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# PERFORMANCE MEASUREMENT FRAMEWORK FOR MULTI-ROLE AIRCRAFT UNDER PERFORMANCE BASED LOGISTICS

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## ABSTRACT

Under Performance Based Logistics (PBL), the vendor of weapon system is paid for their after-sales service based on the outcome of performance; therefore, it is very important to establish the way to measure outcome of performance accurate. This paper makes an attempt to develop a framework of measuring performance outcome which is specified for multi-role aircraft based on operational availability. The approach for operational availability using the value of stratified uptimes based on modular architecture is suggested to provide realistic measurement of performance when there is a PBL contract for a multi-role aircraft and the vendor is compensated by his outcome of performance.

*Keywords: operational availability, performance based logistics, multi-role aircraft, operational readiness*

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# 1 INTRODUCTION

In a defense sector there have lately been a lot of budget reduction and other constrains, which means spending money in a cost effectively way gets more and more important. The manager in defense sector would therefore need to have a thoroughly made plan on how to spend the limited budget on weapon system acquisition, operation and sustainment. Usually when planning the budget of defense, the portion put off for sustaining weapon system is greater than the portion put off for acquisition of new weapon system. This would usually mean that once a certain weapon system is bought, there would be slight chances to acquire another brand new weapon system in near future due to the budget constraints and high cost of procurement. Therefore, to utilize the amount of money available and the limited budget, the manager of the defense sector would wish to buy a weapon system which will be able to do different roles rather than one specialized role. Especially in the air force, this would be the case. The acquisition programs for fighter jet are converged to a multi-role aircraft. In a way, getting multi-role aircraft would increase the unit cost compared to the unit costs of a specialized aircraft. This is due to the fact that a multi-role aircraft will need more subsystems and techniques to apply the different functions the aircraft holds. But acquiring a fleet of multi-role aircraft would be cheaper than fleets of single role aircraft, since you would need fewer units to cover all the demands.

In recent years the cost of weapon system has been increasing due to high technologies and to meet complicated requirements. Therefore, the lifetime of a weapon system usually tends to increase consistently due to high acquisition cost. This would mean that the manager of defense sector would focus more on sustaining the weapon system during its lifetime. Currently the mean lifetime of fighter jets is more than 20 years (National Research Council 2001) and as a consequence of this long lifetime the strategy to buy new weapon system is less important than the strategy to sustain weapon system.

An after-sale service system is especially needed for capital equipment such as power plant, equipment for manufacturing industry, information networks and weapon systems where the effect of equipment downtime is highly critical and causes expenses to recover the side-effect (Jin et al. 2011). There are two major types of after-sales service systems to sustain a certain weapon system. The first system is the traditional way which is time and material contracts (T&MC). Under T&MC the vendor is compensated for the amount of resources such as parts and labor consumed to repair the equipment of downtime. The vendor would therefore not be encouraged to improve reliability of their equipment. A low reliability will cause more failures and there will be higher demand on parts and labor which will bring unexpected profit to vendor during after-sales service period. The other one is performance based logistics (PBL), which has been emerging in the recent years. Under PBL the vendor is paid for their after-sales service based on the outcome of performance. The equipment with lower reliability will cause frequent failure and the outcome of performance will not meet a certain level of customer expectation. In which case, the vendor will not be compensated due to that low outcome of performance(Guajardo et al. 2012).

If we want to make after-sales service contract based on PBL, it is very important to establish the way to measure outcome of performance accurate. The vendor will prefer a certain way to make the outcome bigger than real value because the vendor will make more money based on that outcome. That is why the customer needs to struggle with vendor to define a way to measure outcome of performance, which will reflect the real outcome.

This paper makes an attempt to develop a method of measuring performance outcome which is specified for multi-role aircraft, rather than single role aircraft, based on operational availability. The operational availability is a popular metric to measure performance outcome, but we believe that the current concept of operational availability is too simple to implement to a multi-role aircraft which consist of many subsystems and is able to conduct various missions.

# 2 STATUS AND PROBLEMS

## 2.1 Performance Based Logistics

Since the age of weapon systems gets longer, it is more considerable factor to sustain them during long-term period. As a consequence of this increase, the operation and maintenance costs have also increased, for instance during period of 1999 to 2006 the cost for avionics in aircraft has increased (National Research Council 2001). Now the manager of defense sector is focusing more on cost effective ways to maximize the performance and reliability of the system while reducing operation and maintenance cost (Jin et al. 2011). As mentioned earlier, T&MC, which is traditional and material based contracting, is not appropriate when we consider reliability of a weapon system. PBL, also known as performance based contract (PBC), is that the user actually pays for the performance outcome of the equipment instead of paying for resources such as spare parts and labor for repair during lifetime (Defense Acquisition University 2005). Therefore, when we use PBL approach, reliability of a weapon system will be higher, compared to T&MC approach since the vendor will be paid for outcome of performance not material based (Guajardo et al. 2012).

Under PBL measuring the accurate performance outcome is critical and there are many factors which cause big arguments between the vendor and customers. Based on the outcome (Availability) the vendor can make money and get the chance of incentives when they exceed the goal of performance outcome while there is risk of penalties (Nowicki et al. 2006). As a consequence of this penalties and incentives, the vendor tries to amplify the outcome than what he actually does. Thus in customer side he should pay attention to define metrics of performance that accurately express the customer's needs and outcome of performance because one of the most important elements of PBL strategy is the tailoring of metrics to each weapon system and PBL implementations are unique to each weapon programs that previously successful PBL metrics will not be implemented in exactly the same way (Defense Acquisition University 2005).

The most popular metric of aircraft for PBL is operational availability which measures the portion of time that a certain weapon system is ready to perform an assigned mission (Office of the Secretary of Defense 2009). The operation availability ($A_0$) is expressed by Eq. (1).

$$\frac{Uptime}{Uptime + Downtime} \qquad (1)$$

The uptime usually means the period of time when a weapon system is available for a mission, on the other hand the downtime reflects the period of time when the system is not available due to maintenance, etc.

## 2.2 Multi-role Aircraft

A multirole aircraft can easily be described as an aircraft designed and produced to perform different missions in combat, for instance air-to-air attack and air-to-surface attack(Dictionary). The big difference between a multi-role aircraft and a dedicated aircraft is that while the multi-role aircraft uses a common airframe for multiple tasks, the dedicated aircraft uses one single airframe for one explicit task (Tellis 2011). The main drive to develop a multirole aircraft was cost reduction and in 1968 a multination European project, named "Multi-Role Combat Aircraft", produced an aircraft capable of tactical strike, air defense and maritime roles. With the complexity and sophistication of modern warfare, mission adaptability for aircraft has become more important than ever (U.S. Department of the navy 2003). An aircraft that could swiftly adapt changing circumstances and missions would easily be preferred by defense departments with low budgets.

When the Department of Defense of a country wants to choose and buy an aircraft, there should be a speedy, but thoroughly made decision process that is focused on the right metrics, taking both technical and political consideration into account (Tellis 2011). However, political consideration will always be the key. When choosing an aircraft every military force would try to improve their military capacity (Koehn et al. 2004). Given the great economic challenges many countries are facing now, there will not be a lot of money to invest. So getting as much as possible out of the available money would be first priority for many countries. This does not mean that quality in the aircrafts should be greatly reduced, but rather choose wisely and take the military force's needs in account.

What a multi-role aircraft can provide countries and governments with low budgets and economic difficulties is an all-in-one package. With a multi-role aircraft the military force in various countries would be able to fulfill several needs in one investment. Getting one of these packages would certainly mean that you would lose some accuracy and effectiveness in most of the roles and missions the aircraft can perform in, compared to what a dedicated aircraft would perform, but in a time of shrinking defense budgets this option may be the best solution, as well as giving most product for the invested money.

## 2.3 Modular Architecture for Multi-role Aircraft

Product architecture is the scheme by which the functional elements of the product are arranged into physical chunks and by which the chunks interact (Prencipe 1998). Product architecture is important when developing and designing an aircraft, since these architectural decisions are made during the early stages in a development process. These architectural decisions have a great impact on the overall performance of the aircraft, as they influence the simplicity of changes, development opportunities and the ability to achieve certain performance levels. There are two distinctive types of product architecture, integral and modular architecture. In this paper we will mainly focus on the modular architecture, which includes a one-to-one mapping from functional elements in the function structure to the physical components of the product (Prencipe 1998).

The concept of modular design in the aero-craft business dates back to the early 1970s. It was introduced and used to ease the maintenance of aircrafts (Prencipe 1998). This would happen if they had standardized components, and reduced number of customized components, so that they could change without interfering or affecting other components. A big advantage with this design approach is that the supplier would gain tremendously strategic flexibility to meet different customer requirements in terms of thrust and performance. All in all, the introduction of this innovative design concept enable producers to meet evolving customer requirements without bearing the cost of designing and developing new engines from scratch (Prencipe 1998). A modular design makes it possible to manage both old and new aircrafts more affordably. By changing single parts and not the full system you would be able to save a lot.

Upgrading, maintaining and extending the life of an aircraft are both challenging and costly actions. When critical components need maintains, because of failure or fatigue, some components and systems will be old-fashioned and hard to come by. Aircrafts, which have long-lifetime, basically guarantees this scenario, as there is a great pace on technological developments. By choosing to have a modular design on your aircraft, you could avoid this problem. This design method gives the military force the opportunity to focus the capabilities on few modules and by doing this they would gain strategic and organizational flexibility.

In this paper we will use the term modules. A module can consist of one or several components, and they would all be a part of the modular architecture that has been described.

## 2.4 Level of Operational Readiness for Multi-role Aircraft

Since the multi-role aircraft consists of multiple subsystems and has to conduct various missions, sometime it is not possible to conduct all missions due to failure on a certain module. Therefore we need define the level of operational readiness of multi-role aircraft to express status of mission capability (Balaban et al. 2000). The air force defines three primary levels of operational capability which are fully mission capable (FMC), partially mission capable (PMC) and not mission capable (NMC). FMC means that an aircraft is able to do all of its assigned missions. PMC indicates that an aircraft can perform at least one of assigned mission, but not all of them. PMC can also be used to express that an aircraft can do all or some of assigned mission but not with full mission performance (U.S. Air Force 2012). Let say a fighter jet is conducting an air-to-ground mission with precision-guided munitions but for some reason the aircraft has degraded performance with a guidance module while it is still capable of performing that mission, the fighter jet is not able to do mission with full mission performance. The last one, NMC, means that an aircraft cannot perform any mission. All these levels are determined by status of modules also known as subsystems of aircraft. Figure 1 and 2 show simple examples of PMC and NMC based on modular architecture we discussed earlier.

Absolutely the level of operation readiness depends on the number of modules which is working under modular architecture of multi-role aircraft shown as Figure 1 and 2. When every module is available, the aircraft has the status of PMC with full mission performance. In case of failure on a certain module or modules, depending on importance of those modules, the status of multi-role aircraft will be PMC or NMC. For instance the engine is vital subsystem of aircraft. When the engine which has great importance has failure the aircraft will be NMC since it is not able to take off. But just with autopilot failure the aircraft is still able to do its assigned mission in that case the aircraft is PMC.

## 2.5 Need to Modify Operational Availability

When we just simply apply Eq. (1) to the case of multi-role aircraft to measure operational availability, there can be big difference between the result of Eq. (1) and real value of operational availability. For instance, if an aircraft is FMC during all of uptimes, Eq. (1) is appropriate to measure operational availability. However the status of multi-role aircraft spreads out levels of operational readiness such as FMC, PMC and NMC, we need to modify Eq. (1) to accommodate characteristics of multi-role aircraft.

PMC is the most difficult part to express its level. If an essential module is out of work, the size of damage to an aircraft is considerably big. Also if multiple modules are not working it will have bigger effect on the whole system than when a single module is out. Therefore the uptime should have different values depending on which modules are working and which ones are not.

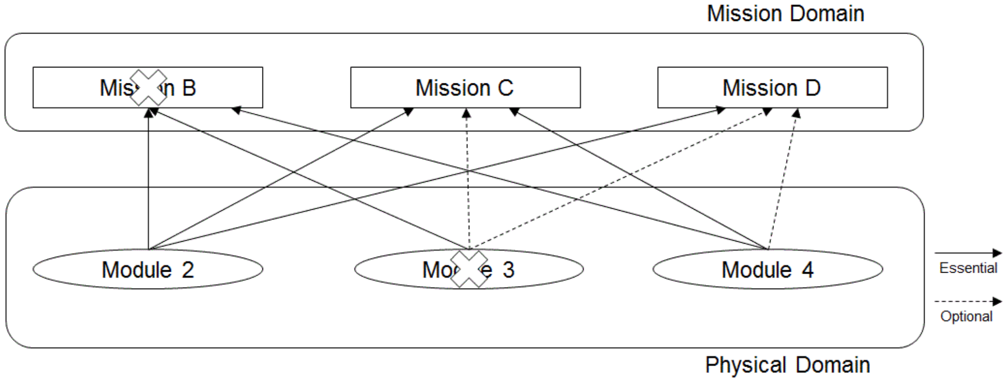


*Figure 1. Example of PMC (Partially mission capable)*

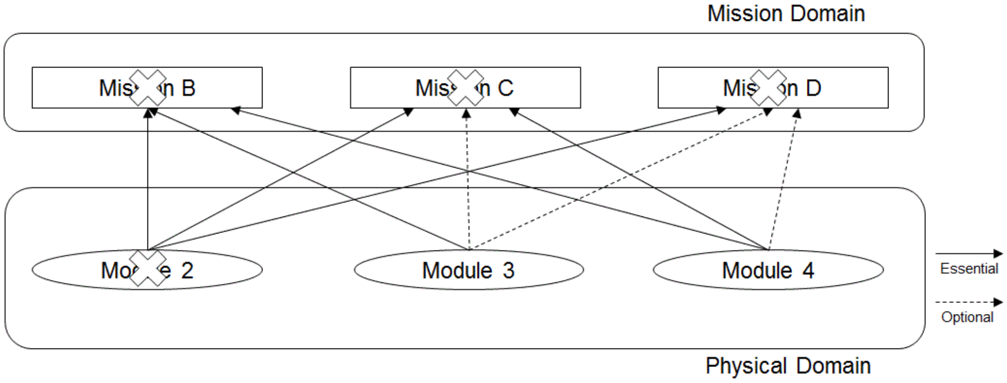


*Figure 2. Example of NMC (Not mission capable)*

According to these reasons we want use a value of stratified uptime for multi-role aircraft instead of simple uptime as Eq. (2). Figure 3 shows that there can be an overestimation of operational availability with Eq. (1) which will cause over compensation to the vendor. The following section will discuss how we can measure the operational availability with value of stratified uptimes.

$$\frac{Value\ of\ stratified\ Uptimes}{Uptime + Downtime} \tag{2}$$

$$A_o = \frac{Uptime}{Uptime + Downtime} \rangle A_o = \frac{Value\ of\ Stratified\ Uptimes}{Uptime + Downtime}$$

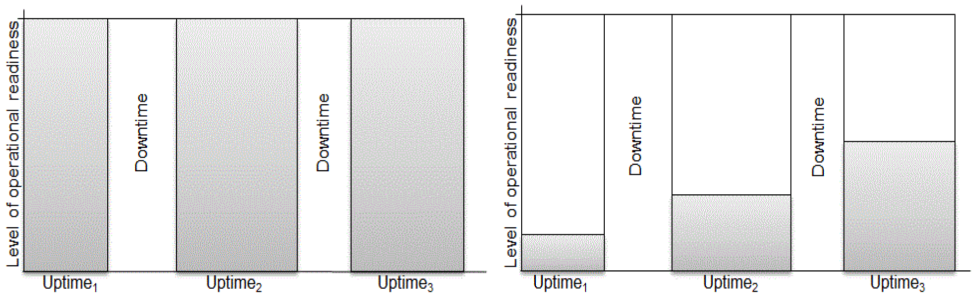


*Figure 3. Difference between non-stratified (left) and stratified uptimes (right)*

# 3 MODEL

## 3.1 Level of Operational Readiness

First of all, we need to assume that performance and capability of multi-role aircraft are generated by modules which are running. Therefore, the aircraft has degraded level of operational readiness depending on the number of modules malfunctioned. In this paper we will interpret performance and capability based on the number of modules functioning correctly.

Consider a multi-role aircraft with a number of missions and modules. We would like to disassemble the entire aircraft and divide the chunks of components, modules, into three different groups:

- Group 1: Modules which are critical, in the sense that failure of one the parts results in all missions being unavailable for use.
- Group 2: Modules which are critical for some missions and optional for others. A failure on one of these components would result in some missions being unavailable, but some will be almost unaffected and will still be available.
- Group 3: Modules which are optional, in the sense that it is a part of the aircraft to improve the performance of the mission. A failure on a component of this group would not make a mission unavailable.

In our analysis, we assume that the modules operate independently; meaning availability and failure of one the parts does not affect the availability of other parts. We also assume that the parts are connected in parallel, meaning that if one or more parts fail, the overall aircraft will not be affected as long as the components with failure do not belong to the mentioned group 1.

In Figure 4 we can see the different groups of modules that were earlier discussed. Module 2 is essential for all of the missions and a failure in this part would result in all missions being unavailable for use. Module 3 is only essential for mission B and optional for both mission C and mission D. A failure in this module will result in mission B being unavailable, while the two other will still be available for use.

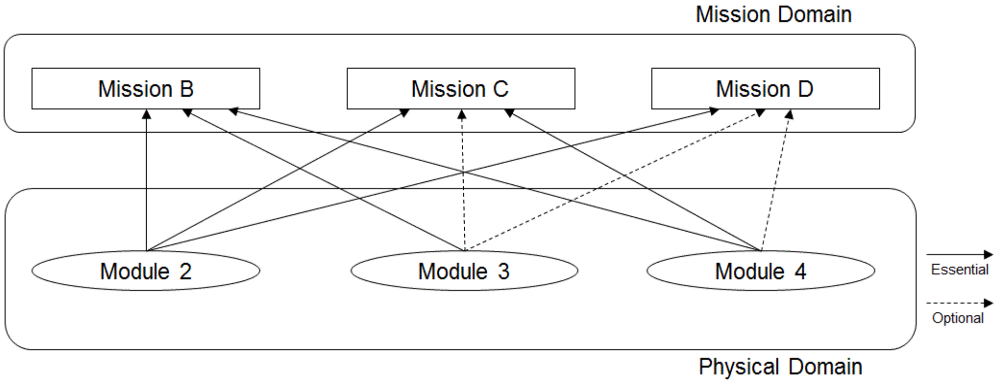


*Figure 4. Connection between missions and modules*

A multi-role aircraft would have $i$ different missions it is supposed to perform, and the value of performance and capability generated by the various modules in a certain mission can be expressed as $V_i$, where $i$ would indicate which mission $( i= A, B, C, \ldots, Z)$.

As mentioned, the components will be divided into $j$ different modules. A multi-role aircraft will therefore consist of $M_j$ modules, where $j$ indicates which module $(j = 1, 2, 3, \ldots, n)$. Every one of these module will have a value $X_{ij}$ which indicates the value of importance of a module to a mission:

- A essential module $j$ for a mission $i$ will have the value $X_{ij} = 1$
- An optional module $j$ for a mission $i$ will have a value $X_{ij}$ between 0.99 and 0.01. To simplify the model, we would like to assume that three different kinds of non-critical modules in our analysis, with the value 0.3, 0.2 and 0.1.
- A module with no effect on a mission will have the value $X_{ij}= 0$.

We put the discussed information into a table based on the US air force MESL (Minimum Essential Subsystem List) (U.S. Air Force 2012) as Table 1.

*Table 1. Information table based on the US Air Force MESL*

| | FSL (Full System List) | Mission Type A | B | C | D | … | Z |
|---|---|---|---|---|---|---|---|
| Module No. | $M_1$ | $X_{A1}$ | $X_{B1}$ | $X_{C1}$ | $X_{D1}$ | | $X_{Z1}$ |
| | $M_2$ | $X_{A2}$ | $X_{B2}$ | $X_{C2}$ | $X_{D2}$ | | $X_{Z2}$ |
| | $M_3$ | $X_{A3}$ | $X_{B3}$ | $X_{C3}$ | $X_{D3}$ | … | $X_{Z3}$ |
| | $M_4$ | $X_{A4}$ | $X_{B4}$ | $X_{C4}$ | $X_{D4}$ | | $X_{Z4}$ |
| | $M_5$ | $X_{A5}$ | $X_{B5}$ | $X_{C5}$ | $X_{D5}$ | | $X_{Z5}$ |
| | ⋮ | | | ⋮ | | | ⋮ |
| | $M_n$ | $X_{An}$ | $X_{Bn}$ | $X_{Cn}$ | $X_{Dn}$ | … | $X_{Zn}$ |

To calculate the value of performance and capability we would have to transform this table into a matrix computation as follows:

$$\begin{pmatrix} V_A \\ V_B \\ V_C \\ \vdots \\ V_Z \end{pmatrix} = \begin{pmatrix} X_{A1} & X_{A2} & X_{A3} & \cdots & X_{An} \\ X_{B1} & X_{B2} & X_{B3} & \cdots & X_{Bn} \\ X_{C1} & X_{C2} & X_{C3} & \cdots & X_{Cn} \\ & & \vdots & & \\ X_{Z1} & X_{Z2} & X_{Z3} & \cdots & X_{Zn} \end{pmatrix} \begin{pmatrix} M_1 \\ M_2 \\ M_3 \\ \vdots \\ M_n \end{pmatrix}$$

If a module of a multi-role aircraft is able to run then $M_j = 1$, if not $M_j = 0$.
The value of performance and capability of mission i generated by the various modules can be found as follows:

$$V_i = \sum_{j=1}^{n} X_{ij} M_j \quad for \;\; j = 1, 2, \cdots, n \tag{3}$$

Before we measure the total value of performance and capability of all missions, we need to consider the importance of each mission to a multi-role aircraft. For example, we are not able to put the same weight on both mission A and mission B if mission A is more frequently assigned to an aircraft than mission B. Therefore, we have to multiply $\alpha_i$, the importance of a mission to a multi-role aircraft, to $V_i$ , the value of performance and capability of each mission, as follows:

$$\alpha_i = \frac{sorties\ of\ mission\ i}{total\ sorties} \quad for \;\; i = A, B, \cdots, Z \tag{4}$$

This Eq. (4) allows us to calculate $T_{CPC}$ which is the total value of current performance and capability of a multi-role aircraft as

$$T_{CPC} = \sum_{i=A}^{Z} \alpha_i V_i = \sum_{i=A}^{Z} \alpha_i \sum_{j=1}^{n} X_{ij} M_j \quad for \;\; i = A, B, \cdots, Z \;\; and \;\; j = 1, 2, \cdots, n \tag{5}$$

To calculate $T_{FPC}$, which is the total value of full performance and capability of a multi-role aircraft, we assume that all modules of an aircraft are working. That means $M_j = 1$.

$$T_{FPC} = \sum_{i=A}^{Z} V_i = \sum_{i=A}^{Z} \alpha_i \sum_{j=1}^{n} X_{ij} \quad for \;\; i = A, B, \cdots, Z \;\; and \;\; j = 1, 2, \cdots, n \tag{6}$$

If we want to express FMC as 1, we need to normalize values of Eq. (5) over the value of Eq. (6), that is $\beta_k$ which refers to the level of operational readiness during $Uptime_k$ as Eq. (7)

$$\beta_k = \frac{\gamma \times T_{CPC}}{T_{FPC}} \tag{7}$$

We want to define a variable γ that could simplify the total value of current performance and capability of a multi-role aircraft.

$$for \quad \gamma = \begin{cases} 0, & if \;\; failure\ on\ a\ module\ which\ is\ essential\ to\ all\ missions \\ 1, & otherwise \end{cases}$$

If a module from group 1 has a failure the entire system will shut down, as no missions are available. So before using our methodology to calculate the level of operational readiness during $Uptime_k$, one should look for modules failed in the aircraft, and divide them into the specified groups. If any components occur in the group 1, the value of $\gamma$ will be $0$, which implicates that there is status of NMC and we will be able to skip Eq. (3), (5) and (6). If no modules occur in group 1 then the system will have $\gamma$ as $1$. In this case to calculate the level of operational readiness, we have to use our methodology.

### 3.2 Value of Stratified Uptimes

In Figure 3, there are a number of uptimes and downtimes. The level of operational readiness of multi-role aircraft is different within each uptime depending on status of modules. Therefore, the value of stratified uptimes could be expressed by the area of uptimes in Figure 3. Total sum of area for stratified uptimes could be calculated by Eq. (8), where $\alpha_k$ is the level of operational readiness during $Uptime_k$.

$$value\ of\ stratified\ uptimes = uptime_1 \times \beta_1 + uptime_2 \times \beta_2 + uptime_3 \times \beta_3 + \cdots \qquad (8)$$

Generally speaking when all modules of a multi-role aircraft are working correctly during $Uptime_k$, that is $M_j$ is 1 for all $j$, $\beta_k$ will be 1 as FMC, while it will be from 0 to 0.99 as PMC or NMC. Applying Eq. (8) into Eq. (2), we are able to measure the operational availability which is closer to real value.

## 4 SIMULATION AND ANALYSIS

We have constructed an experiment to simulate the value of stratified uptime of a multi-role aircraft with the possibility to perform several missions. The model computes the uptime for such a set of multiple missions, where each mission is composed of a number of modules, some critical and some optional. We assume that there are not any components from Group 1 that has a failure, which indicates $\gamma = 1$.

Figure 5 and Table 2 give an overview of the input parameters used in the simulations.

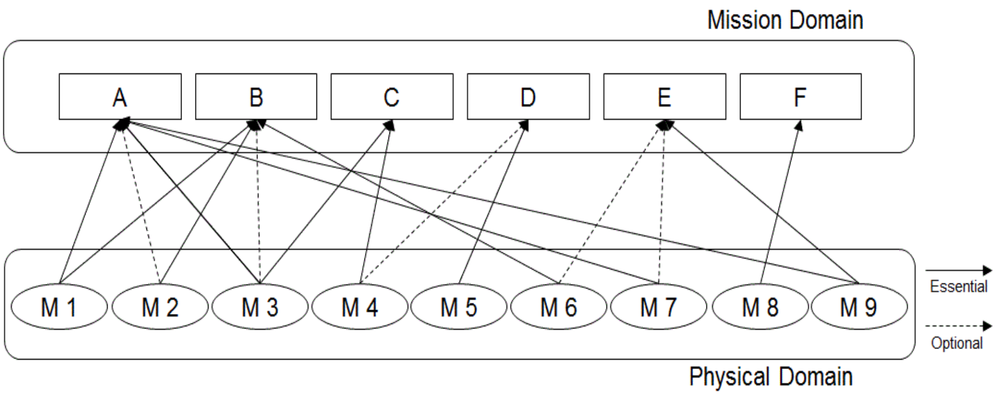


*Figure 5. Simulation domain overview*

*Table 2. Simulation input table*

| | | Mission Type | | | | | |
|---|---|---|---|---|---|---|---|
| | FSL (Full System List) | A | B | C | D | E | F |
| Module No. | $M_1$ | $X_{A1}$ | $X_{B1}$ | 0 | 0 | 0 | 0 |
| | $M_2$ | $X_{A2}$ | $X_{B2}$ | 0 | 0 | 0 | 0 |
| | $M_3$ | $X_{A3}$ | $X_{B3}$ | $X_{C3}$ | 0 | 0 | 0 |
| | $M_4$ | 0 | 0 | $X_{C4}$ | $X_{D4}$ | 0 | 0 |
| | $M_5$ | 0 | 0 | 0 | $X_{D5}$ | 0 | 0 |
| | $M_6$ | 0 | $X_{B6}$ | 0 | 0 | $X_{E6}$ | 0 |
| | $M_7$ | $X_{A7}$ | 0 | 0 | 0 | $X_{E7}$ | 0 |
| | $M_8$ | 0 | 0 | 0 | 0 | 0 | $X_{F8}$ |
| | $M_9$ | $X_{A9}$ | 0 | 0 | 0 | $X_{E9}$ | 0 |

Given we know the importance value of the optional modules; we can insert the value of importance in the table. If we give every module their value of importance to every mission, we get:

*Table 3. Simulation value table*

| | FSL (Full System List) | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| | | Mission Type | | | | | |
| Module No. | $M_1$ | 1 | 1 | 0 | 0 | 0 | 0 |
| | $M_2$ | 0.3 | 1 | 0 | 0 | 0 | 0 |
| | $M_3$ | 1 | 0.1 | 1 | 0 | 0 | 0 |
| | $M_4$ | 0 | 0 | 1 | 0.1 | 0 | 0 |
| | $M_5$ | 0 | 0 | 0 | 1 | 0 | 0 |
| | $M_6$ | 0 | 1 | 0 | 0 | 0.2 | 0 |
| | $M_7$ | 1 | 0 | 0 | 0 | 0.2 | 0 |
| | $M_8$ | 0 | 0 | 0 | 0 | 0 | 1 |
| | $M_9$ | 1 | 0 | 0 | 0 | 1 | 0 |

We also assume that all $\alpha_i$ have the same weight; therefore, all missions have the same importance to the multi-role aircraft in this simulation.
If we move forward with our model, we transform the table with the importance values into a matrix formula. This gives us the opportunity to calculate the value of performance and capability generated by the various modules and the level of operational readiness during $Uptime_k$.

$$\begin{pmatrix} V_A \\ V_B \\ V_C \\ V_D \\ V_E \\ V_F \end{pmatrix} = \begin{pmatrix} 1 & 0.3 & 1 & 0 & 0 & 0 & 1 & 0 & 1 \\ 1 & 1 & 0.1 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.2 & 0.2 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{pmatrix} \times \begin{pmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 4.3 \\ 3.1 \\ 2 \\ 1.1 \\ 1.4 \\ 1 \end{pmatrix}$$

$$\alpha_A \times V_A + \alpha_B \times V_B + \alpha_C \times V_C + \alpha_D \times V_D + \alpha_E \times V_E + \alpha_F \times V_F = \frac{1}{6}(4.3+3.1+2+1.1+1.4+1) = 2.15$$

When all modules are working, the values in Table 3 give us the total value of full performance and capability of a multi-role aircraft, $T_{FPC}$ as 2.15. If Module 8 breaks down, this will cause mission F to be unavailable. In this particular case no other missions will be affected by the failure on Module 8. The total value of current performance and capability, $T_{CPC}$, will now be 1.98, which is lower than $T_{FPC}$. Therefore, the level of operational readiness $\alpha_k$ will be 0.92 as PMC not FMC.
If we have maintenance data as Figure 6, the operational availability measured by Eq. (2) will be 0.917 while 0.976 by Eq. (1). In case which the goal of operational availability is 0.95, the vendor will be compensated by the result of Eq. (1) while not compensated by Eq. (2).

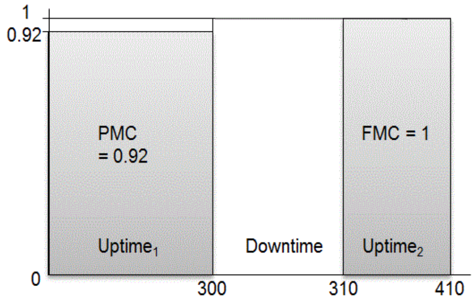


*Figure 6. Another case*

## 5 CONCLUSION

This approach for operational availability using the value of stratified uptimes is suggested to provide realistic measurement of performance when there is a PBL contract for a multi-role aircraft and the vendor is compensated by his outcome of performance. Because there is a level of performance satisfied which will generate big difference in the result of revenue to the vendor, we need to tailor the performance metric to customer's specific system. The interpretation, based on modular architecture, for operational availability will give a practical method which can be implemented to the current maintenance systems of air force fighters. Simply adjust $X_{ij}$ which indicates the value of importance of a module to a mission, the manager of air force is able to generate performance metric specified to his multi-role aircraft. To make this research more perfect, future research to examine the value of importance of a module to a mission should be conducted and interdependency between modules should be reflected to our model.

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