EMERGING ASPECTS IN THE PROCESS OF MODERNIZING INTEGRATED AIRSPACE SYSTEM

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***Abstract**: This article describes an optimization model of the Surface-To-Air Missile System as a technical integrated system. The theoretical model of optimization describes the basic relationships between the Life Cycle Cost of the system and the frequency of upgrades related to the moral decay, in time. The financial crisis has forced an extension of the system operation even if the system is outdated. Therefore, a new modernized version has been designed.*

***Keywords**: LITS (Large Integrated Technical System); SAMS (Surface-to-Air Missile System); LCC (Life Cycle Cost); Cb(t) (unit acquisition cost related to the operating time) Cm(t) (Cumulative cost for preventive maintenance during the operating time); Cr(t) (Average unit cost for Repairs).*

1. INTRODUCTION

Numerous specialists in the scientific field of missiles have approached major topics related to missiles (regarded as typical examples of bodies with variable mass) such as: improvement of missiles' flight performance and of their dynamic stability, or, possibilities of minimizing guidance errors and of optimizing modernization processes.

The twentieth century has been regarded as a complex temporal space characterized by continuous quantitative increase and qualitative change, both of these coordinates contributing to the ongoing process. In this context, intuition is not sufficient in appreciating the complexity of a technical integrated system, therefore, although it is very difficult to do so, a clarification of theoretical background is mandatory. The complexity S of the system consisting of sub-systems or complexity elements $S_{i,}$ i=1,2,3……,n will further be determined based on the relation:

$$S= \sum S_i K_i \qquad (1)$$

where K_i represents the number of type *i* elements in the system. The first large technical systems were designed following the anti-air defense. By a careful analysis of the guidance systems of surface-to-air from the perspective of automated systems, we can highlight the requirements imposed on them and their functioning principles, in tight connection with gathering data related to movement parameters of air targets.

Figure 1 shows a simplified scheme of a missile system in a tight functional connection with its constituent elements; the final aim of it being the optimization of one of the efficiency criteria or more. The experience in designing and exploiting of modern airspace integrated systems proves a greater and greater technical and technological complexity, holding financial implications. This endeavor requires a long time up to its accomplishment – from 2 to 5 years -, in accordance with the system's complexity. To determine more precisely the connections between elements of a technical system, we must define the following: S1-matrix of connections between input and output; S2-matrix connections between elements of input and output of the system; S3-matrix connecting the input vector of the system with the output vector out of the totality of elements; S4-matrix connecting the input vector of the totality of elements in the system with the output vector of the system.

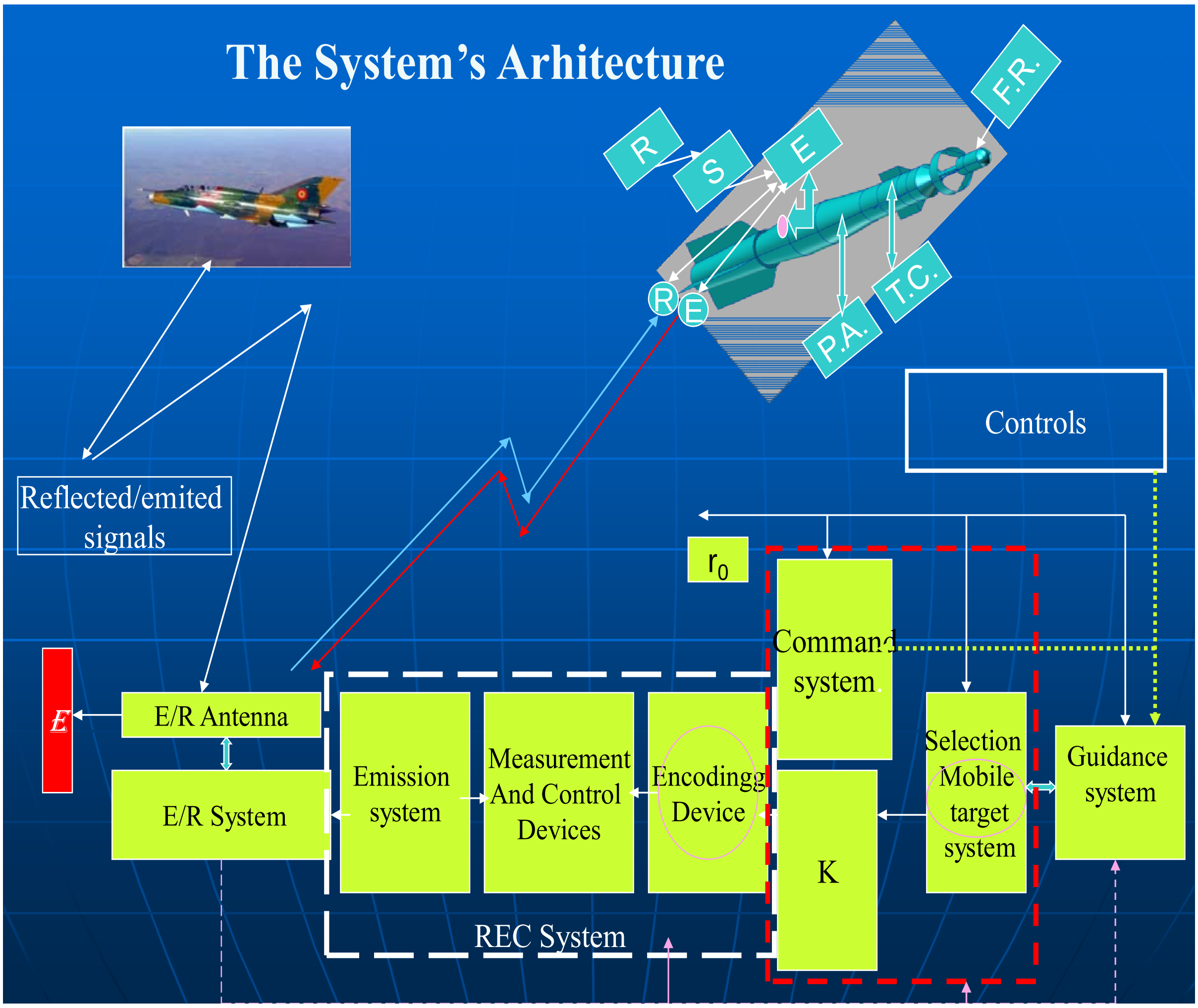

Fig. 1. Architecture of an airspace integrated system

Connections between the four vectors of the system and of the totality of elements, as well as the four matrixes of connection are shown in Figure 2:

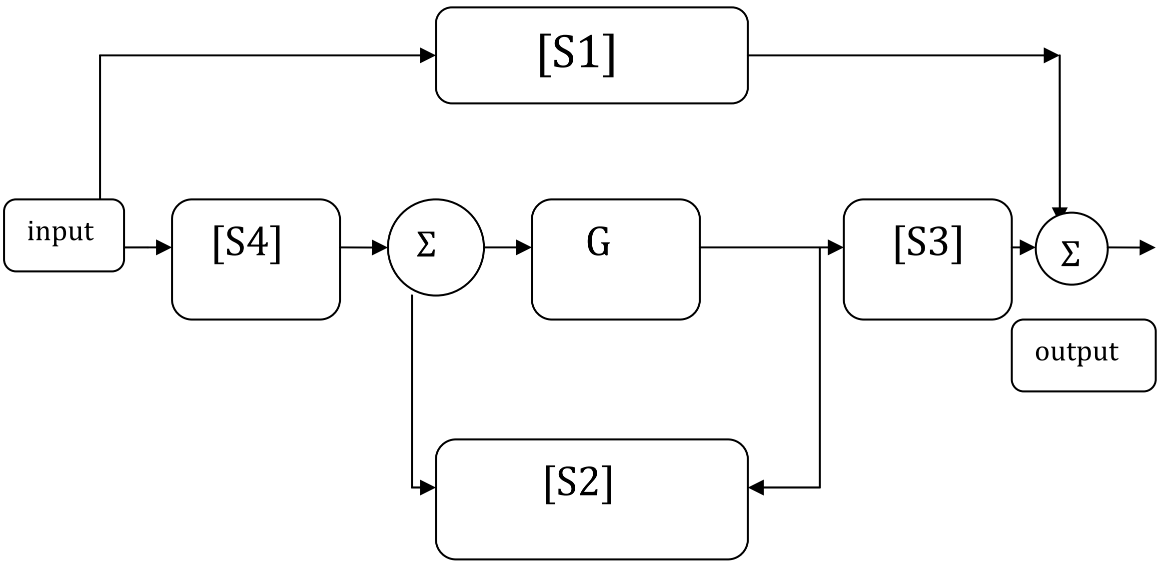

Fig. 2. Structural scheme of a large technical system's interconnections between the elements listed above

Under the circumstances of the current economic crisis, it is more and more obvious that an extension of the exploitation time, correlated with the sub-systems' modernization is absolutely necessary.

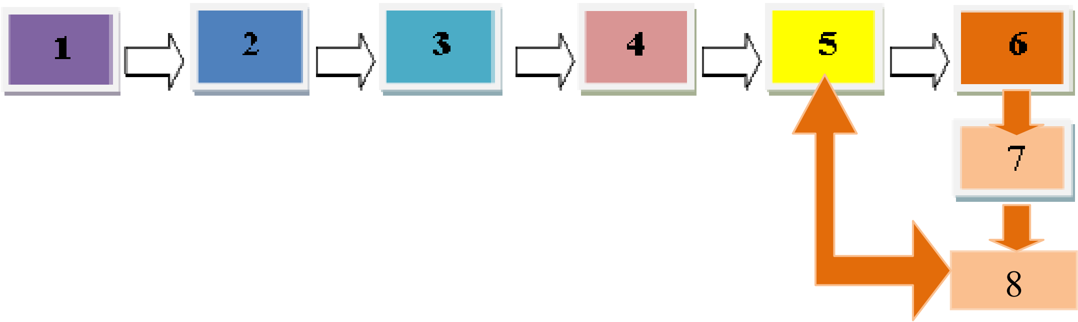

Fig. 3 Structural scheme of extension of the exploitation time.

Legend:
1 – General concept;
2 – Analysis of the system;
3 – Design;
4 – Achievement;
5 – Exploitation;
6 – Extension of resource under exploitation;
7 – Revitalization;
8 - Modernization

Maximum efficiency *(E)*, under the modern battlefield conditions, is defined as the sum between the totality of targets intended to be destroyed ($\sum_{i=1}^{n} n_i$) and the percentage of targets' destruction (θ_i), in relation with the number of launched missiles ($\sum_{j=1}^{n} i_j$) multiplied with the number of launching ramps (M).

$$E = \frac{\sum_{i=1}^{n} n_i + \theta_i}{\sum_{j=1}^{n} i_j \cdot M} , \quad (2)$$

where $\theta_i = \frac{\sum_{k=1}^{n} p_k}{N}$, and $\sum_{k=1}^{n} p_k$ represents the sum of hits per target, N - number of targets;

Within the large integrated systems, efficiency focuses on such a variant of structure and functioning, able to assure the mission's accomplishment, at minimal costs. The general perception of the efficiency criterion consists of a minimization of costs:

$$\min C = \min M [\sum C_i] E > E_{dat} \quad (3)$$

where:

C – represents the minimal cost minimal;

C_i – represents the cost of part *i* of the system made up of I elements;

E_{dat} – represents the value of imposed efficiency.

The specialized literature also offers a reverse form of the efficiency criterion. In this case, obtaining a maximum effect is sought, under the conditions where expenses represent limiting factors.

Accordingly:

$$M[\sum C_i] < M_{dat} \quad (4)$$

where M_{dat} stands for the average value of expenses.

Lately, the surface-to-air missile systems have been subjected to a series of modernization that mainly aimed at:

- Improving identification characteristics of radar stations, especially in case of interference with signals reflected from fixed targets;
- Introducing the TV video capture for air targets detection, in correlation with reducing the amount of time necessary for missiles preparation;

- Improving protection sub-systems against jamming.

Given these modernizations, the system is able to accomplish its mission; yet, it is greatly subjected to obsolescence, as shown in Figure 4:

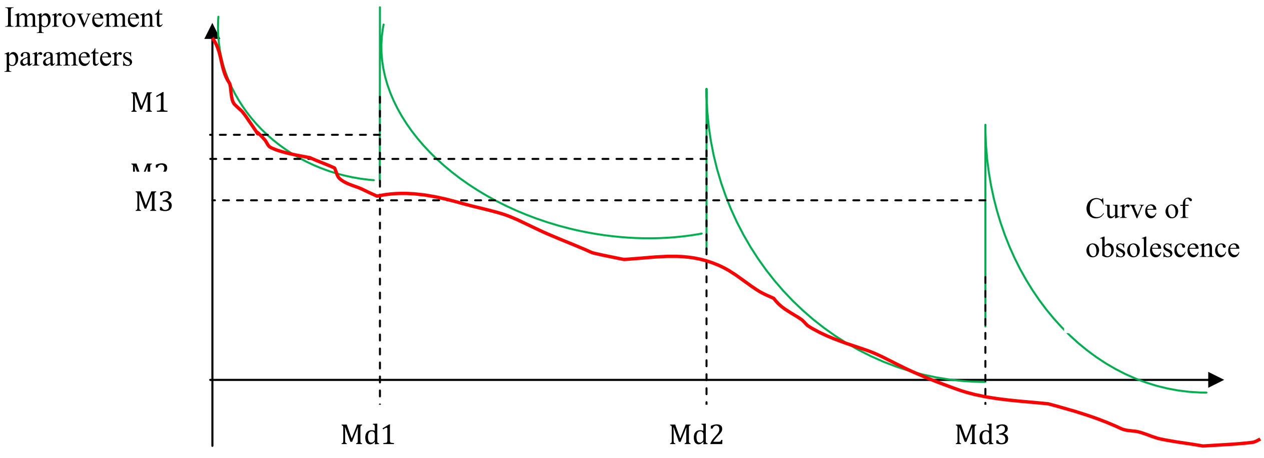

Fig. 4 Dependence of modernizations, in relation with time and obsolescence

Exploitation expenses need to take into account the exploitation period of time and they include the operating, servicing, maintenance, transportation and preservation personnel. The quantitative assessment of operating costs, in relation with the economic efficiency is possible using the standardized coefficient K_{ec}- representing the increasing of accumulations throughout one year, in relation with the amount of accumulations at the beginning of one calendar year:

$$K_{ec} = C_i - C_{i-1} / C_{i-1} \qquad (5)$$

The qualitative assessment of exploitation expenses makes use of the standardized coefficient for economic efficiency, K_{ec} - representing the increase of accumulations throughout one year, in relation with the amount of accumulations at the beginning of one calendar year:

$$K_{ec} = C_i - C_i - 1/C_i - 1 \qquad (6)$$

C_i, C_i-1-stand for expenses at the end of the years i and i-1. Expenses related to different periods of time throughout the exploitation process need updating to the same time reference, as shown by the relation:

$$C_i = C_i^n (1+K_{ec})^i \qquad (7)$$

C_i^n- expenses at the beginning of the period

In practice, it is possible for the system to have exhausted its given resource, still, it continues to hold an operational capacity. Optimization involves a proper selection of the means used for this purpose, together with a good selection of the utilization strategy. Generally speaking, this issue may be referred to as follows: total expenses needed for assuring the system's functioning, C, represents a function that depends on functioning and recovery characteristics, $x_1,\dots x_n$, on characteristics reflecting the quality of control, $y_{1,\dots} y_{n,}$ and characteristics related to control strategies, $z_1,\dots z_n$. Since the operation is aimed at being executed at the lowest cost as possible, cost C needs to be minimized:

$$C = \min C(x_1,\dots,x_n, y_1,\dots y_n, z_1,\dots z_k) \qquad (7)$$

under the following limiting conditions:

$$G_1(x_1,\dots,x_n, y_1,\dots y_m, z_{1,\dots,} z_k), [<,=,>] G_i^{(o)} \qquad (8)$$

$$G_2(x_1,\dots x_n, y_1,\dots y_m, z_{1,\dots,} z_k), [<,=,>] G_2^{(o)} \qquad (9)$$

$$G_s(x_1,\dots x_n, y_1,\dots y_m, z_{1,\dots,} z_k), [<,=,>] G_s^{(o)} \qquad (10)$$

Where $C(x_1,\dots x_n, z_k)$ represent the total amount of expenses used for exploiting the system. $G_1, G_2, G_s, \dots$, exploiting criteria of the system. $G_i^{(0)}$ $G_2^{(0)}$,...,$G_s^{(0)}$ given values for these criteria.

The system exploitation is appreciated by means of general criteria such as: coefficient of operational status; likelihood of interruption-free operation. Related to the optimal resulting or given value of control authenticity, the following particular problems of optimization may appear: finding the optimal set of the system's parameters that need to be controlled, so that the system to be able to accomplish the totality of operations regarding minimal material and financial consumptions; establishing the optimal accuracy for the functioning elements composing the system. It is well known that the high fidelity of a measurement apparatus increases the system's cost. The technical maintenance quality is appreciated by the operational preparation coefficient, for accomplishing tasks at any time. The operational preparation coefficient (under the desired regular distribution) is given by the relation:

$K_{op\,/}= \lim \int P(t)dt$ (11)

For the static exploitation process:

$K_{op}=M[t_f]/M[t_f]+M[t_n]$ (12)

a relation where $M[t_f]$ is the average value (the mathematical expectation) of the functioning interval of the item, without any disturbances, while $M[t_n]$ is the average value of the time interval in which the item is deficient or it is between two consecutive operational moods.

2. ASPECTS REGARDING AN OPTIMIZATION DESIGN IN RELATION WITH THE LIFE CYCLE CONST OF A MISSILE SYSTEM

The major condition of the presented optimization model is for it to display a proper curve distribution Cc(t). Another important condition for optimization lies in the existence of a minimal local point, sufficiently powerful O (T_{opt}, Cc_{min}), which will ease the identification of this point, although the technical-economic data are not complete.

2.1 The average acquisition cost of one unit of the sub-system.

The relation Cb(t), expresses the dependence of the average acquisition price for one unit of the sub-system, in relation with its operation timing. It is defined by the relation: Cb(t)= Cb/t. The graphic representation of this relation is an equilateral hyperbola. It is noticeable how its value decreases at the same time with the extension of the exploitation time.

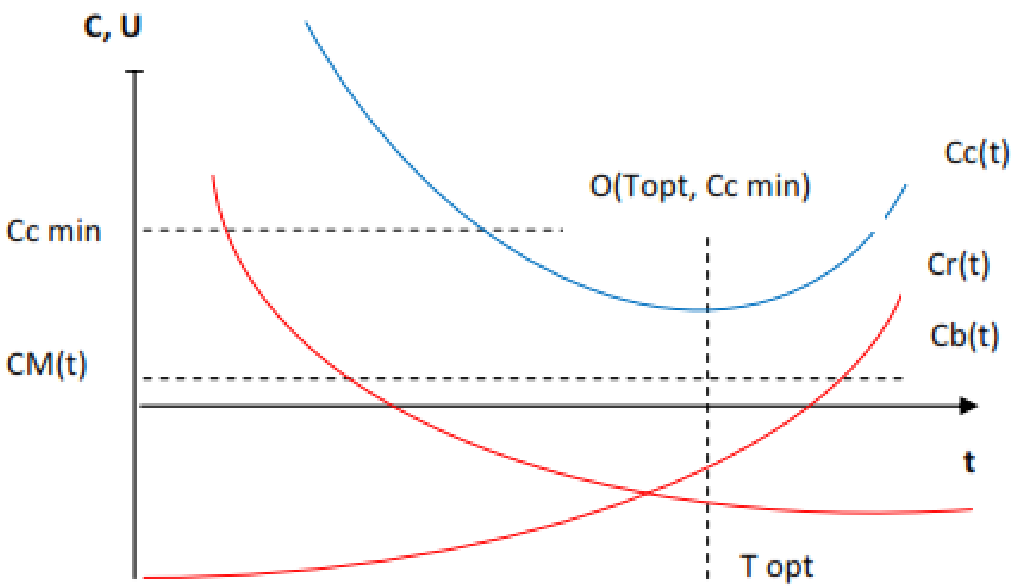

Fig. 5 Dependence of the average acquisition price for one unit of the sub-system

2.2 The average cost for preventive maintenance.

The relation Cm(t), expresses the dependence of the average cost for preventive maintenance of each unit, related to its operational time: Cm(t)=Cm(t)/t, where Cm(t) represents the sum of costs necessary for achieving preventive maintenance of sub-systems throughout their operational time. By extension, individual actions of preventive maintenance do not vary too much; therefore, Cm may be considered to be constant.

2.3 The average cost for repairing one unit of the sub-system.

The graphic representation of the relation Cr(t), shown in Fig. 5, displays the intersection and the gradual increase of operational value timings, throughout the study.

3. CONCLUSIONS

We can argue that keeping the anti-air missile system in a good functioning state is possible only by upgrading it. Consequently, the following steps are required:

- digitalization of calculus systems;
- replacement of emission-reception system by a phased antennas net, which could lead to the system compacting;
- replacement of liquid fuel, which necessitates increased maintenance;
- compacted module-built construction of the research systems and of the systems with increased mobility guidance.

The use of a new concept of optimization of the missile system would eventually lead to an increase in probability of air targets destruction ad to a complex prefigured tactical situation, in this era of economic crisis.

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