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A PHM-based Modeling Approach for Fighter Mission-Health Incident Matrix

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Fighter missions are decomposed into submissions following corresponding schedule and logic relationship based on mission decomposition technology, and according to the interrelationship between mission-function and function-system analysis, the correlation model is established between function requirement and function analysis, after that, satisfaction content is adapted to judge whether the recent system function could fulfill the requirement. A case study on air combat mission is used to illustrate the performance of the methodology. The process shows the feasibility of mission-health incident matrix in mission planning and optimization.

1. Introduction

PHM technology provides an approach for monitoring fighter health and predicting the subtle performance degradation real-timely with continuous test and analysis on each unit. Recently, the assessment of fighter suitability for given mission is determined by simple detection and pilots experience, which always hides failure and leads an incomplete mission or even accidents. Generally, health condition of each unit affects the implementation of corresponding functions and missions directly. After analyzing the relationship between a given mission and necessary systems, the mission-health matrix could launch assessment for each stage of given missions and offer a list of executable missions for pilots to guide performance real-timely.

During the establishment of mission-health matrix model, mission decomposition is used to list the names, schedule and duration of submissions, and then, function analysis is adapted to connect mission-function and function-system separately to illustrate the mapping relation of mission–function–system. Specifically, from the view of mission, the accomplishment of given mission is based on the implementation of corresponding function, this is the foundation of mission-function analysis, meanwhile, from the view of system, a fighter is composed of several systems, and each system contains various modules, obviously, modules work supports the function operation, this correlation is the foundation of function-system analysis. The mapping relationship is shown in Figure. 1.

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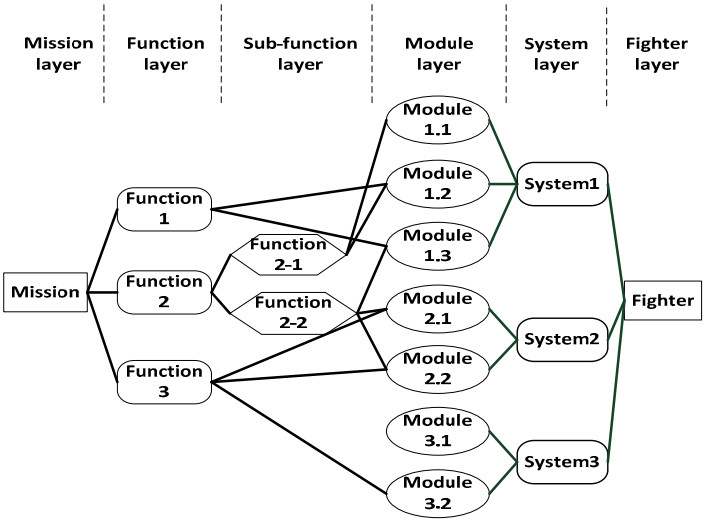

Figure 1 : The mapping relationship between mission and system

2. Preparation for mission-health incident matrix

2.1 Mission decomposition

Mission decomposition lists the schedule and duration of given mission, including all the submissions and their logical order (Dong et al, 2012). Fighter mission decomposition can be carried out as follows.

a) Analyze the mission profile and model the coordinate with height and duration.

b) Description the schedule with proper mission index, and separate the mission into seven steps such as climbing, fighting, and landing.

c) List the submissions in each step according to function operation.

Figure. 2 shows a given mission decomposition of a fighter.

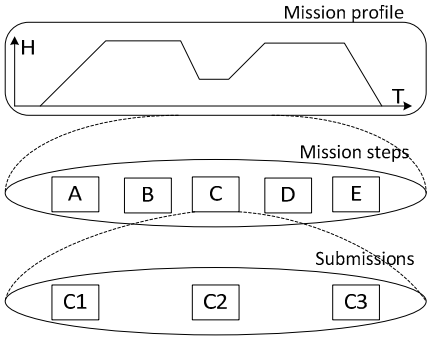

Figure 2: Illustration of mission decomposition

2.2 Mission index description

Mission index should describe the implementation of given mission adequately (Xiao et al, 2012), so appropriate index parameters are essential for given mission. Generally, one index parameter could not describe a mission comprehensively, more index parameters are necessary for the mission consequently. The confirmation of index value is a complex and iterative process, firstly, analyze the value range to guarantee the rationality, and then set the index value according to the actual mission situation, after that, calculate the obtained index value to ensure the accuracy.

2.3 Function requirement analysis

Function requirement analysis focus on the future possible missions and corresponding content including mission opponent, mission scale, mission mode and mission environment, these elements should be concerned about when analyzing the requirement. Function analysis could be launched as Figure. 3.

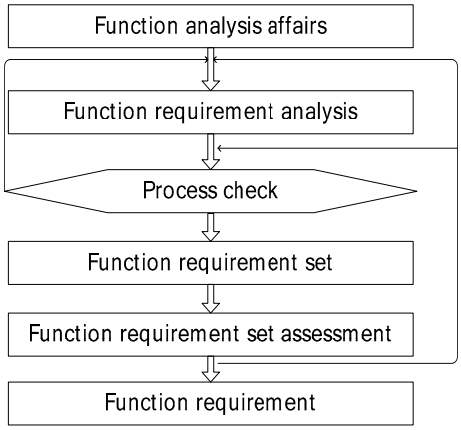

Figure 3 : Process of function requirement analysis

Various missions have different requirement for fighter systems by their mission properties, for instance, the necessity content of each system and the performance content of each module differ a lot. Function importance degree of various missions is the chief difficulty in establishing the mission-system matrix, which embodies the contribution of modules for different missions, the higher the function importance degree, the more rigorous the modules to the mission. In general, function importance degree of all the systems and modules is obtained from function requirement analysis and listed in tabular form for further analysis including three degrees, namely, perfect performance(A), degraded performance(B) and unnecessary(C), as shown in Table. 1. What's more, function levels of each module for a particular function should been given in function description.

Table 1 : Illustration of function importance degree

System	Function	Function importance degree for missions		
		Mission 1	Mission 2	Mission 3
System 1	Function 1.1	B	B	A
	Function 1.2	A	A	A
	Function 1.3	C	A	B
	Function 1.4	B	B	C
	Function 1.5	A	C	C
System 2	Function 2.1	B	A	B
	Function 2.2	A	B	A
	Function 2.3	C	A	A

2.4 System description

System description focuses on the function requirement which related to the given mission, mainly includes the type, quantity, location and correlation of the modules. System description could launch as follows.

a) From the system design scheme point of view, list the hierarchical structure of the flight, including system, subsystem, and modules;

b) According to function requirement, confirm the type and quantity of necessary modules;

c) Analyze the correlation of modules for the given mission and summarize all the modules targeting the given mission.

3. Establishment process of mission-health matrix

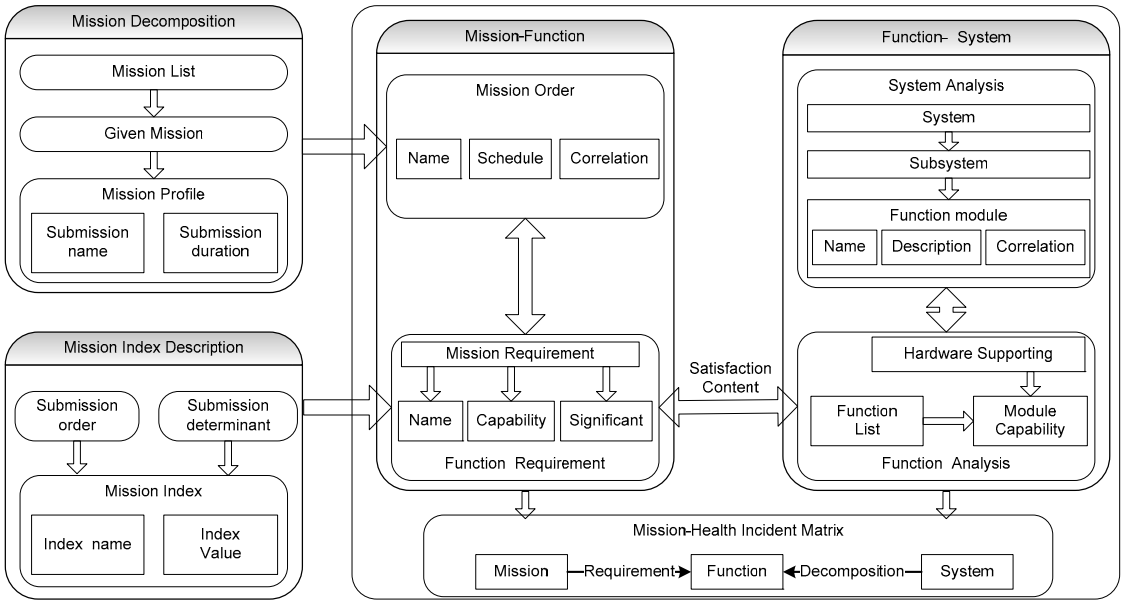

Figure 4: Establishment process of mission-health matrix

The establishment process of mission-health matrix is shown in Figure.4, mission decomposition provides the mission profile including the name and duration of submissions which presents information for mission order arrangement in mission-function analysis, meanwhile, mission index confirmation provides the accuracy index name and value for mission requirement analysis in mission-function analysis. And then, a correlation research between mission order and mission requirement is carried out in mission-function analysis, and what's more, another confirmation research between system analysis and function analysis is launched either, in this correlation, system analysis offers the hierarchical structure of a flight, and function analysis offers the corresponding function of modules. After that, the satisfaction content analysis between function requirement and function analysis is operated to justify whether the recent function provided by corresponding modules in current health condition could fulfill the function requirement. At last, mission and system is connected by function, this is the core of mission-health incident matrix. It should be emphasized that the satisfaction content analysis which concerns the validity and accuracy of judgment information is the key point in incident matrix establishment.

4. Case study

Consulting the mission set in fighter life cycle, take the air combat training mission for example to illustrate the mission-health establishment process.

4.1 Mission profile analysis

Air combat training mission aims to provide more experience of remote attack and short range attack for pilots. The mission profile is shown as Figure. 5.

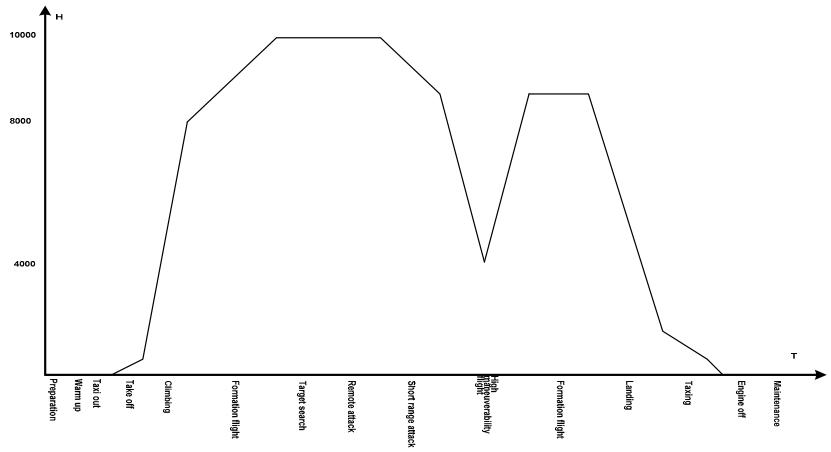

Figure 5 : mission profile

4.2 Mission index description

According to the influential factors to the mission, height, Mach and duration are selected as the mission index, and a portion of reasonable index value are listed in Table. 2.

Table 2: Index value

Submissions	Number	Height	Mach	Duration (s)
Preparation	1.1	0	0	400
Takeoff	1.4	0	0→0.3	40
Climbing	1.5	10→8,000	0.7	300
Remote attack	1.8	10000	0.6	500
Short range attack	1.9	10,000-,8000	0.6-0.8	200
Formation flight	1.11	8,000	0.6	500
Landing	1.12	8,000→10	0.3→0	400

4.3 Mission-function analysis

Corresponding requirement tends to differ in accordance with various submissions, take flight management system (S1), mission system (S2) and electromechanical system (S3) for example, and correlation function requirement and a portion of function importance degree (FID) are listed in Table. 3.

Table 3 : Function importance degree

Submissions	Number	Function requirement					
		S1	FID	S2	FID	S3	FID
Preparation	1.1			Mission load	B	Fuel filling	B
				Weapon load	A	Cockpit closed	A
						Engine afterburner	A
Takeoff	1.4					Undercarriage retract	B
Climbing	1.5			Navigation			
				Tracking	B		
Remote attack	1.8	Stowage open		Guiding	A		
				Firing	A		
Short range attack	1.9	Stowage open					
Formation flight	1.11			Navigation			
Landing	1.12						

4.4 Function-system analysis

Take the navigation function in air combat training mission as example. For the implementation of navigation, necessary modules of the subsystem CMN in mission system and their function level (1-10, 1means the lowest significance while 10 means the highest significance) are listed in Table. 4.

Table 4 : Modules requirement and function level

System	Subsystem	Modules	Function description	Function level
Mission system	CMN	VMAP	Power amplifier	5
		VMRA	Frequency conversion	5
		DDM	Management	9
		BMDT	Signal processing	10
		Warning	Alarm processing	5
		Mains	Voltage conversion	6
	Display system			
	Weapon system			

4.5 Mission-health incident matrix output

After analyzing corresponding function requirement for air combat training mission and the related modules requirement for navigation function, a mission-health incident matrix example is shown in tabular form as follows in Table 5. In this example, modules in CMN subsystem for navigation function in formation flight is analyzed to illustrate the correlation between mission and system, and then, health condition of the modules from PHM monitoring can be made a great advantage of for mission management and planning, which will provides more feasible and available information for pilots and commander.

Table 5: Mission-health incident matrix

Submission	NO.	Function analysis					Function level	Modules	Subsystem	System
		S1	S2	FID	S3	FID				
Preparation	1.1		Mission load	B	Fuel filling	B	…	…	…	…
			Weapon load	A	Cockpit closed	A				
…	…	…	…		…		…	…	…	…
Formation flight			Navigation				5	VMAP	CMN	Mission System
							5	VMRA		
							9	DDM		
							10	BMDT		
							5	Warning		
							6	Mains		
					…		…	…	Display system	
					…		…	…	Weapon system	
…		…	…		…		…	…	…	…

5. Conclusion and discussion

In this paper, a mission-health incident matrix establishment methodology that applicable to mission planning and optimization is proposed mainly including mission decomposition, system description and their relationship. The presented methodology could connect given mission and corresponding modules systematically and purposefully to represent their correlation with the help of PHM technology. Ongoing and future work will focus on the improvement and extension of this methodology. Furthermore, more implementation will be carried out to verify the feasibility of this methodology.

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