OPERATIONAL AVAILABILITY OF THE TECHNICAL OBJECT

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Abstract

The most important issue for each system is its effectiveness E_f, which depends on reliability, availability and maintainability (RAM). The operational availability (A_o) even for mature systems usually has large improvement capabilities. One of the most critical parameter of A_o is ALDT (Administrative and Logistic Delay Time). The article presents most important aspects of operational availability, taking into account the helicopter operating from frigate as the object for analyzing. In spite of the fact that such helicopter is specific, the presented topic is common, and useful for each system, including ship propulsion system, its accessories and their reliability.

Keywords: *reliability, technical object availability, operational availability*

1. Introduction

The goal of each system designer is that his or her system will perform its functions in any conditions, independently to any kind and intensiveness of any impact of inner and outer factors. The real world with practical conditions of system working guarantee that the system will meet problems in the future, hard to predict during design process, which could disturb or even stop its work eventually. The question is: how prepare the system to protect it from disturbances.

The effectiveness measure of the system is the probability performing the job by the system successfully. This is presented by below equation:

$$E_f = R \cdot G \cdot O \tag{1}$$

where:

E_f - probability that the system will perform the mission successfully;
R - probability that the system will perform its intended functions for a specified intervals,
G - probability that the system will be available to perform its intended functions in required time,
O- probability that the system will be suitable for its intended functions and specified conditions.

Each of the elements mentioned above has crucial importance for entire system performance.

This paper is focused on readiness, or more precisely, on operational availability (A_o) of the technical object – the item (TO), which could represent any object or system, including propulsion system, single engine, and its accessories.

The maritime helicopter performing its missions from middle class ship has been chosen as the object for the analysis. Despite to its specific functions and missions, it could be good example to present the A_o and the way for modeling its value.

2. Technical object (TO) availability index

One of the most important parameters of the maintenance of the TO is its availability.
Availability is a function which characterizes its ability to start to perform specified task(s), in specified conditions just after, or previously determined time after, when it is called.
The measure of the availability is „K“ index, which determines the probability of the event, that the item will be at UP state at random moment of time [18].

$$K_g = \frac{E(T_k`)}{E(T_k`) + E(T_n)} \tag{2}$$

where:

$T_k`$ – random variable- determining UP time of the item between failures,
T_n – random variable- determining the time of the repair.

Practically in most cases we use simplified relation, which describes steady value of K - index, assuming that the time of using (operating) and the time of recovery have both exponential distribution..

$$K_g = \frac{MTBF}{MTBF + MTTR} \tag{3}$$

where:

MTBF – Mean Time Between Failure,
MTTR – Mean Time to Repair.

All military forces maintain the enormous number of systems, which are to be used when it is needed, so they must have high level of availability.
The availability of systems is widely described in NATO and US Department of Defense standardization documents: [10, 11, 12, 13, 14, 17].

There are few availability indexes:
A_i – (Inherent Availability) - (designed),
A_a – (Achieved Availability) - (technological),
A_o – (Operational Availability) - (practical).

The equation (3) for K_g index is true as well as for A_i index - inherent availability

$$A_i = \frac{MTBF}{MTBF + MTTR} \tag{4}$$

The A_i is calculated during design process (it includes reliability parameter - MTBF and connected with it the time of repair - MTTR). This shows that A_i does not include all parameters which are met during real operation conditions of TO. Specially it does not include the time which is necessary to perform preventive or any scheduled maintenance and time for logistic system response.

Next index - A_a (availability achieved technologically) includes preventive maintenance already but still ignores the delay of the logistic system.

$$A_a = \frac{MTBM}{MTBM + MMT} \tag{5}$$

where:

MTBM - Mean Time Between Maintenance on the object,
MMT - Mean Maintenance Time on the object.

In the real operation the most important is the real level of availability of TO, which is described by operational availability $A_{o.}$ This index includes all real time factors, which have impact on availability of the item (TO).

The general relation for A_o is:

$$A_o = \frac{Tup}{Tup + Tdown} \tag{6}$$

where:

T_{up} – Up time of the object
T_{down} - Down time of the object
Up time – time that the item is in the customer's possession and works
Down time – total time that the item is not operable / not usable
The sum of times: T_{up} and T_{down} – gives us the TT (Total time of considered item operation period).

US Navy [17] definition for operational availability (A_o): probability that the system will be ready to perform its specified function, in its specified and intended operational environment, when called for at a random point in time.

$$A_o = \frac{MTBM}{MTBM + MMT + MLDT} \tag{7}$$

where:

MTBM – Mean Time Between Maintenance,
MMT – Mean Maintenance Time (for all type of maintenance: preventive-scheduled, corrective – non scheduled),
MLDT - Mean Logistic Delay Time.
A_o is determined by reliability (MTBM), maintainability (MMT) and supportability (MLDT – Mean Logistic Delay Time).

Slice different definition of operational availability is presented in the NATO standard document [11]: the probability that an equipment / system at any instant in the required operating time will operate satisfactorily under stated conditions where the time considered includes: operating, corrective and preventive maintenance, administrative delay time and logistic delay time.

I order to be closer a little bit to the real conditions of item operation, for more precise determination of Ao, is easier to apply below relation:

$$A_o = \frac{OT + ST}{OT + ST + TPM + TCM + ALDT} \tag{8}$$

where:

OT - Operating Time,
ST - Standby Time,

TPM - Total Preventive Time,
TCM - Total Corrective Time,
ALDT - Administrative and Logistic Delay Time.

TPM – dependent on the item maintenance system, item maintainability, personnel skill level, maintenance material package – taken with the item for operation period, properly calculated for range and depth,
TCM – dependent on the item reparability, spare parts package properly calculated for range and depth and support equipment (SE) set all taken with the item (i.e helicopter spares and SE stored on the ship), skills of maintenance personnel, availability of additional (non organic for item) repair facility, etc.

There is unbroken link between TCM and ADLT, because in most cases the logistic system is alerted and run when the item failure occurred and the spares or material package does not cover the needed material, or there is no proper specialist, or equipment or data on hand to perform the Corrective Maintenance.

$$ALDT(wg.NATO) \equiv MLDT(wg.USNavy) \tag{9}$$

ALDT includes:
MSRT - Mean Supply Response Time,
$M_{adm}DT$ - Mean Administrative Delay Time) – for obtaining necessary data, publications, documents, special support equipment, personnel, training.

I would like to focus your attention on the fact, that among of these three measures: TPM, TCM, ADLT, which determine the Time UP, the ADLT measure has definitely the most significant impact on A_o value, because it dominates the others. The estimated range of ALDT is from several to hundreds of hours, or even (but very rarely) up to few thousand of hours.

3. Shipboard helicopter

In order to fulfill the requirement of the contemporary maritime operation theatre the shipboard helicopter is operationally integrated with the ship weapon system. Thanks to this the helicopter increases the offensive and defensive capabilities of the ship. Practically it increases the chance of the ship to survive on the modern sea battle field.
For this paper the SH-2G type helicopter operating form the Oliver Hazard Perry class frigate was chosen as the object for the analysis.
The SH-2G Super Seasprite helicopter was designed according to US Navy LAMPS (Light Airborne Multi Purpose System) Mk. I concept [7]. The main goal of LAMPS is to increase the combat capability of the single ship by improving capabilities of her own helicopter.
According to LAMPS Mk. I the helicopter must be ready to perform following tasks:
1. primary missions:
- ASW – Antisubmarine Warfare,
- ASST - Anti-Ship Surveillance and Targeting)

Present conflicts for War on Terror have added to primary missions also the asymmetric missions – ship antiterrorist protection.
2. secondary mission:
- VERTREP – Vertical Replenishment,
- SAR - Search and Rescue,
- MEDEVAC - Medical Evacuation,
- COMREL – Communications Relay.

Additionally LAMPS required that the shipboard helicopter must have the HIFR (Helicopter In Flight Refueling) capability.

The operation of the maritime helicopters (performing tasks from costal bases or ships) is definitely more complicated than the land base helicopters operation, due to specific maritime weather conditions: increased level of humidity and salt of water and atmosphere, and rapid changes of the weather conditions (wind, fog, precipitation).
For the shipboard helicopters the above phenomena level are multiplied by open ocean conditions, and appears additional problems unique for maritime deployment.

4. Availability of helicopter on ship

Taking into account the equation (1), the operating model of aircraft (ME) could be presented in categories of probability [4, 5]:

$$ME(t,\tau,\theta) = R(t_o,\tau)\cdot G(t_o,t_1,\tau,\theta,ZL)\cdot O(\tau,\theta,ZL) \qquad (10)$$

where:

ME - probability of performing the aviation task (ZL) at the operating model of aircraft,
$R\ (t_o, \tau)$ - reliability of aircraft,
$G(t_o, t_1, \tau, \theta, ZL)$ - availability to perform the task ZL, after the θ time and maintained during the aircraft mission time - τ,
$O\ (\tau, \theta, ZL)$ - suitability as function of technical means and measures necessary to perform the ZL task,
t - current time,
θ - time of achieving the availability $G(\theta)$, where $\theta = t_1 - t_o$,
τ - time of aircraft mission.

The above aircraft model which realizes the air task (ZL) could be presented on graphic form. Besides mentioned parameters as: availability (G), reliability (R) i suitability (O), the ME model considers such elements as: Flight Safety (BL), Durability (T_R), Survivalability (Ż), Maintainability (P_E) and Logistics (L).

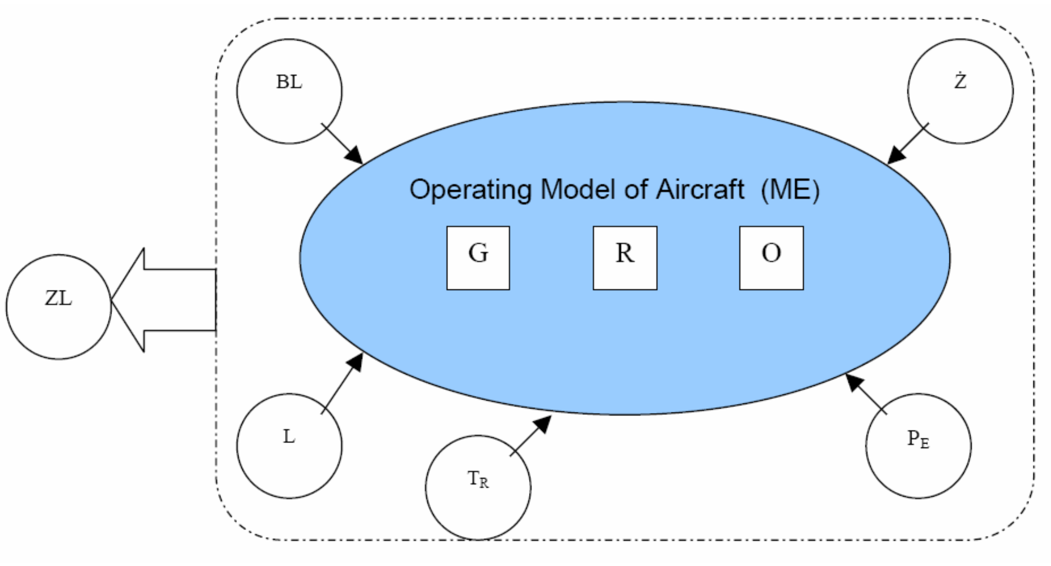

Fig.1 Operating Model of Aircraft conducting the Air Task

Based on above model, in similar way we can describe the Operating Model of Ship conducting the Sea Task (ZO).

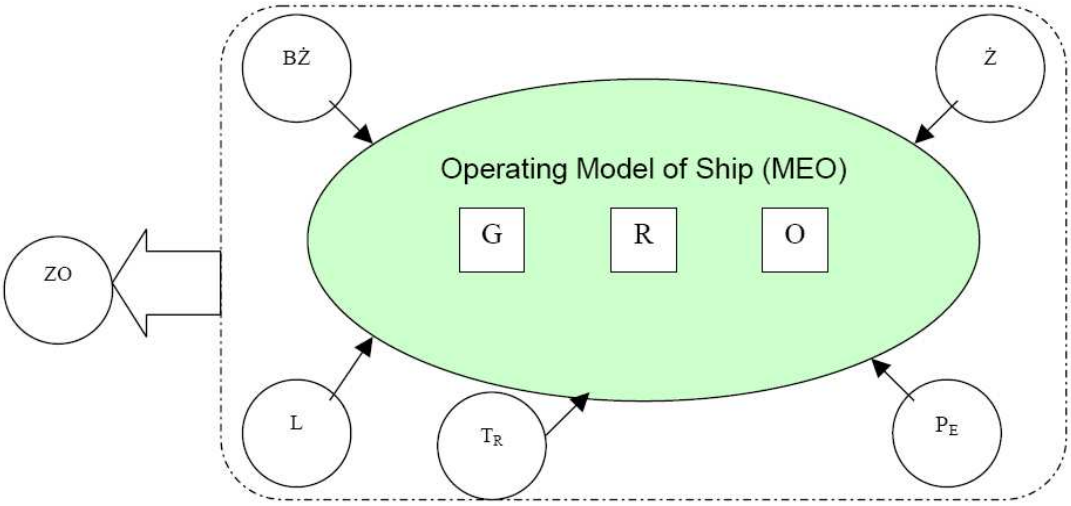

Fig 2. Operating Model of Ship conducting the Sea Task

The components of the MEO model depend on parameters of particular subsystems of the ship or those which have impact on the MEO. In spite of the fact that aviation detachment is onboard of the ship during the maritime mission, and it is integrated with ship weapon system, the Operating Model of Shipboard Helicopter (MEŚP) should be separated from Operating Model of the Ship (MEO) because of its specific operation, maintenance in reference to ships systems.

Having analyzed the MEŚP, we need to remember that Air Task (ZL) is subordinate to Sea Task (ZO) and that MEŚP and MEO models have close relationships in range of: availability, dependability and suitability. Moreover between these two models there is the a sphere, where MEŚP elements are included in MEO model structure as well. This is for instance: food, accommodation, medical assistance ship services and common supply channel of the logistic system. This intersection is eliminated when the helicopter performs the mission for non host ship (i.e. other ship from own Task Group).

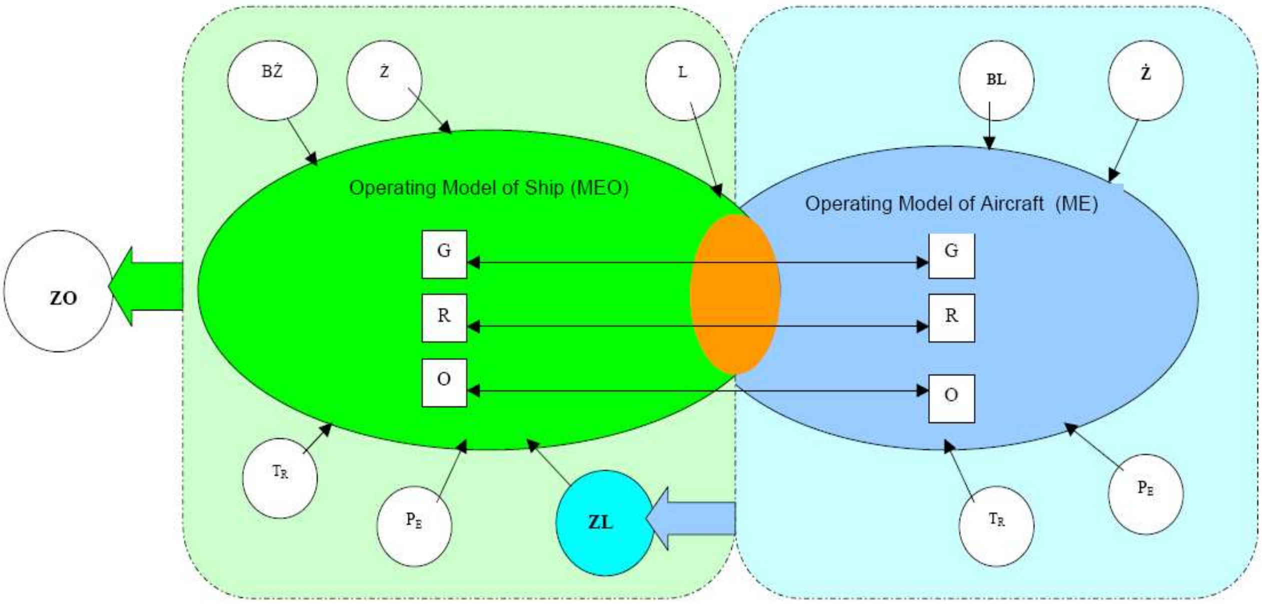

Fig 3. Operating Model of Deck Helicopter conducting the Air Task for home ship.

The set of factors having influence on helicopter maintenance process during deployment we can divide into 3 groups:

- I - requirements;
- II - limitations;
- III – operational – environmental conditions.

Group I - ship mission requirements for helicopter operations

Group II – set of limitations of the ship and helicopter (aviation detachment), which reflects the capability to fulfill the requirement of the Group I,

Group III -describes the outside conditions, which generally no ship, neither aviation detachment have influence on, but must be considered during the mission as well.

Group I requirements includes:

- the basic - priority of the ship mission,
- requirement of helicopter multipurpose usage (multipurpose missions),
- requirement of availability of the helicopter for the total time of the ship mission (deployment) readiness for 24 hours a day , 7 days a week,
- requirement of availability far away from home base and supply channels,
- requirement of all weather i climate conditions readiness,

Group II – limitations includes:

- ship class which determines her dimensions and autonomy:
  - limited dimensions of the landing deck on the ship,
  - limited maintenance and storage space,
  - limited accommodation and food services capabilities,
- capability of aircraft facility on the ship,
- ship repair shops capabilities,
- operational limitations of the helicopter:
  - frequency and duration of Preventive Maintenance (PM),
  - frequency and duration of Corrective Maintenance (CM),
  - limitation of available of flight hours (due to higher level of maintenance requirement or time components status)
  - limitation of performing the air mission (ZL) because of safety of helicopter operation (usage and maintenance)
- limited number of helicopter maintenance personnel embarked on ship,
- health limitation (psycho and physical) of the ship crew and aviation detachment,
- lack of the spare helicopter on the ship;
- limited access to spares and PM material, based on taken packages and effectiveness of supply channel of the logistic system,
- limitation of the logistic system (especially delay of it reaction).

Group III includes:

- region of operation (distance from home base and supply pipes),
- time of the mission (deployment),
- climate – weather conditions,
- composition and capabilities of the other ships of the Task Group,
- the goe – political conditions (peace, war),
- the combat capability of the enemy.

5. Conclusion

Presented above set of factors show us, how many elements have influence on keeping the helicopter on the ship during deployment time ready to use when it’s needed. Because of limitations and parameters impact, there is no possibility to achieve the 100% of A_o for his helicopter during several months deployment. Based on experience of the US Navy and Doutche Marine the available asymptotic level of A_o (for 1 embarked helicopter) is 90%. Taking into account presented before examples the biggest potential for improvement had Group II – limitations. Searching the better Ao we should focus the attention on ALDT parameter. Similar method for Ao improvement could be chosen for other than helicopter systems, for instance a ship and her subsystems.

This article shows that during analysis the effectiveness of any system, including ship propulsion system, there is necessary to deeply consider of the system availability, which is modeling by both: its subsystems and outside parameters.

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