Design of Optimum Payload for Mid-life Upgrade of Helicopters (Stage V-VI)

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ABSTRACT

To meet additional mission requirements of new battle scenarios and to incorporate state-of-the-art mission systems, mid-life upgrade of helicopters is a cost-effective option. To upgrade, "mission payload systems" with advanced technology are to be evaluated for incorporation in helicopter design. This requires tools to ensure that mission capabilities are not compromised. In this paper, the framework adopted to develop a "decision making tool" for maximising the mission capabilities derived from a payload is discussed.

Keywords: Systems thinking, helicopter upgrade, mission payload systems, decision support system.

INTRODUCTION

Helicopters are an indispensable part of defence forces. Most of the helicopters designed are delivered in different versions to meet the varying mission requirements (Sweetman 1996). To meet additional mission requirements and to incorporate state-of-the-art mission systems, mid-life upgrades to helicopters in service have proved to be a cost-effective option (Zwol & Zijm 1996; Vergroesen 1996). New mission systems can be retrofitted to an existing helicopter and the resulting upgraded helicopter can deliver additional benefits to the operator as an all-new helicopter. Under the present restricted budget atmosphere, upgrades are viewed as a preferred option to entirely new aircraft projects (Sweetman 1996).

Jackson (1997), briefly refers to new technologies for incorporation in commercial aircraft design in the systems engineering process. The incorporation of "mission payload systems" with advanced technology for upgrade of maritime helicopters requires tools to ensure that "mission capabilities" are not compromised. Sinha et al. (1995, 1996 a), demonstrated the use of a systems approach in developing a conceptual model for multi-mission helicopter modifications. This provides the baseline to develop a framework to study maritime helicopters and its expected mission capabilities through mid-life upgrade.

The first phase (Stages I to IV) of research in the "Design of Optimum Payloads for Mid-life Upgrade of Helicopters" (Figure 1) by Sinha et al. (2000), resulted in the design of a "Mid-life upgrade system" for maritime helicopters. The design process considered the operational needs of maritime helicopters and the operational environment from a systems perspective. The system hierarchy developed by Sinha et al. (2000) identified the mission systems of the payload. To design an "effective payload" comprising of the appropriate systems – one that delivers the expected degree of mission capabilities, for upgrade of the helicopters, requires a mission contribution study to evaluate the relative importance of the components and attributes of the mission payload system. This paper attempts to develop a "Decision making tool" for design of an effective payload by an analysis of inter-intra mission contribution relationships of the components and attributes of the mission payload systems. This tool for efficient payload management aims at maximising the degree of mission capabilities to be met.

MID-LIFE UPGRADE SYSTEM

Systems thinking offers an avenue, whereby, slated and future helicopter missions, which are disparate, could be considered by a holistic approach for the design of a Mid-Life Upgrade System (MLUS). The MLUS is first viewed as a transformation process, in a conventional input-process-output system configuration. The operational needs of maritime helicopter missions and the operational environment constitute the inputs to the MLUS. The MLUS outputs are the mission capabilities that meet the mission requirements arising from the operational needs and environment. A holistic view of the helicopter upgrade problem as a transformation process is presented in Figure 2.

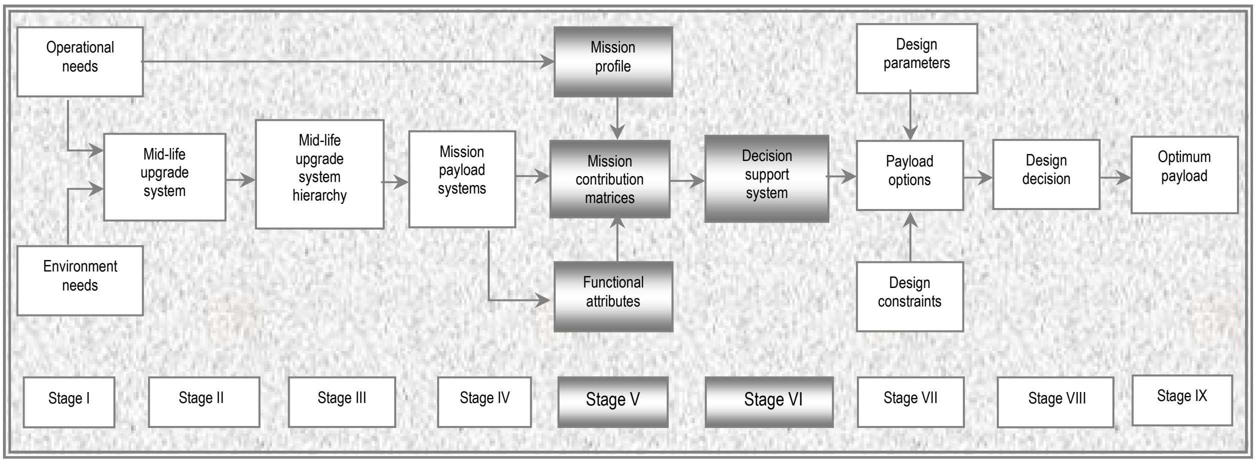

Figure 1. Systems framework for the design of payloads for mid-life upgrade of helicopters

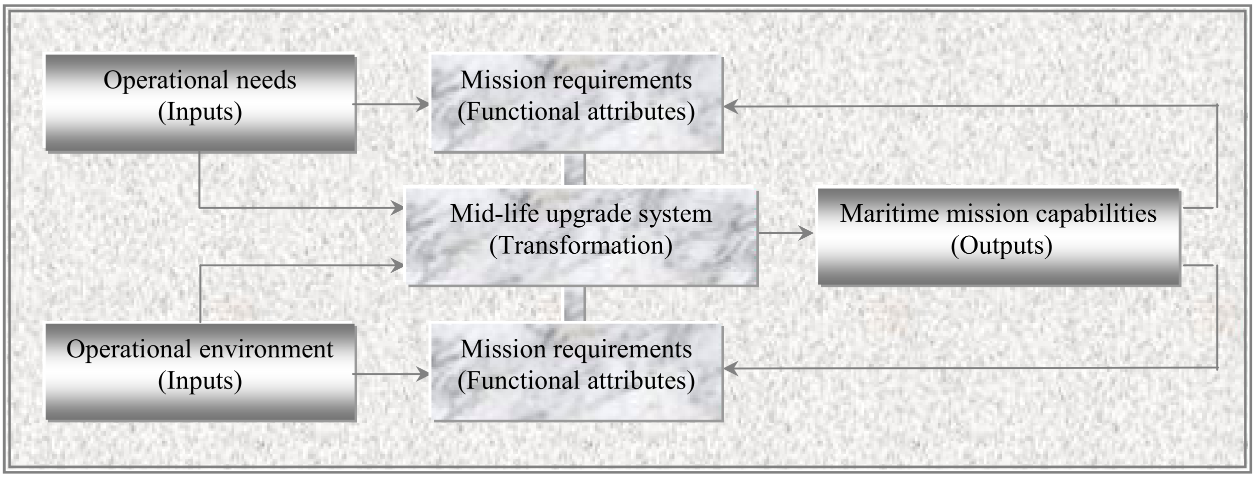

Figure 2: Mid-life upgrade system-Transformation process

Having set the upgrade problem of helicopters in a systems perspective, the inputs of the MLUS are identified from the slated missions of maritime helicopters. Sinha et al. (2000) carried out the mission analysis of maritime helicopters and presented the operational needs (inputs) in an offensive, defensive and logistic format. The operational environment (inputs) considered were threat, weather, time of operation and terrain, that stretched from confined space to open sea.

The operational needs and environment were translated into major mission requirements in a fashion that the required attributes (functional characteristics) of the MLUS were designated. The mission requirements are elaborated further for a deeper insight of the MLUS attributes. The operational needs, environment and the corresponding mission requirements (attributes) and capabilities (outputs) are presented in Table 1 and Table 2.

Sinha et al. (2000) arrayed the MLUS in a hierarchical structure to identify the subsystems (hardware components) that could fulfil the functional characteristics (attributes). The partial system hierarchy developed by considering the elaborated attributes identified in this paper (Table 1 and Table 2) is presented in Figure 3.

To maximise the helicopters mission capabilities, all major functional attributes of the MLUS are to be fulfilled by the hardware components of the mission payload system. This requires a mission contribution analysis of components and their attributes. Sinha et al. (1996 b) demonstrated a methodology of identifying the relative mission contribution levels of components and their attributes of a multi-mission helicopter system. The components and their attributes of the MLUS are analysed similarly on a matrix format, considering the 'mission profile', to firstly identify the mission contribution relationships between the system elements as follows:

- Component-component : Interdependence for mission contribution;
- Component-attribute : Functional characteristics that enable component's contribution to mission; and
- Attribute-attribute : Interdependence for mission contribution.

Secondly, the mission contribution relationships are classified to grade the level of mission contribution. The classifications are as follows:

- Highly indispensable : Mission has to be aborted;
- Indispensable : Part mission may have to be aborted;
- Very important : Mission effectiveness is substantially degraded;
- Important : Mission effectiveness is degraded; and
- Dispensable : Mission effectiveness is unaffected.

By following the above process, the importance of the components and their attributes in mission contribution are quantified and is referred to as the 'Mission Contribution Value' (MCV). By normalising the MCVs, Normalised Mission Contribution Values (NMCVs) are evaluated that quantified the relative mission contribution of the components and their attributes. The mission contribution matrix and the evaluated MCVs and NMCVs are presented in Table 3.

Table 1:Maritime missions - Inputs outputs and requirements

Operational needs (Inputs)	Mission requirements (Attributes)		Mission capabilities (Outputs)	
Offensive	Fire power	• Light weight attack of submarines. • Shadowing and targeting of surface contacts. • Provide support information to aircraft or missile system. • Limited forward air control for air attack. • Battle damage assessment. • Self defence.	Offensive warfare capabilities	Maritime mission capability
	Tactical flying	• Terrain flight/ Nap of earth flight. • Aggressive low level manoeuvering. • Day/ night/ all weather		
	Communicating	• Air traffic communication. • Tactical communication.		
	Operator activity	• Interpret inputs. • Weaponry. • Dispense EW counter measure. • Human stress.		
Defensive	Fire power	• Support boarding or search parties. • Self defence.	Defensive warfare capabilities	
	Reconnaissance & Surveillance	• Detect, identify, classify, locate and prosecute targets. • Combat search.		
	Aerial assault & extraction	• Insertion of boarding or search party. • Extraction of boarding or search party.		
	Tactical flying	• Terrain flight/ Nap of earth flight. • Aggressive low level manoeuvering. • Day/ night/ all weather.		
	Communicating	• Air traffic communication • Tactical communication		
	Operator activity	• Interpret inputs. • Weaponry. • Dispense EW counter measure. • Human stress.		
Logistics	Search	• Over land and sea for survivors or debris.	Logistic support capability	
	Aerial replenishment	• Cargo to personnel or ships. • Delivery of rescue personnel or survival equipment.		
	Transportation	• Transport combat troops. • Transport personnel and supplies. • Transport light stores on ships.		
	Aid civil authorities	• Visits and displays. • Support firefighting. • Support police operations.		
	Evacuation	• Evacuate stretcher cases with attendants.		
	Tactical flying	• Terrain flight/ Nap of earth flight. • Day/ night/ all weather.		
	Communicating	• Air traffic communication. • Tactical communication.		
	Operator activity	• Interpret inputs. • Troop or cargo handling. • Casualty handling. • Human stress.		

Table 2: Environment - Inputs outputs and requirements

Operational needs (Inputs)		Mission capabilities (Outputs)		
		Maritime mission capabilities		
		Defensive sub-mission	Offensive sub-mission	Logistic sub-mission
		Mission requirements		
Natural	Marine	• Open ocean • All sea state • Salt laden air • Sea water spray • Wave wash	• Open ocean • All sea state • Salt laden air • Sea water spray • Wave wash	• Open ocean • All sea state • Salt laden air • Sea water spray • Wave wash
	Confined	• Ships • Vegetation	• Ships • Vegetation	• Ships • Vegetation
	Terrain	• Desert • Unprepared sites • Obstacles	• Desert • Unprepared sites • Obstacles	• Desert • Unprepared sites • Obstacles
	All weather	• Tropical • Hot • Wintery • Cyclonic • Rainy	• Tropical • Hot • Wintery • Cyclonic • Rainy	• Tropical • Hot • Wintery • Cyclonic • Rainy
	All times	• Day • Night	• Day • Night	• Day • Night
	Situation	• Hot and wet	• Hot and wet	• Hot and wet
Natural and Manmade	Threat	• Hostile • Non-hostile	• Hostile • Non-hostile	• Hostile • Non-hostile
	Interference	• Electro magnetic	• Electro magnetic	• Electro magnetic

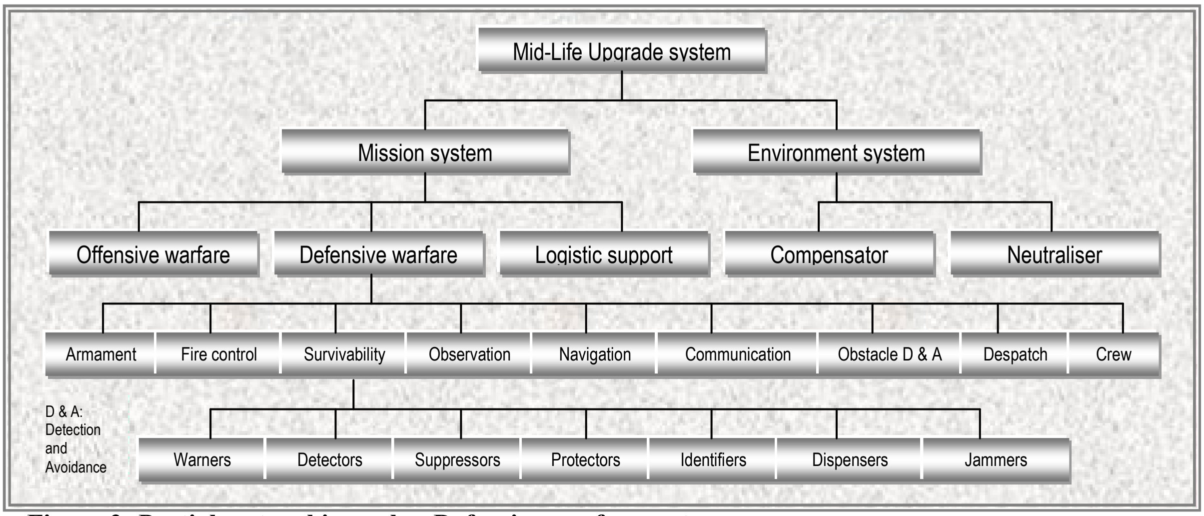

Figure 3: Partial system hierarchy -Defensive warfare system

DECISION SUPPORT SYSTEM

With the relative mission contribution of the components and attributes of the mission payload systems established, the next step is to develop a decision making tool that aids in the design of an effective payload. The tool is to support decisions in the choice of the appropriate mission systems and their attributes in a manner that the mission capabilities derived from the payload is maximised. This is achieved by considering the evaluated NMCVs of the components and attributes. The tool is thus a 'Decision Support System' (DSS) for mid-life upgrade of maritime helicopters.

The DSS is developed in a tier format, by placement of mission systems and their attributes in order of their NMCVs. The systems with higher NMCVs are in the upper tiers and those with lesser values in the lower tiers. The DSS formulated is presented in Figure 4. By giving utmost consideration to components and attributes of the upper tiers while designing payloads, the mission contribution would be higher, and thus, the mission capabilities of the helicopter derived from the resulting payload would be maximised.

Table 3: Mission contribution matrix - Defensive warfare mid-life upgrade system

Component		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Armament	C 1	-	5	5	5	3	3	-	2	5	-	-	-	-	-
Fire control	C 2	5	-	5	5	3	3	-	2	5	-	-	-	3	-
Survivability	C 3	5	5	-	5	3	2	3	3	5	-	-	-	4	-
Observation	C 4	5	5	5	-	2	2	4	4	5	-	-	-	-	-
Navigation	C 5	3	3	3	2	-	1	2	2	3	-	-	-	4	-
Communication	C 6	3	3	2	2	1	-	1	4	5	-	-	-	5	-
Obstacle D & A	C 7	-	-	3	4	2	1	-	-	3	-	-	-	-	-
Despatch	C 8	2	2	3	4	2	4	-	-	4	-	-	-	-	-
Crew	C 9	5	5	5	5	3	5	3	4	-	-	-	-	-	-
Particle separator	C 10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erosion protector	C 11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corrosion protector	C 12	-	-	-	-	-	-	-	-	-	-	Component and Component			-
EM protector	C 13	-	3	4	-	4	5	-	-	-	-				-
Conditioner	C 14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Attribute															
Armed recce & survl	A 1	5	5	4	5	3	3	2	-	5	-	-	-	-	-
Support B/ S parties	A 2	4	4	5	3	3	3	-	5	5	-	Component and Attribute			-
Self protection	A 3	3	3	5	3	2	2	1	-	4	-				-
Insert/ extract parties	A 4	-	-	3	2	1	4	-	5	5	-	-	-	-	-
Terrain flight	A 5	-	-	3	5	2	-	5	4	4	-	-	-	3	-
Air traffic commn	A 6	-	-	-	-	2	5	-	-	3	-	-	-	5	-
Tactical commn	A 7	-	-	4	3	4	5	-	5	5	-	-	-	5	-
Interpret inputs	A 8	-	-	4	5	4	3	3	2	5	-	-	-	-	-
Agg manoeuvring	A 9	-	4	5	3	-	-	2	3	5	-	-	-	-	-
Counter measure	A 10	-	-	5	3	-	2	-	-	4	-	-	-	3	-
Weaponry	A 11	5	5	4	2	-	3	-	3	4	-	-	-	-	-
Stress	A 12	3	3	5	4	2	4	2	4	5	-	-	-	1	3
Marine	A 13	-	-	3	4	5	4	3	4	4	-	-	5	4	4
Confined	A 14	-	-	-	3	5	4	5	4	5	-	-	-	5	-
Terrain	A 15	-	-	-	3	4	2	4	-	4	5	4	-	-	-
All weather	A 16	-	-	3	4	3	2	5	3	5	4	-	4	-	5
All time	A 17	-	-	3	5	5	-	4	4	5	-	-	-	-	-
Hostile	A 18	5	5	5	4	2	4	-	5	5	-	-	-	-	-
Situational	A 19	-	-	-	-	-	-	-	-	-	-	-	3	-	4
Electromagnetic	A 20	-	3	3	3	5	5	2	-	-	-	-	-	5	-
Component/ Attribute		1	2	3	4	5	6	7	8	9	10	11	12	13	14
MCV		53	63	99	96	75	81	51	72	117	09	04	12	47	16
NMCV		**0.08**	**0.08**	**0.12**	**0.12**	**0.09**	**0.10**	**0.06**	**0.09**	**0.15**	**0.01**	**0.01**	**0.02**	**0.06**	**0.02**

Attribute and Attribute

Attribute		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Armed recce & survl	A 1	-	4	5	3	5	2	5	4	5	4	5	4	5	-	3	4	4	5	3	3
Support B/ S parties	A 2	4	-	4	5	4	2	5	4	3	1	4	4	5	4	2	4	4	5	2	2
Self protection	A 3	5	4	-	5	3	1	5	3	3	1	3	3	5	4	2	4	4	4	2	4
Insert/ extract parties	A 4	3	5	5	-	4	1	5	3	3	1	4	3	5	4	1	4	4	4	2	4
Terrain flight	A 5	5	4	3	4	-	-	4	3	4	2	4	4	4	-	4	4	4	5	-	3
Air traffic commn	A 6	2	2	1	1	-	-	-	3	-	-	-	2	3	4	-	4	4	-	2	4
Tactical commn	A 7	5	5	5	5	4	-	-	5	4	3	4	4	4	3	3	4	4	5	2	5
Interpret inputs	A 8	4	4	3	3	3	3	5	-	4	4	4	5	4	4	2	3	3	5	2	-
Agg manoeuvring	A 9	5	3	3	3	4	-	4	4	-	2	4	4	4	3	2	3	3	5	2	-
Counter measure	A 10	4	1	1	1	2	-	3	4	2	-	-	3	4	-	3	3	3	5	2	5
Weaponry	A 11	5	4	3	4	4	-	4	4	4	-	-	4	4	4	4	3	3	5	2	-
Stress	A 12	4	4	3	3	4	2	4	5	4	3	4	-	4	5	3	4	4	5	2	-
Marine	A 13	5	5	5	5	4	3	4	4	4	4	4	4	-	4	-	4	4	4	3	3
Confined	A 14	-	4	4	4	-	4	3	4	3	-	4	5	4	-	-	4	4	4	2	5
Terrain	A 15	3	2	2	1	4	-	3	2	2	3	4	3	-	-	-	2	2	4	2	2
All weather	A 16	4	4	4	4	4	4	4	3	3	3	3	4	4	4	2	-	4	4	2	-
All time	A 17	4	4	4	4	4	4	4	3	3	3	3	4	4	4	2	4	-	4	2	4
Hostile	A 18	5	5	4	4	5	-	5	5	5	5	5	5	4	4	4	4	4	-	2	2
Situational	A 19	3	2	2	2	-	2	2	2	2	2	2	2	3	2	2	2	2	2	-	1
Electromagnetic	A 20	3	2	4	4	3	4	5	-	-	5	-	-	2	5	2	-	4	2	1	-
Component/ Attribute		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
MCV		73	68	65	65	61	32	74	65	58	46	61	76	72	58	41	64	68	77	34	39
NMCV		0.06	0.05	0.05	0.05	0.05	0.03	0.06	0.05	0.05	0.04	0.05	0.06	0.06	0.05	0.03	0.05	0.05	0.07	0.03	0.04

CLASSIFICATION OF MISSION CONTRIBUTION

Inter- and Intra- functional relationship

- **Highly indispensable** (Mission has to be aborted) : 5
- **Indispensable** (Part mission may have to be aborted) : 4
- **Very important** (Mission effectiveness is substantially degraded) : 3
- **Important** (Mission effectiveness is degraded) : 2
- **Dispensable** (Mission effectiveness is unaffected) : 1

LEGEND

A : Attribute   Agg : Aggressive   B/ S : Boarding / Search   Commn : Communications   C : Component   D & A : Detection & Avoidance   EM : Electromagnetic   Recce & Survl : Reconnaissance & Surveillance

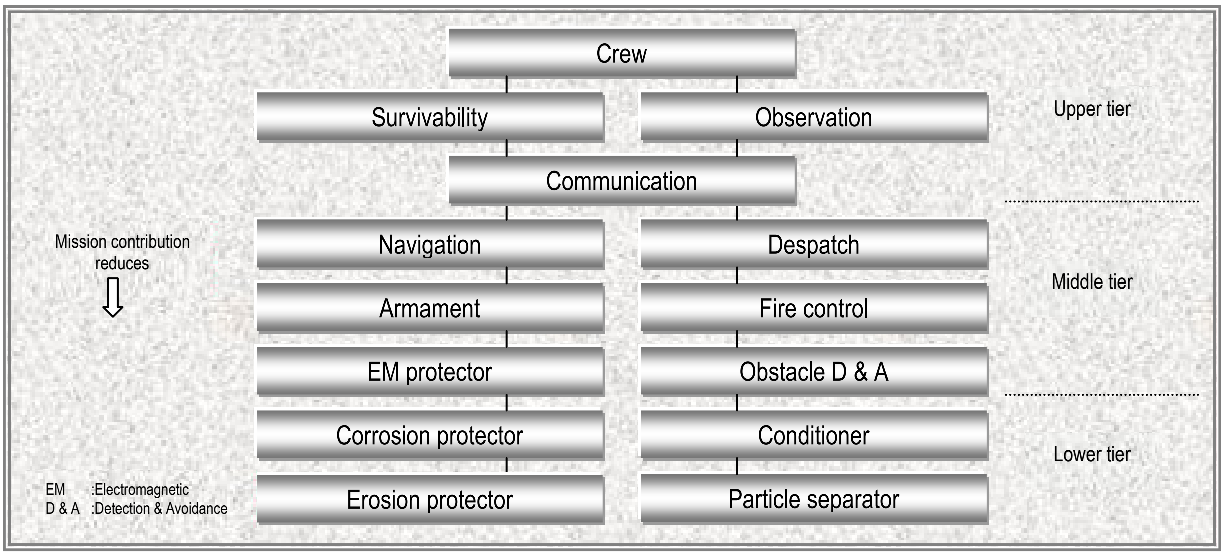

Figure 4: Decision support system -Defensive warfare system

DISCUSSION

The mission contribution analysis of the mission payload systems in a matrix format provides the means to quantitatively assess the degree of mission contribution of the components and their attributes. Layout of DSS in a tier format presents the order in which the components and attributes are to be considered in mission payload design. Various payloads can be designed with the aid of DSS by varying the component/attribute composition.

The crew, survivability, observation and communication systems are the major contributors to the mission. Individually they contribute in the order of 15% to 10%, a total of 49%. This falls in place as the helicopters in a defensive posture contribute mainly to reconnaissance and surveillance. The next tier comprises of the mission systems required for insertion, support and extraction of boarding and search parties, which in fact is the next important role of a defensive helicopter. The systems of lower tier have no major mission contribution.

CONCLUSION

This paper provides a methodology for development of a decision making tool to aid mission payload design for maritime helicopter upgrades. The payload design is driven by a single factor - maximising the mission capabilities of the helicopter. The design of an optimum payload requires consideration of additional system design parameters and constraints. Stages VII, to IX of the research program will address the optimum payload design.

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