggest challenge for resolving the personal protection. Though the requests are numerous, it is clear that protective equipment is not to be adjusted to each mission, separately.

ADAPTATION POSSIBILITIES OF THE PILOT'S PHYSIOLOGICAL FUNCTIONS	"TARGET" ORGANS
• RESPIRATORY FUNCTION, DURATION OF "CLEAR MIND" - HYPOXIA	BRAIN
• CIRCULATION SYSTEM TOLERANCES OF THE PROLONGED EFFECT OF ACCELERATION, "G–LOC", LOSS OF CONSCIOUSNESS	EYE, BRAIN, CIRCULATION
• REGULATION OF THE BODY TEMPERATURE, COMFORT, HEATSTROKE, SWEAT, SHAKING, FREEZING	BRAIN, SKIN, LIMBS
• TOLERANCES OF THE NOISE AND VIBRATIONS, COMMUNICATION AND COMFORT	EAR, NERVOUS SYSTEM
• RADIATION AND POISONING SENSIBILITY	CELLS, BRAIN
• LIMITS OF PERSISTING CATAPULTATION	SPINE, HEAD, SKIN, SKELETON

EXTERNAL FACTORS
THE CHANGE OF THE ENVIRONMENT
• PRESSURE DECREASE • EXTREME TEMPERATURES • SOLAR GLARE
INFLUENCE OF THE PLANE
• HYPERGRAVITATION • HYPOGRAVITATION • NOISE • VIBRATION • SPEED (KINETIC ENERGY)
ENEMIES' THREATS
• ENEMIES WEAPONS • FIRE, SMOKE • NUCLEAR FLASH • LASER • NBC CONTAMINATION
WAR DOCTRINE
• RIVAL'S SOLUTION OF THE LSS • TASK (MISSION) • COMBAT TACTICS



THE INFLUENCE OF THE LSS FOR A PILOT
FIRST DEGREE OF PROTECTION - COCKPIT
• MAINTENANCE OF THE AIR TEMPERATURE IN COCKPIT • MAINTENANCE OF THE PRESSURE IN COCKPIT • PARTIAL PROTECTION OF FIRE, NOISE AND STROKES
SECOND DEGREE OF PROTECTION - SUITS AND PERSONAL GARMENT
• OXYGEN SUPPLY (BREATHING GAS) • INCREASE OF THE TOLERANCE LEVEL OF G LOAD • MICROCLIMATE - VENTILATING SUIT, • PRESSURE CONTROL IN FLIGHT SUIT - ALTITUDE SUIT • ESCAPE, SURVIVAL, PROTECTION FROM FIRE, SMOKE, WATER, STROKES, NOISE

FIGURE 1 – Pilot's protection needs in a military plane

Particular attention is paid and serious difficulties occur when personal protection is planned for a fighter because the elements of the war doctrine are added to all external factors. It makes the pilot's aim in air battle consisted of mental characteristics and plane's possibilities, to gain the advantage and to force the enemy to defense. Keeping the maximal concentration in those conditions require not only tolerant life or working terms, but reaching the highest level for vital human functions. So, the protection is to be optimal and adequate to the top plane's performances, created at least equal or better than rival's.

Integration of the protective functions in the Life Support System

New technologies and advantages of the microprocessing communication with plane's data computer enable high level of integration of the protective functions considering the optimized complexes structures of protection based on valuable criteria in aeronautics [4]: high operative readiness, reliability, functioning, minimal mass and dimensions. Personal protection includes, also, next elements of the coplex system:

- scientific variety and a complex of functions;
- global aims of the system and local aims of the subsystems;
- automated conduction on highest level;
- need to adjust to different work conditions.

There is a functional entirety connecting mentioned characteristics and ensuring a systemic approach to solving the protection of pilot during flight. It is recognized as Life Support System (LSS).

The optimization examples of the theory of systems [3], were used in this paper for the prove that a systemic approach to resolving noted problems is obligate. It is realized on an example of fictions military multipurpoe plane though in a digested form.

Global aims of the LSS

The first step in creating protection is to determine global aims. Knowing these aims limit the amount of environmental analysis, as the aircraft's characteristic, anatomical and physiological human features, respectively. Near, these weight factors, selection criteria, limits and priorities of work, precise local aims of the subsystems, also support all needed elements for the optiomalization of the entire system.

Global aims of the LSS feature as common tasks in front of various pilot's and plane's equipment for maintaining the terms under which vital physiological human systems function in flying conditions. In other words, the aim of the LSS is to keep necessary circumstances for life and work of a pilot.

Considering this definition, global aims of the LSS are following physiological and anatomical requests:

a) protecting the pilot from low pressure influence at the high altitudes during flight;
b) ensuring the normal metabolism and thermal comfort during flight or the preparation for a flight, as making possible temporary bearable level of discomfort in termic extremely inconvenient and labile environments, as well,
c) preventing excessive dislocation and distension of intern organs, opposing the inertial motion of organic fluids in circulation system during hypergravitation in maneuvering under high G loads;
d) neutralizing the effects of high level of noise and vibrations on the pilot's organism, preserving the communication of pilot with his pair or the base;
e) ensuring quick ejecting and safe parachuting, landing and selfaid, during flight or on earth.
f) Protecting the pilot from sunglare, heat and radiation if the plane comes near atomic blast or is flying through a NBC contaminated atmosphere.

Previously defined the global aims of the LSS, point at physiological functions and anatomical features of a pilot who need to be protected. They could guide the analysis of the external factors of influence on body physiology. Particular realization of unified protection must consist of mutual action of several subsystems (Fig 2).Technically, these systems can be considered as independent units but their functions, capacities and conduction are coordinated and directed to the common aim of the system.

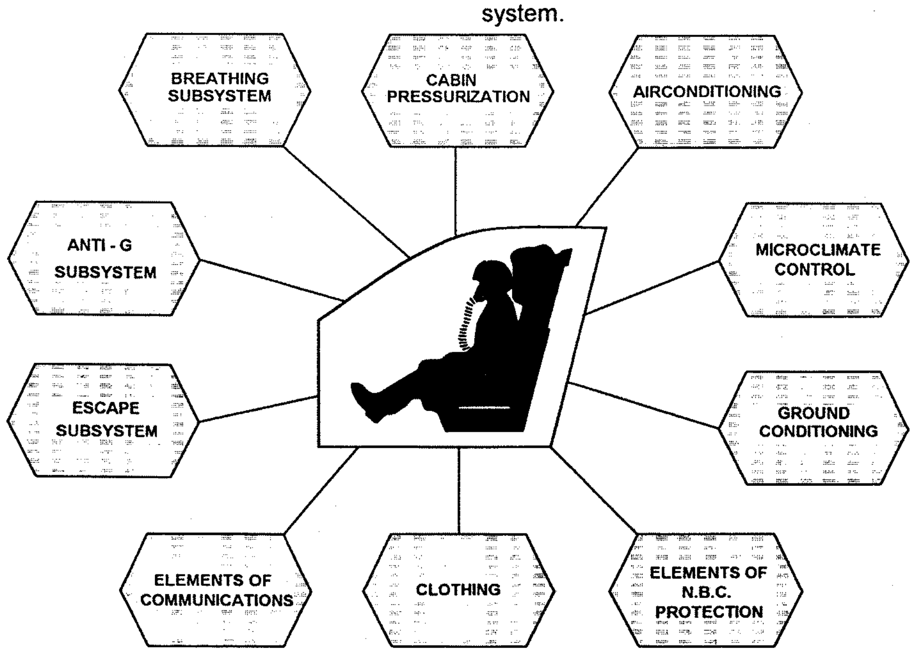


FIGURE 2 - Subsystems of the Life Support System

Flight characteristics of the aircraft A2000

To describe an object, in this case, to edit data on flight characteristics, purposes, tactical and technical requirements of an aircraft, is of the outmost importance for approving concept of the LSS. The plane A2000 joins the modern generation of multipurpose airplanes such as MIG–29, F–16, F–18, SU–27, Rafale, EAP, Gripen, Lavi. It's tasks are various: to support land and navy forces, to participate in antiaircraft defense, tactical and strategic reconnaissance, as an interceptor and fighter in a direct battle. Concerning the limited space and mostly known flight characteristics of mentioned planes, this paper will describe a single, not standardized mission of A2000: interception, attacking with high speed the high flying target and involvement into a direct air battle (Fig.3). This is a particular mission because it burdens LSS significantly.

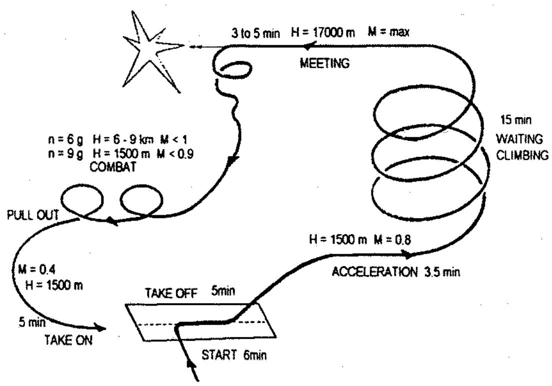


FIGURE 3 - A mission with reaching maximal altitude

Previous experience have shown that a direct air combat usually starts by maneuvering on high subsonic speeds with a huge loss of energy, then reaches maximal attacking angles and leads to the edges of load values instantly.

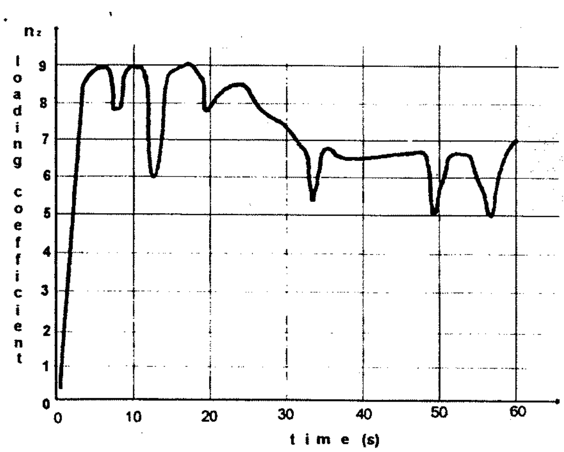


FIGURE 4 – Characteristics of workload in an air fight

Limited workloading for the aircraft A2000 is 9 Gz. Practically, there is a tolerance of workloading of ±1Gz. For that reason, automatic devices in conducting a flight control system must prevent an uncontrolled excess of permitted loading and penetration flight angles. It releases the pilot from watching the accelerometer while critical maneuvering is on. An example of normal acceleration (n_z) during a minute of an air fight is presented at Fig 4.

As maneuvering possibilities depend on the speed of an aircraft and the atmosphere density, a graph on Fig 5. explains approximated calculations' envelopes while A2000 is able to reach loading coefficient of 6, 8 and 9 Gz in stationary turn.

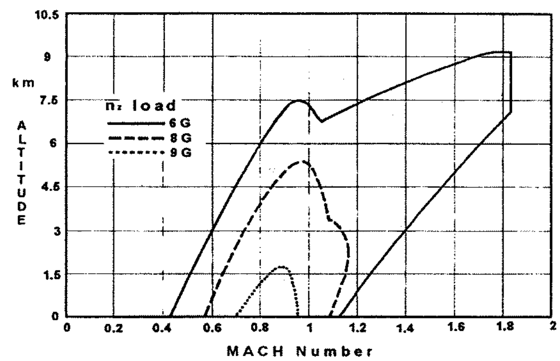


FIGURE 5 - Envelope of load

Envelopes of speeds and flight altitudes of plane A2000, with and without additional combustion of engine are presented at Fig 6.

Optimal flight speeds – speeds of plane's cruising are 0.5 to 0.85 M and are reached at heights of 6000 to 9000 m. Flight ceiling is touched by maximal thrust what actually means that the aircraft is on this flight altitude within 5 to 10 minutes.

Human biosphere, earth atmosphere

Various nature of the LSS implies that atmosphere characteristics and rules of the space in which A2000 will operate, should be treated from two aspects. The first of those is the evaluation of medical and physiological terms in flight surrounding. It is consisted of analyzing the quality of atmosphere from the vital physiological human functions point of view in altitude's zones, known as „physiological zone“, „physiologically compensable zone“ and „zone equivalent to space" considering the physical laws inside.

The second aspect considers formation of a precise specification of surrounding conditions under which the aircraft A2000 will operate. That means that chosen envelope of projecting terms is able to influence particular components or subsystems' capacities (e.g. airconditioning) which consequently influences the mass, dimensions and costs.

The advantages MIL standards [15] offer when the reliability required and military availability of the plane are considered. These are: the choice of lower and/or higher criteria for extreme para–meters' values of environment, the acceptance of a certain risk in project, the development of particular envelopes for surrounding conditions according to it's function on a plane or to it's input (place). All of these possibilities are valuable for the LSS, because the LSS is projecting not only to compensate changes in idealized „standardized atmosphere" but not to consider most of deviations form standardized variables continuously present in the real atmosphere.

It was not possible to show a complete specification of environmental features (tempe–rature, pressure, humidity, wind solar energy and their combinations) so the Figure 6 illustrates a derived envelope of temperatures for A2000.

Analysis of the human vital physiological functions

Analysis of the human vital physiological functions presents an important part of the LSS project with the aim to define the request coming from physiological, physical and mental possibilities of a pilot [8]. Translated in technical requirements, these are input information for the LSS project. The base of analysis must be wide. It is necessary to include situations when a pilot is undisturbed while flying (routine flights), when one invests strong psycho–physical efforts for maximal usage if the plane (air fight), when extreme situations involve survival with out injuring.

A brief commentary of the analytic basics follows and only for those parts of aerophysiology when a particular attention must be paid for the A2000 performances and the global aims of the LSS.

Respiration (hypoxia)

To alleviate the influence of hypoxia there should maintain the partial pressure of oxygen in alveoles, from 80 to 133 mbar [8]. In that way, a normal arterial oxygen supply above 87% is reached and circumstances for hypoxia are locked in an indifferent zone. In the aircraft A2000, it could be assessed in two ways: by a pressurized cockpit and by inspiring the breathing gas with regulated oxygen concentration [10] (see Tab 1). On high altitudes, pure oxygen is being inspiring with overpressure in trachea and contrapressure on pilot's body.

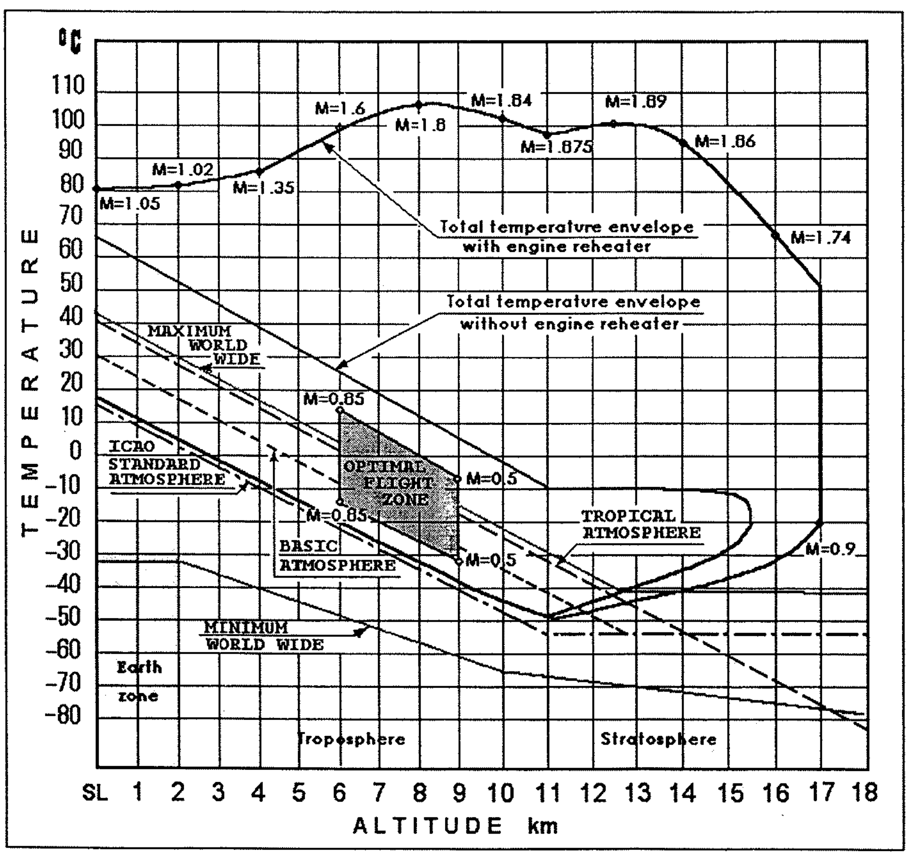


FIGURE 6 – The envelope of temperatures for A2000

Flight altitude (m)		Barometric pressure (mbar)		Contend O_2 in cockpit air (%) + PPB (mbar) = ekvival.high	
Geopotencial	Cockpit	Atmosphere	Cockpit	Unpressurized cabin	Pressurized dp=300mbara
0	0	1013	1013	21	21
1500	1500	843	843	25	25
2000	2000	795	795	27	27
3048	2000	709	795	31	27
4572	2000	572	795	40	27
5650	2000	495	795	44	27
6096	2400	439	739	49	29
7620	3300	376	676	62	31
9144	4250	300	600	81	36
10364	4900	249	549	100	39
12192	5800	184	484	100=ekv.3048m	45
12192	5800	184	484	100+20=ekv.0m	45
13100	6250	156	456	100=ekv.4500m	49
13100	6250	156	456	100+20=ekv.3048m	49
15240	6950	115	415	100+40=ekv.5400m	56
15850	7100	105	405	100+77 / 30s	57
18288	7700	72	372	100+96 / 60s	64

Table 1. Oxygen supply in breathing gas according to function of barometric height

A baro-injury and decompression sickness

The protection from disturbances caused by pressure changes is a pressurized cockpit and maintaining cockpit's height bellow 9.000 m, altitude suit and denitrogenization [10] by inspiring pure oxygen as a preventive measure.

Vibrations, noise and talk communication

This particular problem is solved most effectively by muffling the origin of vibrations or, but the helmet and personal protection device contribute too.

Effects of acceleration

Bad effects of positive acceleration are blood pressure decrease and deceased flow rate through the brain. Every measure which neutralizes these effects is orientated to keep an adequate pressure on the eyes level.Practically, there is a combination of four possibilities for the protection up to 9 Gz:

- individual preparation - "breathing maneuver",
- application of the "antigravitation" suit and "G" sensible breathing system (PPB breathing)[13],
- the position of body, meaning the back seat' s angle and
- choice of pilot (inborn characteristics).

Load during escape

Primar aim of the escaping subsystem is to enable pilot's survival with out injuring in any of possible escape situations. The most critical and unpredictable combinations of escape offer escape with possible injuring. The requirements of the designed points for this subsystem are defined on extreme limits of body persistence when exposed to mechanical forces. Supersonic plane A2000 is complicating the realization of the LSS design, because it requires solution of protection from five factors with a lethal potential of each:

- load of the high–G, body–axis acceleration (seat ejection),
- load of the body transverse,high-Q deceleration
- windstrike and blast effects of dynamic air flow,
- spinning, vortex and strike when parachute opening
- atmosphere influence on high altitudes.

Body temperature regulation, comfort

Under specific circumstances in the cockpit it is very difficult or even impossible to assure all factors influencing the comfort optimally. For this reason, in transient conditions of flight and very inconvenient climatic conditions all three degrees of discomfort should be encountered. Thermal comfort in an fight plane cockpit involves all terms under which the pilot, during the flight or it's preparation, feels good with out occurrence of body shaking because of cold or sweat because of heat.

The thermal comfort is obtained by a combination of suit, the effect of microclimate, air-conditioning of the cockpit and ground conditioner.

Central Designing Point, concept and general performances of the LSS

Analyzing the flight performances and tasks to fulfill, it is suggested that the aircraft A2000, in most of all situations, will fly with optimal speed, altitude and moderate acceleration (patrolling, routine flights, education, reconnaissance, even during military missions). In these circumstance there are no high requirements for the LSS.

However, there are typical task – phases of the mission requiring maximal engagement of particular subsystem for which practical performances and capacities of the LSS are being determined. These are reaching the maximal altitude, very low flight with high speed (following land form), and flying with high workloading. Accented flight segments are dominantly important for the LSS and, often, associated in A2000's action as a fighter in a direct combat. Thus, the LSS is an included element of a war' doctrine. The system is involved during entire mission, from duty in the cockpit to keeping the maximal concentration while entering the complexed military maneuvers. A full contribution and a coordinated work of all subsystems is required. That is way a mission with maneuvering typical for an air flight is a model for accepting the concept of the LSS for A2000, in this paper. It presents CENTRAL DESIGNING POINTS of the system engaging almost every subsystem of the LSS for:

- flight altitudes H =100 to 5000 m
- flight speeds: v = 0.8 to 1.0 M,
- normal acceleration: n_z = 7 to 9 Gz,

pointing out following physiological requirements:

- a complete thermal comfort,
- oxygenation of hemoglobin in blood of a pilot above 87% – „clear mind" conditions for hypoxia in an indifferent height zone,
- prevention of the occurrence of G–LOC („black veil") – permitting the blood circulation to the brain while hypergravitation is on,
- endurance of the clear communication of pilot with his pair or a base,
- increasing safety and moral, thus making providing possible for pilot to eject safe in all extreme situations.

Though every other mission request lower criteria for the entire LSS, it is understandable that profiling capacities and local performances of each subsystem will depend on a mission which maximally loads the subsystem. That's the moment to compromise and accept lower standards for comfort, but with out a reverse effect on performances of the system in CENTRAL DESIGNING POINT.

Considering previous fact, basic concept of the LSS, adapted for the aircraft A2000 is on the following principles:

- the level of pilot's protection is to be adjusted to the needs of A2000; to apply modern and efficient protective devices and provide fast adoption to new and better solutions;
- met to compromise for any of physiological terms in the CENTRAL DESIGNING POINT which consides all subsystems;
- out the CENTRAL DESIGNING POINT compromises and lower criteria for the optimization of the system can be accepted;
- the capacities and performances of particular subsystem should be determined on LOCAL DESIGNING POINTS for each subsystem;
- to realize a high system effenciencu adopting the solutions of high operative readiness, reliability and effects with minimizing the masses of components.

As the terms and requests in the CENTRAL DESIGNING POINTS were defined, the concept of the system accepted and protection needs, as ell as previously adopted criteria were analyzed, the conditions for defining basic characteristic of the LSS for the aircraft A2000 are fulfilled:

1. For the hypergravitation protection is accepted a solution of integrated functions of classic anti–G protection and Positive Pressure Breathing. This solutions, for same man, increasing efficiencu of protection for about 3 Gz.It also requires improvements in pilot's suit, breathing subsystem, anti–G subsystem and their internal intelligent connection.
2. For the hypoksia protection, a solution of integrated functions of pressurizing the cockpit and gas breathing with regulated oxygen inspiration is accepted. Pressure breathing is expected when the cockpit is decompressed. This solution minimizes the oxygen producing device installed in the plane, increases the efficiency of the subsystem and influences decreased mass of the anti–G and weight protective subsystems. It, also, requires improvements of the oxygen mask sealing quality and application of a suit with contra–pressure chambers on pilot's torso.
3. For the decompression sickness protection functions of pressure breathing and anti–G in an integrated pilot's suit are provided. It is the way to minimize the mass for this particular function and includes wearing of pressurized gloves, as well as added microprocessoring device for conducting pressure regulators, anti–G and breathing subsystems.
4. Thermal comfort is provided by functions of the cockpit area air-conditioning and microclimte in the flight suit, supported by a ground conditioner and thermal isolation of the cockpit. It offers a maximal efficiency to the system and provides a decreased mass of the air-conditioning subsystems. Further, requirements are installation of the microclimate subsystem and coordination with the air-conditioning subsystem of the plane (cockpit and electronics area).
5. Protection from noise is provided by integrated effects of acoustic processing of the cockpit and personal protective equipment. It is a reliable solution which decreases the mass, also.
6. Protection from N.B.C. contamination and smoke is provided indirectly: by a pressurized cockpit, breathing the uncontaminated gas from subsystem breathing reservoirs and by flight

suits characteristics. It is an effective, reliable and of minimal mass solution.

7. Successful escape is guaranteed by an eject seat with controlled impulsive loading, a controlled path in all combinations of positions, speeds and heights in the moment of catapulting. It is also provided by personal equipment – suits, helmet and mask of top performances. This is a high effective solution with increased survivability on high speeds and low altitude. It requires a seat microprocessor, a large number of rockets for path's correction, and additional devices for speed and acceleration measuring, as well s an intelligent connection with the plane's computer.

Previous characteristics of the LSS for the aircraft A2000 point out hang, almost generation differences among existing concept and solutions of pilot's protection of 2000's. An improvements, new devices, integrated functions of protection as on the personal suit and equipment and in plane's appliances consequented from extreme requirements of the plane itself, environment, physiological possibilities and anatomical characteristics of the man.

CONCLUSION

The need for further research and the importancy of completion of protection functions in an integrated LSS was the main intention of this paper. Nevertheless, it is not possible to avoid detailed investigation on every subsystem when the actual realization of the project is on. Outstanding significance is of the mutual functional dependence and interactive connections in conducting the subsystems.

On ideological resolution of a practial subsystem is determined consequently through following stages:

- the tasks of the subsystems involved in LSS – local aims of the subsystem,
- general characteristics and their internal connections,
- determination of the local designing points (steps),
- anticipation of the capacity of the performances and
- definition of conducting functions following priority level.

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