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INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2014
Brasov, 22-24 May 2014

CONSIDERATIONS ABOUT THE LIFE EXTENSION PROGRAMS BY TECHNICAL RESOURCE RENEWAL APPLIED TO THE SURFACE-TO-AIR MISSILES

Marius RADULESCU*, Vasile SANDRU**

*Electromecanica Ploiesti, Romania, ** „Henri Coanda" Air Force Academy, Brasov, Romania

Abstract: *The work-paper presents few considerations regarding the opportunity that a life extension program to be applied in the case of a ground-to-air missile as an Air Defense Missile System (ADMS) component. A model of a hypothetical AD missile is built and serves as a base for the technical and economical reasons for the extension life decision. Using some market data for the missile's components, the authors try to balances the life-extension costs with those of the complete replacement ones. The scientific, technical and technological support needed for applying such a program is set also. The conclusions refer to the multitude of the factors which are involved in the life extension program management.*

Keywords: *missile, lifecycle, efficacy, program, costs*

1. INTRODUCTION

The air power represents the main force multiplier of an armed force. This assertion allows the huge efforts make by the owners to maintain the advance of the aerial features in the endowment. Any military organization must be able to counter the aerial menace at an appropriate technological level. This level is done today by the Air Defense Missile Systems (ADMS) using the air defense (AD) missile or SAM's. If the aerial means evolves for increasing survivability and efficacy, the ADMS's and the SAM's default must keep the same trend [3].

This implies the quickly change the SAM generation every time when the aerial threat significantly change the characteristics or the continuously up-grade of the existing ADMS until the consumption of their operational life.

The frequently replacement of the whole ADMS involves great expenses, and requires the access to the ultimate state-of-art in branch. Only the major scientific and military powers can practice this way and with corresponding costs.

The majority of other ADMS keepers may take in account the possibility of the extension system's life cycle using the life extension processes as the technical resources carry-over, the technical resource renewal and the improving up-grade.

2. THE OPERATIONAL LIFE OF THE SAM SYSTEM

2.1 The main ADMS composition

An ADMS is a complex assembly, assuring not only the battle engagement, but also the learning [2], the training and the maintenance functions as a base for the integration into the armed forces architecture [6], generally composed by:

- Self-propelled launcher
- Missile
- Mobile summary checking station
- Maintenance checking station
- Replacement vehicle
- Mobile Command Post
- Field training equipment
- Class simulator
- Descriptive documentation
- Flight employment documentation
- Maintenance documentation
- Teaching complete (pads, sliced inert missile, system elements)

Every component of the ADMS has his own active life date, depending of some operational factors, like:

- Complexity
- Using regime
- Critical and expendable elements
- Availability of sub-components on market
- Morale usage

Figure 1 – A view of a SHORAD type ADMS

Basically three life extension processes creates the technological base to maintain in endowment a certain ADMS [4]. These processes are:

- The technical resources carry-over
- The technical resource renewal
- The up-grade

This work-paper analyses the second process, having a medium complexity and in this way being more accessible for a medium technological industrial support, and applied for the main ADMS component – the SAM only.

2.2 AD missile (SAM) – the most perishable system element

Between the ADMS components, the missile represents one of the most dynamic elements, direct connected with the potential target performance evolution. The main hardware and software aspects including in the missile structure that are relatively quickly affected in time are the following:

- The fuel and the igniters of the propulsion unit
- The explosive of the warhead
- The thermal battery (or/and other power sources)
- The guidance and control algorithm
- The command and accord function of the proximity fuse

Generally a short / medium range SAM has an operational technical resource of 10 years, while other ADMS's components has 15 to 20 years of resource. Furthermore a system operates 2 to 3 versions of the missile until complete replacement.

By the technical resource renewal process a system regains a new operational life period, but without the increasing performances.

2.3 The principle SAM organization

Generally a missile destined to an ADMS has an organization like the following schedule:

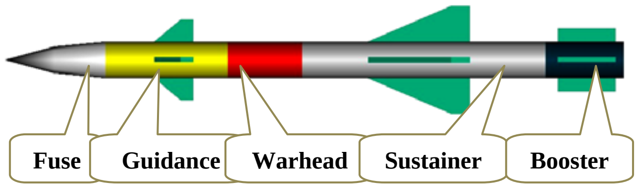

Figure 2 – General missile organization

According with its type, the missile could have some differences in organization. For the work-paper purpose we can suppose an assembly composes from a succession of compartments comprising an electro-magnetic fuse, a guidance section a warhead and a propulsion unit with a booster and a sustainer, alongside three aerodynamically sets.

Fuse	Checking on stands	200	64	10150

Even from the initial project, a relatively complex technical system like a missile disposes of the interfaces that permits to change a compartment when a new equipment generation will be ready or for the same type replacement only.

3. THE TECHNICAL RESOURCE RENEWAL PROGRAM CRITERIA

3.1 Missile's components lending to replacement

The main components that the program will be applied are shown in the figure 3:

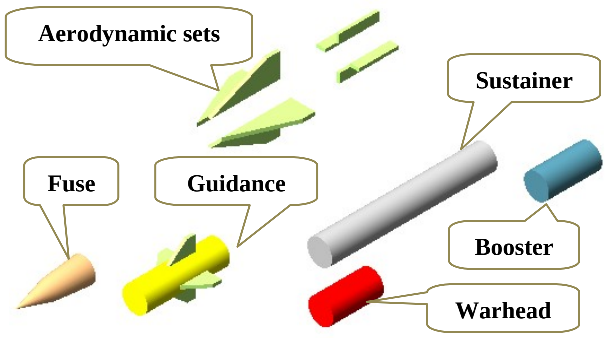

Figure 3 – The main SAM compartments

For the purpose of concept here exposed, a real close price data can be identified in the specialized literature [9], like the follows:

* rounded

#	Component	Weight [kg]	Cost indicator [USD/lb]	Estimated price * [USD]
1	Guidance Unit	12	10400	275500
2	Proximity fuse	8	7400	130500
3	Warhead	15	4800	159000
4	Sustainer rocket motor	67	4200	621000
5	Booster rocket motor	18	3600	143000
	Sum	**120**		**1329000**

3.2 The volume of the means that the program will be applied

In order to have an economical reason to develop a technical resource renewal program, a number of systems and a number of missiles respectively must be the subject of the process.

However, for the accounting necessity, we can hypothetical consider a limited number of systems in endowment like follows:

- 18 ADMS in three battalion type units, having 4 missiles each and another 4 in the unit depot
- 1 ADMS belonging to an application school unit
- 1 reserve ADMS as forces generally reserve
- 2 ammunition fire units as forces reserve for each ADMS

This account a total of: 144 + 8 + 8 + 160 = 320 of missiles.

For the calculus necessity we consider the price for a new missile as 1.33 USD millions that climb the affair value to a total of about 425 USD millions.

3.3 The resource renewal program

Considering the entirely 320 pcs missile batch into the resource renewal program, and 10 pcs of this will be lost in partial/final tests for 310 remaining missiles we can evaluate the financial effort needed to accomplish the task.

Section	Operation	Material cost [USD]	Labor hours [25USD/hr]	Estimated price [USD]
0	1	2	3	4
Guidance (cost / pcs)	Battery replacement Interfaces refit Checking on stands	600	80	13900
Fuse	Checking on stands	200	64	10150

0	1	2	3	4
Warhead (cost / pcs)	Dismantle Cleaning Destroy of the old charge Recharging with new explosives Replacement of igniters Assembly	1500	16	5400
Sustainer (cost / pcs)	Dismantle Cleaning Destroys of the old fuel Recharging with fuel Replacement of igniters and squibs Assembly	4800	88	22750
Booster (cost / pcs)	Dismantle Cleaning Destroys of the old fuel Recharging with fuel Replacement of igniters and squibs Assembly	1600	48	10900
Airframe (cost / pcs)	Missile general checking Sections dismantle Interfaces refit Compartments checking Assembly	300	64	12100
Sub-Assembly tests (cost / batch)	Capacity tests after refitting	4200	420	290
		for 310 missiles		
Delivery (cost / pcs)	Boxes including at USD 2200 third-part co-work	100	16	6390
Final test (cost / batch)	Missile general checking, including 2 targets at USD 38000 third-part co-work	6600	420	660
		for 310 missiles		
Technological documentation (cost / batch)		1200	3240	1600
		for 310 missiles		
Technological devices	Including USD 66000 third-part co-work	7700	2160	1420
		for 310 missiles		
Cote	10 missile of 1,33 USD million each of batch destroyed	13.3 USD mill	0	42900
		for 310 missiles		
Total				**128460**

This approximated result shows that for a medium-size air-defense missile [5], the resource renewal program involve a cost at less than 10% of the new one.

In the same time, the cost of the TRR program rejoins at approximately:

310 missiles x 128.460 USD each ≈

40 USD millions.

3.4 The restored value of the missile

The restored value of the missile will be calculated with the formula:

$$V_a = (V_i + V_{TRR})*T_{LC}/(T_{LC} + T_{RL})$$

where V_a - actual value

V_i - initial value

V_{TRR} - technical resource renewal program value

T_{LC} - time of lifecycle

T_{RL} - time of restored life

Supposing an operational resource of 12 years for a missile and a restored period of 10 years by applying the resource renewal program, the value of the missile becomes:

$$V_a = (1329000 + 128460)*12/(12 + 10) \approx 795.000 \text{ USD}$$

i.e. approx. 60% of the new product value.

3.5 The program implementing technical and scientific support

In order to be capable to develop a missile life extension program by renewal of the technical resource, an industrial organization must disposes of the following facilities:

- Research and development capacity, including the tactical support doctrine
- Maintenance technological base
- Production capacities, partially in cooperation
- Access on the branch technology market
- Access on the branch materials and equipment market
- Financial support
- Testing infrastructure

A continuously attention must be allowed to the scientific, technical and industrial infrastructure and personnel in order to assures the possibility of life extension programs applied to missiles and missile systems [7].

3.6 Financial risk of the program

Considering the budgetary year allocation at a cash flow of a half of the needed amount, with a 25% growth expectation and 20% of a discount factor, the NPV (Net Present Value) method can be used [1] to verify the financial risk of the project:

$$NPV = -I_0 + \sum_{i=1}^{n} \frac{E(FCF_i)}{(1+WACC)^i}$$

where

WACC - weighted average cost of capital

I_0 - initial investment

i - numbers of years before cash flow occurs

NPV must be > 0 in order to consider the project feasible.

If some uncertainty of budgetary cash flow is considered, respectively did exist 50 – 50 percent chance to have in the second year an allowance of 25 USD millions or down at 20 USD millions, according [8] we can calculate the NPV as:

$$NPV = 0.5\max\left[\frac{-20}{1.2}+\frac{25}{1.2^2},0\right]+0.5\max\left[\frac{-20}{1.2}+\frac{20}{1.2^2},0\right]$$

= 0.5max[-16.666+17.361, 0]+ 0.5max [-16.666+13.888, 0]= 0.3475 + 0 = 0.35 > 0

4. CONCLUSIONS & ACKNOWLEDGMENT

A superior process aiming to an extended life cycle of a technical system – a missile peculiarly is represented by the up-grade program, which can be applied to few or all the system components. But such a process is most expensive and in many cases requires unavailable know-how type technical data.

Using the available information, we look for few widespread missile models concerning their up-grade programs and costs. Using an inflation calculator [11] we has aligned the costs at the Fiscal Year (FY) 2013, in order to calculate the growth of the costs by applying the modernization program.

System Version	Previous*		Following*
	USD / FY	USD FY13	USD FY13
AIM-9 Sidewinder	AIM-9L 84,000 / 1999	185,500	AIM-9X 664,900
AIM-120 AMRAAM	AIM-120C 400,000 / 1998	567,700	AIM-120D 1,492,000
RIM-67/174 Standard	SM-2ER 409,000 / 1981	1,032,470	SM-6ERAM 4,284,000

*data from [10], [12], [13], [14]

For the studied models, the costs growth is balanced for a medium value of 245%.

System	Growth
AIM-9 Sidewinder	258 %
AIM-120 AMRAAM	163 %
RIM-67/174 Standard	315 %
Media	**245 %**

Regarding in terms of costs to all the three technological way for extend the life cycle of a missile (presented at #2.1) easily can be observed that the TRR program represent an intermediary solution.

Type of life cycle extension program	Approx. Costs *
Technical resources carry-over	10 %
Technical resource renewal	60 %
Up-grade	250 %

* reported to the acquisitions unitary cost

The technical resource renewal (TRR) solution is recommended when the assured performance of the system have an acceptable level alongside of hole system life gained by program.

The TRR is a process that aims to refits the operational life of an expired system replacing some pieces and sub-assemblies olds with the new made ones. The TRR supposes the technologies and equipments destined to:

- dismantling of the systems
- replacement of the pieces and sub-assemblies
- mechanical and electric assemblies
- adjustments and repairs
- coating and watermark
- general and specific tests

The TRR is a process similar to fabrication, executed in a technical-skilled entity, equipped with adequate production and testing facilities.

After the TRR program the system resource is refitted at the nominal value and can be extended in the future. In the TRR process a higher number of products from the application batch are destroyed, so the new certified batch is smaller than the initial number.

An essential aspect regarding the TRR program is the access to the pieces and sub-assemblies that will be replaced, these or equivalent ones must exist on market. That means if the TRR impose the replacement of equipment or pieces which is no longer produces, the program cannot be executed.

The TRR refits the system use capability at the initial values and parameters, but don't correct the morale usage of the equipment.

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