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## SCIENTIFIC-METHODICAL STATEMENTS ON ASSESSMENT TECHNICAL AND ECONOMIC EFFICIENCY OF WORKS DIRECTED FOR EXTENSION OF SURFACE-TO-AIR MISSILES` ASSIGNED MEASURES

*General scientific-methodical statements on assessment technical and economic efficiency of works directed for extension of surface-to-air missiles` (SAMs) assigned measures are formulated. Characteristic of costs connected with SAM assigned measures` extension is given. Equations for comparative assessment of the costs connected with works on SAM assigned measures` extension, and ones needed for purchasing new SAMs are considered. Graphs which allow assessing assumed values of assigned measures` increasing based on available economic resources, and also graphs characterized duration of extending SAMs` lifetime as the function of preliminary stated SAM life cycle are shown.*

***Keywords:*** *assumed values of assigned measures` increasing, duration of extending SAMs` lifetime, technical and economic assessment, works concerned with assigned parameters` extension.*

## Introduction

At present, the scientific-methodical and regulatory support of works directed to the extension of assigned measures (EAM) of a SAMs is not investigated completely. In particular, there are absent technical requirements for SAM components, programs and procedures for operation testing on reliability and other methodical documents. In previous article [1] there were developed scientific-methodical statements concerned with nomenclature of SAM assigned measures (AMs), corresponding reliability measures, and also with procedure of developing a structure and functional diagrams of SAM reliability. This article is the continuation of the aforementioned previous article, and is devoted to developing the scientific-methodical statements on technical and economic assessment of works directed to EAM of the SAMs.

In accordance with [2] for each type of SAMs after conducting the works directed to EAM SAMs, decisions should be developing with assessment of economic expediency of EAM. And work program for EAM should contain results of assessment of their technical and economic efficiency. Therefore, at present, the development of a scientific-methodical procedure concerning the conducting technical and economic assessment of works concerned to EAM is relevant.

**Analysis of modern researches and publications.** At present, problem concerned to scientific-methodical support of works directed to SAMs` EAM is not fully solved. In particular, there are absent regulatory documents, which determine peculiarities of conducting of such works in real situation of Ukraine. Some researches is being done to develop the regulatory and scientific-methodical support of mentioned works. In particular, the standard [3] has put into operation, there have been developed a drafts of documents which determine procedure of SAMs` EAM, and present improving the standard [4], etc.

Analysis of modern researches and publications shows, that the issues of scientific-methodical support of the works concerned with EAM are only partly solved. Some works [5–15] are devoted to partial issues of EAM scientific-methodical support. For example, in [10] the following issues were discussed: substantiating the extent of test for SAMs` and their propulsions; methodical recommendations on assessment the storability measures of SAM airborne equipment; developing a method for determination of real lifetime for SAM transport launching containers [13], etc. At the same time, solution a problems connected with substantiation of AMs` required values, and assessment of technical and economic efficiency of the activities that are planned within the framework of the program of works connected with EAM is actually absent.

According to the aforementioned the object of the article is the increasing the efficiency of the works connected with EAM SAMs by means of improving a scientific-methodical support of considered works within the framework of assessing their technical and economic efficiency.

## Main Part

Assessment of technical and economic efficiency of works concerned with EAM is carried out to determine the possibility and expediency of extension the missiles` AMs on the value of the extending lifetime of items – t. In this case, the value of t can be established on the basis of the following criterion: $t = \min(t_{ec}, t_{tech})$, where $t_{ec.}$, $t_{tech}$ are the values of assigned extending lifetime for SAMs, which are stated under the results of economic or technical assessment of EAM possibility respectively. And at the same time technical assessment is connected with requirements on allowable level of decreasing SAM reliability measures.

Further, the main statements of the article are given as applied to the assessing the economic efficiency of works directed to the SAMs` EAM.

When planning a works on EAM customer should provide for the following:

– costs of works on the assessing the possibility of increasing the AMs to the value t which exceeds the preliminary assigned value $T_e$;

– costs of works connected with realization for each SAM of measures necessary for providing its exploitation during the extended period $[T_e, T_e + t]$;

– additional costs conditioned by acquisition of spare parts (SPs) for recovering and maintaining the up state of SAMs during their exploitation period t in the case of their failures.

On the other hand, increasing the values of AMs excludes the customer's costs for the acquisition of new SAMs, which, if necessary, should be purchased to replace SAMs with completed measures.

If the cost of acquisition n new missiles (n is the size of SAM park) after expiring time $T_e$ makes value $C_{acqn}$, and the total cost for conducting researches on assessment of the possibility to increase the AMs to value t, for realization necessary measures for each missile, as well as for acquisition of SPs for n SAMs is specified as $C_{\sum EAM}$, then the allowable value t for extending AM can be determined from the following condition:

$$C_{ackn}(t,T_e,n) = C_{\sum EAM}(t,T_e,n). \quad (1)$$

If after expiring the time $T_e$, decision on n new SAMs` acquisition is made, then the value of corresponding cost can be found using the following equation:

$$C_{ackn}(t,T_e,n) = C_0 \cdot n \cdot k_1(t,T_e), \quad (2)$$

where $C_0$ presents the cost of single new SAM; $k_1(t,T_e)$ is the coefficient for matching cost of new SAMs` acquisition with the cost $C_{\sum EAM}$.

Value of coefficient $k_1(t,T_e)$ can be obtained using equation: $k_1(t,T_e) = t / T_e$.

It should be noted that in case of supplying new SAMs, customer faces with cost connected with recovering failures appearing during exploitation. In equation (2) such costs is not taken into account, because they are insignificant owing to the following:

– for all new SAMs certain warranty is stated, according to which failures are eliminated by manufacturer;

– failure flux parameter ω for new SAMs is substantially smaller, than for missiles which will be exploited with extended AMs.

Economic expenses connected with EAM can be separated to the following three groups:

1st group represents cost $C_1$, connected with conducting works directed to researching a possibility of AMs` extension on value t exceeded preliminary assigned value $T_e$, and with determining a works necessary for considered extension;

2nd group assumes cost $C_2$, connected with realization for each SAM of works on providing for exploitation during the extending period $[T_e, T_e + t]$;

3d group represents cost $C_3$, connected with supplying SPs for restoring and maintaining an up state for SAM park during the extending period $[T_e, T_e + t]$.

SAMs of various types are characterized during the exploitation by different integrity of up state monitoring which can makes value 0.4…0.7 [3]. In this connection when assessing an economic efficiency of works directed to AMs` extension, it is necessary to select SAM components, up state of which is tested (monitored) during exploitation, as well as components technical state of which is not tested during the operation and is assessed (investigated) at the stage of works on AMs extension.

Total cost connected with AMs` extension can be found using the following equation:

$$C_{\sum EAM}(t,T_e,n) = C_1(t,T_e) + C_2(t,T_e,n) + C_3(t,T_e,n). \quad (3)$$

Value $C_1$ depends on type of each missile, duration of testing, types of testing etc. In practice for most types of SAMs it is assumed $C_1 \approx (2-10)\cdot C_0$. Value $C_1$ has the property that its value does not depend on the number of missiles that are exploited. If necessary, to estimate value $C_1$ for certain types of SAMs it can be obtained empirical dependencies as the functions of extending period t.

Cost $C_2$ includes economic expenses connected with performing all works to provide exploitation during the extending period.

Value $C_2$ varies from value $C_2 = 0$ in case of making decision on AMs` extension without performing any works on each missile, to value $C_2 = C_{crl} \cdot n$, where $C_{crl}$ is the cost of major repairs (MR) for single SAM, including the cost of new components manufactured for replacement at the stage of MR. Unlike $C_1$ cost $C_2$ depends on number of SAMs that are exploited.

Cost on supporting exploitation $C_3$ can be obtained using the following equation:

$$C_3(t, T_e, n) = n \cdot C_{serv} \cdot \overline{K}sp_\gamma(t,T_e), \qquad (4)$$

where n is the size of SAM park; $C_{serv}$ is the mean cost of single failure restoring (servicing) during SAM exploitation; $\overline{K}sp_\gamma(t,T_e)$ – is the upper confidence contour for necessary number of SPs having level $\gamma$.

Value $\overline{K}sp_\gamma(t,T_e)$ taking into account the standard [4] can be obtained (when failure flux parameter $\omega(t)$ is a known function) using equation:

$$\overline{Ksp}_\gamma(t, T_e) = \int_{T_e}^{T_e+t} \omega(\tau)d\tau + \sqrt{\frac{\gamma}{1-\gamma} \int_{T_e}^{T_e+t} \omega(\tau)d\tau}, \qquad (5)$$

where t is the extended value of AM above value $T_e$ for which an upper bound of necessary amount of spare parts is determined; $\gamma$ is the assigned value of a confidence probability.

Concrete form of $\omega(t)$ function as a rule is specified during the works directed to AMs` extension. For most types of SAMs, function $\omega(t)$ outside the interval limited by preliminary assigned measure $T_e$ can be expressed as a linear or quadratic function, parameters of which are determined using regression procedures, based on information obtained at the stage of EAM.

For simplification let us specified that during period $[T_e, T_e + t]$ function $\omega(t)$ =const, then (5) is reduced to the equation:

$$\overline{Ksp}_\gamma(t, T_e) = \omega \cdot t + \sqrt{\frac{\omega \cdot t \cdot \gamma}{1-\gamma}}. \qquad (6)$$

After substitution (2; 4; 6) to (1) the following equation can be obtained:

$$C_0 \cdot n \cdot \frac{t}{T_e} = C_1 + C_2 + n \cdot C_{serv} \left[ \omega \cdot t + \sqrt{\frac{\gamma \cdot \omega \cdot t}{1-\gamma}} \right], \qquad (7)$$

where $C_{serv} = \sum_{i=1}^{z} C_{servi}\omega_i / \sum_{i=1}^{z} \omega_i$; z is the number of SPs` types; $C_{servi}$ is the cost of SPs of i[th] type.

Equation (7) can be used for obtaining estimates of possible increasing the AM value t for SAMs, up state of which can be restored during the exploitation by means of SPs` using.

Also using (7) it can be obtained allowable value of economic expenses for conducting researches directed to increasing AMs on value t and realizing a works necessary for this purpose.

Value of additional costs $C_{ed} = C_1 + C_2$ we obtain using the following condition:

$$C_{ed} \le C_0 \cdot n \cdot \frac{t}{T_e} - n \cdot C_{serv} \left[ \omega \cdot t + \sqrt{\frac{\gamma \cdot \omega \cdot t}{1-\gamma}} \right]. \qquad (8)$$

Below in fig. 1 graphs obtained using equation (8), are shown. Presented dependencies characterize an allowable economic expenses as the function of duration of SAMs` extending lifetime t when fixed preliminary stated lifetime $T_e$. Calculations were conducted for the following conditions:

$C_0 = 100 \cdot 10^3$ equivalent units (e.u.), $C_{serv} = 200$ e.u.,

$n = 800$, $\omega = 0.2$ year$^{-1}$, $\gamma = 0.8$.

Based on analysis of graphs shown in fig. 1 the following conclusions can be made:

– increasing the value of extending lifetime leads to growing economic cost connected with conducting researches on increasing the AMs on value t and with realization corresponded activities;

– when conducting a works on extension to the same period, for SAMs having smaller preliminary stated lifetime assumed economic cost is greater then for items with longer preliminary stated lifetime.

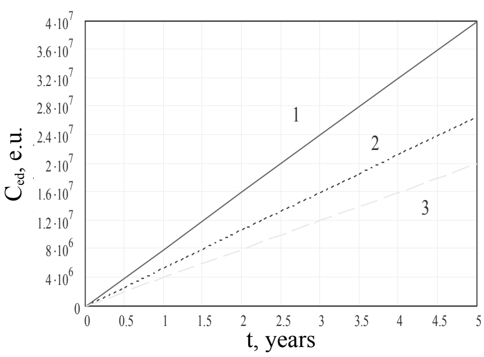


Fig. 1. Assumed economic cost versus duration of SAMs` extending lifetime t for various $T_e$:
1 – $T_e = 10$ years, 2 – $T_e = 15$ years, 3 – $T_e = 20$ years

Equation (7) can be used for determination of assumed value of increasing AMs given specified cost. Also from (7) we can obtain equation for calculating value t:

$$At - B = \sqrt{Dt}\,, \qquad (9)$$

where $A = \frac{C_0}{C_{serv}T_e} - \omega$, $B = \frac{C_{ed}}{n \cdot C_{serv}}$, $D = \frac{\omega\gamma}{1-\gamma}$.

Thus from (9) the following equation for t can be written:

$$t = \frac{2AB + D + \sqrt{4ABD + D^2}}{2A^2}. \qquad (10)$$

Further in fig. 2 graphs calculated using (10) are shown. Mentioned functions characterize dependency of extending lifetime t from preliminary stated lifetime $T_e$ for various fixed costs connected with works during the extending period. Calculations were carried out for the following conditions: $C_0 = 100 \cdot 10^3$ e.u., $C_{serv} = 200$ e.u., $n = 800$, $\omega = 0.2$ year$^{-1}$, $\gamma = 0.8$.

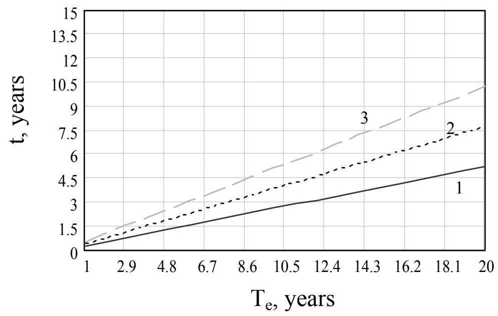


Fig. 2. Duration of SAMs\` extending lifetime t versus preliminary stated lifetime $T_e$ for various cost $C_{ed}$:

1 – $C_{ed} = 20 \cdot 10^6$ e.u., 2 – $C_{ed} = 30 \cdot 10^6$ e.u., 3 – $C_{ed} = 40 \cdot 10^6$ e.u.

Based on analysis of the graphs shown in fig. 2 it can be made a conclusion, that for increasing an extending lifetime, economic cost necessary for conducting researches directed to increasing AMs\` on value t and realizing corresponded works needs to be increased.

Using equation (10) we can obtain assumed value of increasing AMs t given available economic resources for extension of the AMs and providing for SAMs\` exploitation during the extending period.

Equations (8) and (10) have been obtained under the condition that extending value t belongs to time interval $0 < t < T_e$. Taking into account that EAM is carried out by stages, when calculations using equations (8) and (10) are conducted, value $T_e$ is supposed to be equal SAMs\` assigned measure, which stated basing on the results of previous stage. In this case condition $0 < t < T_e$ is always satisfied.

If SAMs contain components, status of which is not tested during exploitation, then such components are tested for assessing possibility of their AMs increasing. And based on results of considered works the following decisions can be made:

– decision A: AM value is extended to necessary magnitude without conducting any activities;

– decision B: after the end of preliminary stated AM, components of given type for all SAMs from the park should be substituted by new ones;

– decision C: after the end of preliminary stated AM all SAMs from the park are subjects to MR.

For decision A it is obvious, that for such components works directed to increasing their AMs need cost only for research of the $C_{1i}$. At the same time values of $C_{1i}$ should satisfy the following condition:

$$C_{1i} \le C_{01i} \cdot n\,, \qquad (11)$$

where $C_{01i}$ is the cost of single set for new component taking into account the cost of conducting works on its substitution on SAM.

After making decision B, costs connected with researches of $C_{1i}$, acquisition of new SPs and conducting works on their installation on SAM, necessary. Such variant is the least economically viable, as costs for its realization exceed costs needed for acquisition and installation of new SPs. In other words:

$$C_{1i} + \sum_{i=1}^{p} C_{2i} \ge C_{01i} \cdot n\,. \qquad (12)$$

Variant C provides costs needed for researches directed to determining the MR size for EAMs on value t, conducting a MR $C_{2mr} = n \cdot \sum_{i=1}^{r} C_{2mri}$, where $C_{2mri}$ is the cost of MR for single i$^{th}$ component. In this case total cost for research and MR should satisfy the following condition:

$$C_{1i} + C_{2mr} \le C_{01i} \cdot n\,. \qquad (13)$$

Conditions (12) and (13) should to be used for assessment expediency of conducting the works on increasing AMs for unmonitored components.

## Conclusions

Based on the results of conducted researches the following recommendations can be given:

– value of the extending lifetime t for SAMs should be selected based on the results of the assessing technical and economic efficiency of works on the EAM according to the criterion $t = \min(t_{ec}, t_{tech})$;

– expediency of conducting works on EAM should be substantiated based on the results of comparing the cost connected with conducting works on EAM and providing for SAMs up state during the extending period, as well as the cost on acquisition of the necessary number of new SAMs;

– when conducting works directed to EAM for SAMs having shorter preliminary stated lifetime, possible economic cost can grows as compared to cost corresponded to works on EAM for SAMs with longer preliminary stated lifetime.

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## НАУКОВО-МЕТОДИЧНІ ПОЛОЖЕННЯ З ОЦІНЮВАННЯ ТЕХНІКО-ЕКОНОМІЧНОЇ ЕФЕКТИВНОСТІ РОБІТ З ПРОДОВЖЕННЯ ПРИЗНАЧЕНИХ ПОКАЗНИКІВ ЗЕНІТНИХ КЕРОВАНИХ РАКЕТ

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*Формулюються основні науково-методичні положення з оцінки техніко-економічної ефективності робіт з продовження призначених показників зенітних керованих ракет (ЗКР). Надається характеристика витрат, пов'язаних з продовженням призначених показників ЗКР. Розглянуті співвідношення для порівняльної оцінки витрат, пов'язаних з проведенням робіт з продовження призначених показників та закупівлею нових ЗКР. Наведені графіки, які дозволяють оцінити припустимі величини збільшення призначених показників виходячи з наявних економічних ресурсів, а також графіки, які характеризують залежність тривалості продовжуваного терміну служби виробів від початково встановленого терміну служби ЗКР.*

***Ключові слова:*** *роботи з продовження призначених показників, техніко-економічна оцінка, припустима величина збільшення призначених показників, тривалість продовжуваного призначеного терміну служби.*

## НАУЧНО-МЕТОДИЧЕСКИЕ ПОЛОЖЕНИЯ ПО ОЦЕНИВАНИЮ ТЕХНИКО-ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ РАБОТ ПО ПРОДЛЕНИЮ НАЗНАЧЕННЫХ ПОКАЗАТЕЛЕЙ ЗЕНИТНЫХ УПРАВЛЯЕМЫХ РАКЕТ

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*Формулируются основные научно-методические положения по оцениванию технико-экономической эффективности работ по продлению назначенных показателей зенитных управляемых ракет (ЗУР). Приводится характеристика затрат, связанных с продлением назначенных показателей ЗУР. Рассмотрены соотношения для сравнительной оценки затрат, связанных с проведением работ по продлению назначенных показателей и закупкой новых ЗУР. Приведены графики, позволяющие оценивать допустимые величины увеличения назначенных показателей исходя из имеющихся экономических ресурсов, а также графики, характеризующие зависимость длительности продлеваемого назначенного срока службы изделий от первоначально установленного назначенного срока службы ЗУР.*

***Ключевые слова:*** *роботы по продлению назначенных показателей, технико-экономическая оценка, допустимая величина увеличения назначенных показателей, длительность продлеваемого назначенного срока службы.*