# FLEET MANAGEMENT SYSTEM FOR AN ADVANCED HELICOPTER PLATFORM – SYSTEM STRUCTURE DEVELOPMENT

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**Abstract:** The investigated advanced defence helicopter fleet will be undergoing a major acquisition process including upgrade under a 20+ year strategic plan. This program develops aims to rationalise the number of helicopter types operated, simplify operational requirements and reduce through life support costs. The helicopter fleet presently comprises of nine helicopter types, to be grouped to three to four fundamental types. A fleet management methodology needs to be developed and modelled for each fundamental type of helicopter. This research will assess current practices in aerospace technology management of military aircraft fleets and establish requirements for both, civil and military rotary-wing platforms and design a specific methodology for the fundamental Multi-Role Helicopter (MRH) of the defence forces. The outcome will be a technology management methodology, demonstrated through simulation for application on the MRH.

This paper adopts a systems approach to develop the fleet management methodology for application on the MRH helicopter platform within a technology management environment. The fleet management system was considered as the total system and the MRH and its support infrastructure were located at the lower levels of the hierarchy. Establishing a systems concept of the various hierarchy levels identified the attributes and relationships of the system components.

## INTRODUCTION

Rotary wing technology provides major benefits to the community and the industry in the civil and military sectors. It has proven its capabilities in service for emergency and military support over the years. Rotary wing platforms cover a variety of missions, conducting passenger and emergency transport, search and rescue tasks, heavy lift duties and military roles. The defence forces operate and maintain a large fleet of rotary wing platforms that require advanced fleet management practices.

Presently, fleet management is mainly based on commercially available tools to manage the maintenance and movements of vehicles [1]. Companies specialising in the development of softwares, customise the tools based on fleet types, resulting in several commercially available tools. These tools assist the operators to increase the availability and enhance service life of the vehicle. The tools are specialised on engineering maintenance support management including operations to cover the allocation of resources [1].

The majority of the providers of fleet management tools and their services are for application on surface vehicle fleets and limited for aviation applications. The complexity of fixed- and rotary-wing systems and their associated support structure makes it challenging in the application for fleet management. The service life of surface vehicles and its type of associated support differ from aircraft on several issues; to illustrate - military aircraft undergo life-extension through mid-life upgrades to enhance mission capability. This requires an in-built flexibility in the technology insertion management system. None of the tools support management of life-extension.

Studies have been initiated in fleet management to investigate issues related to increase in average age of military aircraft fleets [2], and the operational acquisitions costs faced by operators. The research aims to extend the service life [3] of the airframes to enhance operational effectiveness [4] and predict fleet reliability [5]. To address issues of aircraft scheduling, performance and cost management; probabilistic approaches [6, 7] and statistical models [8] are being considered; including single or multiple type fleets to optimise maintenance and training procedures [9].

A fleet management methodology needs to be developed and modelled specific to aerial platforms. In this paper the MRH helicopter platform is considered to demonstrate the development of the methodology. The research will assess current practices in aerospace technology management of military aircraft fleets. It will investigate the requirements for both, civil and military rotary-wing platforms and design a specific methodology for fleet management of the MRH for the defence forces.

This paper adopts a systems approach to develop the fleet management methodology for application on the MRH helicopter platform within the slated technology management environment. The systems approach in this paper is applied on the MRH platform part of the total system only, due to limitations in size and complexity.

## 1. SYSTEM HIERARCHY AND ELEMENTS

A system is composed of components, attributes, and relationships. The components are also referred as subsystems. The attributes are the functional characteristics of the components and also referred as requirements in the design of a system [10]. Relationships are the inter and intra relationships between components and attributes. A system may be part of a larger system in a hierarchy, and its components may be referred as a system. The purpose of the system is achieved by the system elements and their corresponding attributes [10].

Fleet management systems traditionally focus on maintenance and support related issues, comprising of maintenance planning, tracking of flight hours of airframes and subsystems, modifications and upgrade scheduling. To provide the operators joint fleet management capabilities within their fleet [11] the design process needs to capture the operational aspects of the MRH platform. The maintenance planning system is considered as part of a total fleet management system.

### 1.1 Hierarchy Levels 1 to 2

The total system is at the top level of the hierarchy with several other subsystems and components at different levels of the hierarchy. These subsystems and the components need to be further investigated.

Fleet management involves planning and scheduling of a variety of tasks, including maintenance, missions, upgrades, training and modifications, making ‘schedule’ a subsystem of the next level in the hierarchy (Level 1). The second component is ‘infrastructure’, referring to the necessary hardware to support rotary-wing operations. The infrastructure includes air bases and ships, logistic support and the involved personnel (ground and air). As the third component, the MRH platform completes the first level of the hierarchy. The MRH platform is available as a Troop Transport Helicopter (TTH) version and NATO Frigate Helicopter (NFH) version. The primary role of the TTH version is the transport of 20 troops or more than 2,500 kg of cargo, heliborne operations and search & rescue (SAR). It can be adapted to MEDEVAC/CASEVAC missions by fitting up to 12 stretchers or cargo delivery capability. The primary role of the NFH version is autonomous anti-submarine warfare (ASW) and anti-surface unit warfare (ASuW), mainly from naval ships. These aircraft are equipped for day and night, adverse weather and severe ship motion operations. Additional roles include anti-air warfare support, vertical replenishment, SAR and troop transport. The system hierarchy from level 1 and 2 is presented in *Figure 1*.

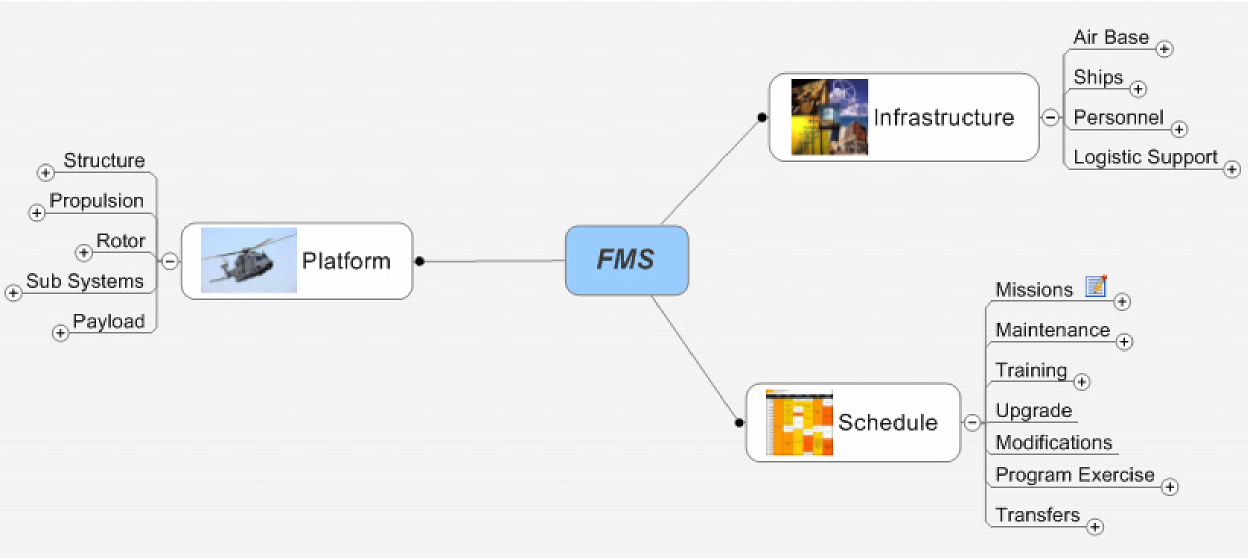


*Figure 1: System Hierarchy – Levels 1 and 2*

### 1.2.1 System Elements – Level 1

The identification of subsystems of the total system provides the avenue for analysis of the system elements – components, attributes, and relationships. At Level 1, the three components are the MRH platform, infrastructure and scheduling, with the principle difference of analysing hardware and software, and hence, the attributes are to be accordingly analysed. A brief analysis of the system components for identification of the system attributes is as follows:

- Platform: The platform is a Level 1 subsystem to the fleet management system and categorised into the hierarchy components. For identification of the MRH system attributes, only Level 1 attributes of the helicopter are investigated, attributes of helicopter subsystems are analysed separately. Flight performance, considered as the key attribute of the MRH, includes a measure of cruise speed and rate of climb at maximum and/or economical condition; hovering ceiling (IGE/OGE), service ceiling, range (typical/ferry/max), endurance, cargo capacity and radius of action. Mission performance depicts the success rate of mission accomplishment followed by the helicopter utilisation rate. This reflects the reliability (MTBF) and availability (design requirement: 97.5% mission reliability [12]) of the platform from an operational perspective. Further MRH system attributes include commonality and interchangeability of personnel and components within the ADF. Interoperability of Army and Navy materiel requires navy ship compatibility of the MRH platform in regards to hangar size, clearances and loads. The attributes of the MRH system are as follows:

  - Flight Performance;
  - Mission Performance;
  - Utilisation Rate;
  - Reliability;
  - Availability;
  - Interchangeability;
  - Commonality;
  - Safety; and
  - Compatibility.

- Infrastructure: The infrastructure refers to the hardware required for rotary-wing operations and support. Although helicopters can operate from remote locations, the air base is considered as the basing location, consisting of paved areas, shelters, buildings, testing, ground support equipment and utilities, special services, assorted equipment and security systems. Air bases are categorised according to the type of equipment, configuration, capacity, and location. Navy ships serve as seaborne mobile bases for helicopters and therefore are essential elements in the defence forces. They distinguish themselves through a small landing deck, hangar, lifts, RAST system, landing aids and safety equipment. Infrastructure furthermore includes the personnel required for rotary-wing operations, categorised according to rank, qualification, experience, seniority and availability. Logistic support completes the infrastructure, characterised through performance, reliability, availability, maintainability and testability [13]. Therefore the attributes of the fleet management system from a infrastructural perspective are as follows:
  - Capacity;
  - Accessibility
  - Compatibility;
  - Qualification;
  - Availability; and
  - Age.

- Schedule: Scheduling consists of activities related to planning and timing of fleet management tasks. These include assignment of personnel and airframes to tasks, including deployment, scheduled maintenance, training, upgrade, airframe and systems modification, program exercise and transfer between locations and operational units. The schedule is required to obtain the unit with a defined operational readiness at any time. The maintenance periodicity and intervals govern the assignment of airframes to the depicted tasks, resulting in a downtime and state of airworthiness for each platform. The time required to accomplish the scheduled tasks safely is considered as a key attribute of scheduling. Thus, the present scope is as follows:
  - Operational Readiness;
  - Maintenance periodicity and intervals;
  - Downtime;
  - Airworthiness;
  - Training time; and
  - Mission enhancement.

### 1.1.2 System Structure – Level 1

To develop the system structure in addition to the identification of the attributes of the components, the inputs, outputs, relationships, and environment need to be identified. The environment may be classified as manmade and natural, as identified in a previous analysis [14], at system Levels 1 to 3 and may be further analysed in detail at the next levels of the hierarchy. The input to the total system comprises of an operational need and the output is of a fleet management capability. The relationships are inter and intra – component & component, component & attribute, and attributes & attribute. The system structure based on the identified system elements and the environment is presented in *Figure 2*.

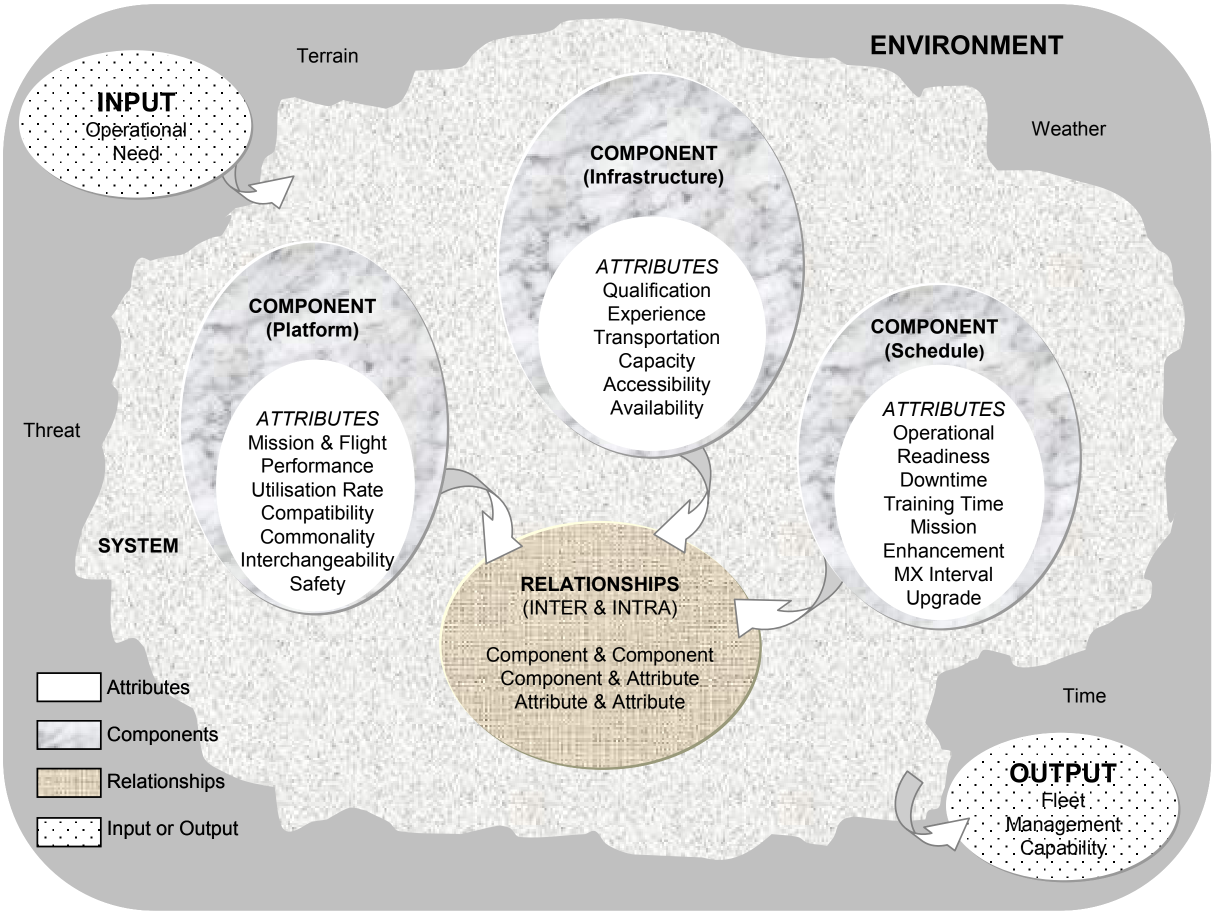


*Figure 2: System Structure – Level 1*

### 1.1.3 System Elements – Level 2

The formulation of the system structure at Level 1 identified the components, attributes, and relationships. The system hierarchy (*Figure 1*) identified the MRH platform components at Level 2, which comprised of the following: a) Structure; b) Propulsion; c) Rotor; d) Sub systems and e) Payload. Due to size and complexity of the overall system, only the component 'platform' is analysed in this paper. The MRH (TTH) platform is designed to meet pre-defined mission requirements – accomplishing a variety of roles, including tactical transport, SAR, MEDEVAC, special operations, electronic warfare, airborne command post, parachuting, VIP transport, and training [15]. The system requirements identified and categorised for each of the level 2 components are as follows:

- Structure
  - Rate of effort per airframe;
  - Radar signature;
  - Crash-worthiness;
  - Fuselage cross section;
  - Type of doors and ramp; and
  - Retractable landing gear.
- Propulsion
  - SFC;
  - Maintainability;
  - APU for electrical engine start;
  - APU for ECS ground operations;
  - Twin Engine (TTM 322-01/9 or T700-T6E);
  - O.E.I. 30” emergency ratings (>2,000 kW each); and
  - 30’ dry running time capability.
- Rotor
  - Maintainability;
  - Titanium main rotor hub;
  - Elastomeric bearings;
  - Composite blades; and
  - RPM.
- Sub Systems
  - Crashworthiness;
  - Maintainability;
  - Supportability; and
  - Compatibility.
- Payload
  - Capacity;
  - Deployment; and
  - Type.

The above are the attributes of the MRH platform subsystems at Level 2.

### 1.1.4 System Structure – Level 2

The system structure is developed similarly to Level 1 by identifying the inputs, outputs, relationships, and environment. The environment at Level 1 (platform, infrastructure and scheduling) is further analysed in detail and identified as time, weather, threat, and terrain [14]. The input is the mission requirements of the MRH, and the output is MRH mission capabilities. The relationships are as previously stipulated inter and intra – component & component, component & attribute, and attributes & attribute. The system structure at Level 2 based on the identified system elements and the environment is presented in *Figure 3*.

## 1.2 Hierarchy Levels 3 to 5

The general functional characteristics (attributes) of the rotary-wing platform systems (Level 2) are performance, maintainability, supportability, compatibility and crashworthiness. These attributes are to be met by the MRH sub-system or its sub-components (Level 3). The mission systems technology need to be grouped based on their functional characteristics, to structure

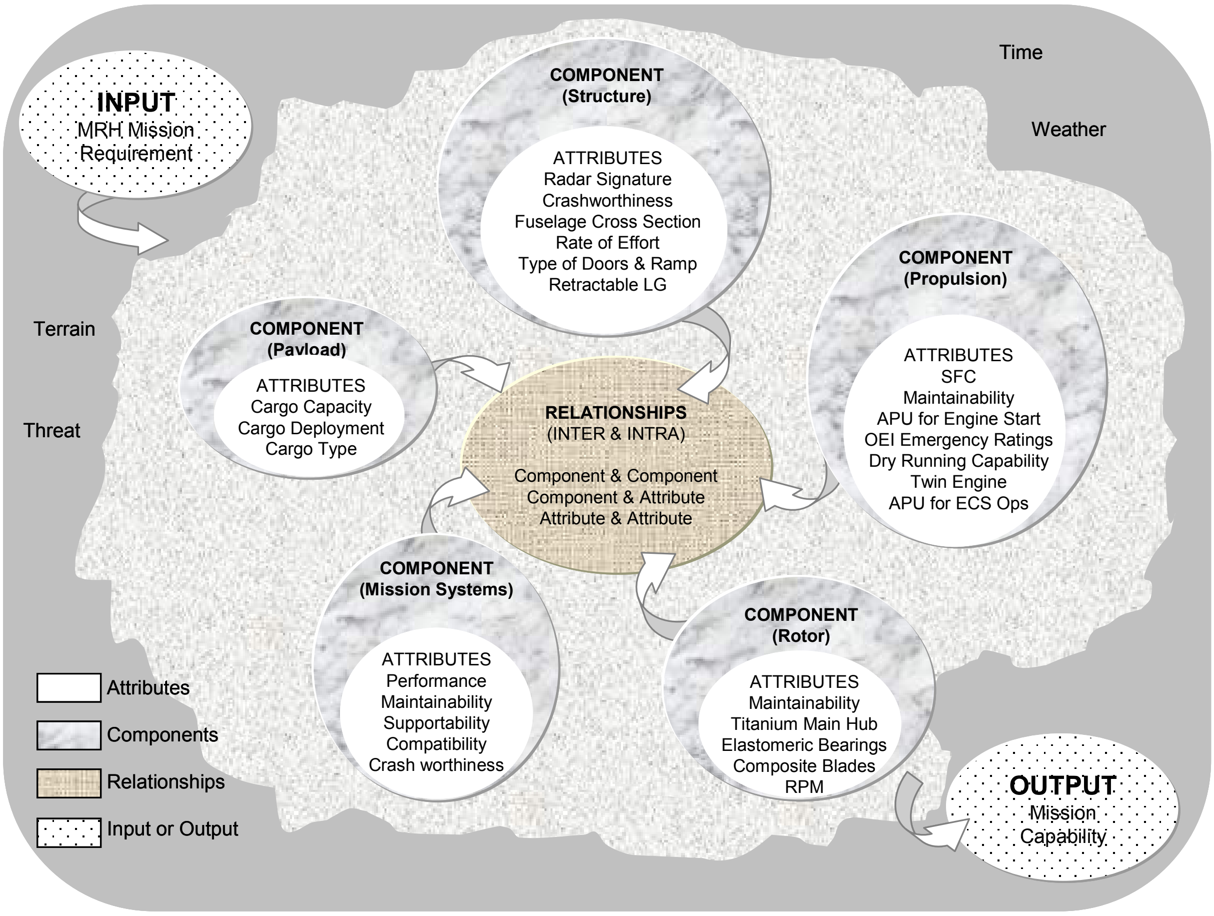


*Figure 3: System Structure – Level 2*

the components at the next level of the hierarchy. An investigation of the functional characteristics of the sub-components [16] of the propulsion system resulted in the following categorisation:

- Main & Tail Rotor Propulsion: (RR/MTU RTM 322-01/9 or GE/Fiat Avio T700-T6E1):
    - O.E.I. 30” emergency ratings (>2,000 kW each);
    - 30’ dry running time capability;
    - Turbo Shaft Engine;
    - Hot & High Conditions; and
    - Corrosion / Erosion resistant.

- Auxiliary Power: APU (SAPHIR 100 model 329, rated at 135kW):
    - Self-starting Capability;
    - ECS Ground Operation;
    - Supplies mechanical power to drive intermediate accessory gearbox;
    - Supplies Electrical Power; and
    - Supplies Bleed Air.

The components of the propulsion systems are Level 4 systems of the hierarchy. The propulsion systems categories are further investigated in detail to sub-categorise the functional characteristics for formulation of the next level of the hierarchy – Level 5. To illustrate, the propulsion categories of the technology are subcategorised depending on the tasks they are designed for – compression, combustion, recuperation, engine control or cooling. In the design process, the slated platform mission requirements will govern the technologies to be considered for the design of the fleet management system.

The MRH platform is one component of the fleet management total system and in the rotary-wing operational environment its technology management requirements may be developed from other components of the system – infrastructure and scheduling.

The lower levels of the hierarchy (Level 4 & 5) for the fleet management system structure and rotary-wing platform needs to be developed accordingly, with due consideration of inter and intra usage of the components for mission accomplishment and a maximum fleet management capability. The fleet management system requirements [14] state the need of a consideration of a variety of tasks and principles for maximum system effectiveness. Thus, the development of the Level 4 & 5 of the hierarchy is in-line with the concept of fleet management.

The system structure design of the component 'infrastructure' and 'schedule' considers the functional structure of the 'platform' to ensure its system compatibility towards operation, personnel, logistic and ground support. Levels 1 to 4 of the MRH platform system hierarchy are presented in *Figure 4*. Similarly to the depicted systems hierarchy 'platform', the components 'infrastructure' and 'schedule' were developed.

### 1.2.1 System Elements – Level 4

Further investigation into the 'propulsion' component, revealed a total of six sub-components of the turboshaft engine. The functional characteristics (attributes) of the components need to be slated in-line with the propulsion requirements of the MRH platform. The brief analysis for the identification of the attributes is as follows.

- <u>Compressor</u>: Each compressor stage consists of rotating vanes and stators which remain stationary. A heat and pressure increase after each stage and the compressor is driven by a shaft connected to the turbine. Furthermore the compressor provides bleed air to the MRH pneumatic system. Thus, the attributes of the compressor are the following:
  - Engine pressure ratio (EPR);
  - Bleed air flow;
  - Stages; and
  - Stall characteristics.

- <u>Combustion Chamber</u>: Fuel is continuously burned in the compressed and moderately fast moving air stream, at all throttle conditions, as efficiently as possible. Since the turbine cannot withstand stoichiometric temperatures, resulting from the optimum combustion process, some of the compressor air is used to quench the exit temperature of the combustor to an acceptable level. Air used for combustion is considered to be primary airflow, while excess air used for cooling (secondary airflow). Combustor configurations include can, annular, and can-annular. The required attributes of combustor are as follows:
  - Configuration;
  - Efficiency;
  - Primary/secondary airflow; and
  - Inlet- and outlet temperature.

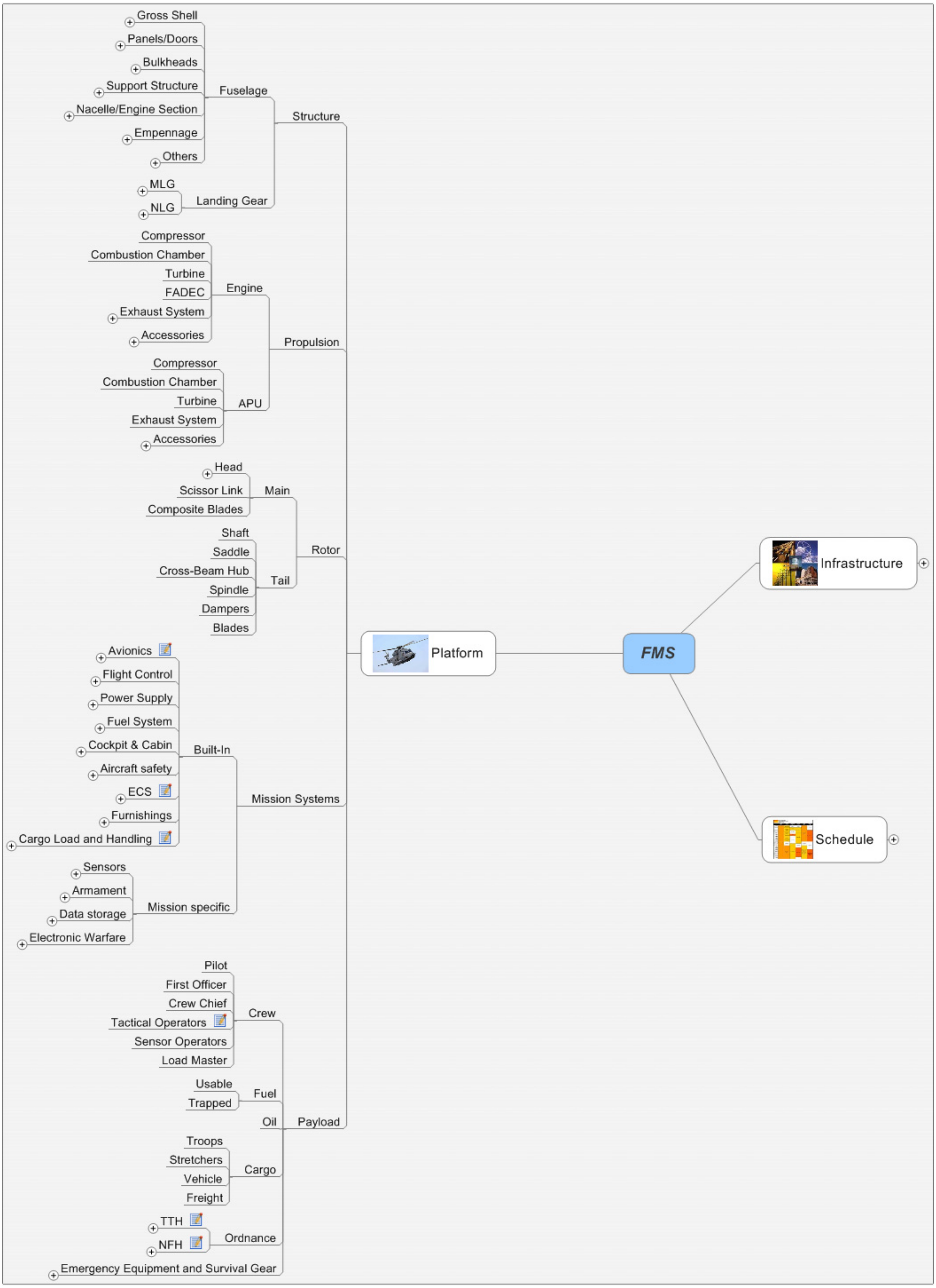


*Figure 4: System Hierarchy of MRH platform – Level 1 to 4*

- Turbine: The turbine recuperates energy from the hot gases leaving the combustor. This energy is used to drive the compressor via the shaft and converted to rotational energy. The turbine needs fewer stages than the compressor, mainly because the higher inlet temperature reduces the $\Delta T/T$ of the expansion process. The blades have more curvature and the gas stream velocities are higher. The required attributes of turbine are as follows:
  - Efficiency;
  - Temperature & pressure ratio;
  - Blade shape; and
  - Stages.

- FADEC: The Full Authority Digital Engine Control system consists of a digital computer and controls all aspects of aircraft engine performance. The required attributes of FADEC are as follows:
  - Function;
  - MTBF;
  - Input;
  - Output; and
  - Manual override.

- Exhaust System: Different to the primary object of a fixed-wing exhaust system to expand the exhaust stream to atmospheric pressure and thereby producing a high velocity jet, the rotary-wing exhaust object is not thrust. It rather reduces the engine heat signature and deflects the air stream upwards, after most of the energy of the hot gas stream has been recuperated by the turbine. The required attributes of the exhaust system are as follows:
  - Heat Signature;
  - Pressure ratio; and
  - Weight.

- Accessories: Engine accessories include a variety of components, depending on engine type and performance. In this analysis only the basic systems are considered to demonstrate the design procedure. The MRH engine accessories include starting system, fuel, electrical, oil, ignition, transmission, cooling and induction system. The general attributes of accessories are as follows:
  - Weight;
  - Maintainability; and
  - Accessibility.

### 1.2.2 System Structure – Level 4

Similar to previous levels, the inputs, outputs, and relationships need to be identified to develop the system structure. The environment was analysed at previous levels - time, weather, threat, and terrain (Sec 2.1.4). The input is a performance requirement and the output is a specific engine performance. The relationships remain inter and intra – component & component, component & attribute, and attributes & attribute. The system structure based on the identified system elements and the environment is presented in *Figure 5*.

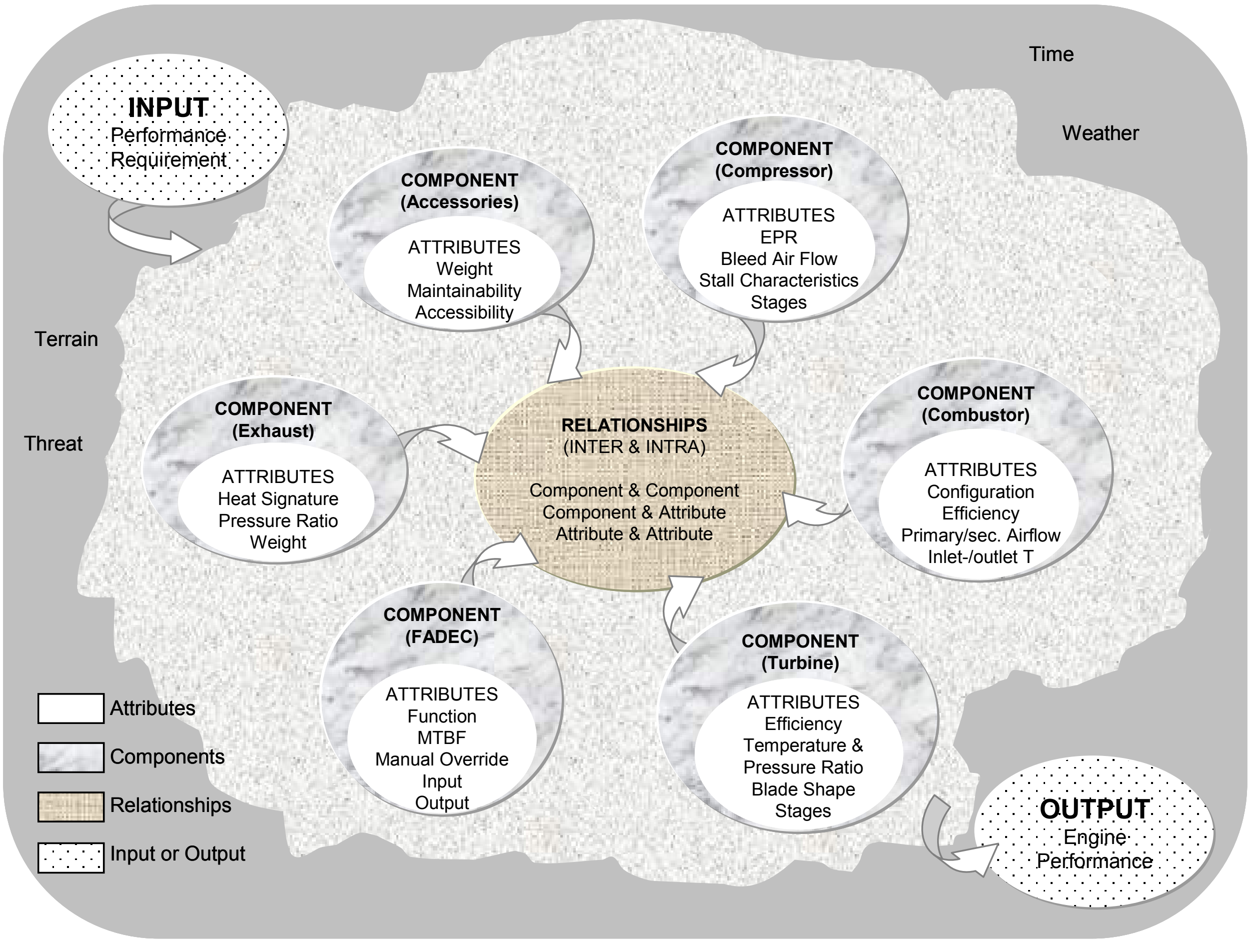


*Figure 5: System Structure – Level 4*

## 2 Results and Discussion

The investigations on fleet management and the MRH platform resulted in the development of the system hierarchy and system structure. This provided an in-sight of the system components and its functional characteristics, including the operational environment. It further provided the foundation to identify the components for the design of a fleet management system and methodology – one that meets the slated system requirements. The various levels of the systems hierarchy and the components and attributes at these levels are discussed below.

<u>Hierarchy Level 1 to 3</u>

The system hierarchy of the MRH platform was considered as part of a fleet management system – total system, which comprised of platform, infrastructure and schedule components. The platform itself was categorised into structure, propulsion, rotor, mission systems and payload. In this paper, only the propulsion system was investigated, due to overall system complexity and size limitations. The demonstrated investigation and procedure is applied to all Level 1 to 4 hierarchy elements of the total system. The engine and APU formed the propulsion system and comprised of the typical components of a turboshaft engine. The system structure at Level 1 (*Figure 2*) thus included the platform, infrastructure and schedule as components, with detailed attributes governed by the required functional characteristics.

The system structure at Level 2 (*Figure 3*) included the structure, propulsion, rotor, mission systems and payload as the components, with the requirements of maintainability, supportability, compatibility and efficiency as the attributes.

Hierarchy Level 3 to 5
The Level 4 and 5 of the hierarchy consisted of the sub-assemblies of the main components of the MRH platform. The sub-assemblies were categorised as compressor, combustor, turbine, FADEC, exhaust system and accessories at Level 4. These were further subcategorised at Level 5. The functional characteristics of these systems provided the input to design the structure of the logistic support system besides maintenance, upgrade, and modification intervals.

The system structure at Level 4 (*Figure 5*) identified a total of six components and their functional attributes were derived from the capability they provide to meet the performance requirements of the MRH.

## 3. Concluding Remarks

The adoption of a system approach to investigate the MRH and support structure in a fleet management context provided the means to systematically develop the system hierarchy. It further resulted in structuring the system at various levels of the hierarchy to identify the system elements.

The last level of the hierarchy presented a format to further investigate the structure of MRH sub-assemblies from a fleet management and support perspective. Current research investigates the components 'infrastructure' and 'schedule' to establish the system hierarchies from Level 1 to 5 for identification of their system elements.

## GLOSSARY

| | |
|---|---|
| ADF | Australian Defence Force |
| APU | Auxiliary Power Unit |
| ASW | Anti-Submarine Warfare |
| ASuW | Anti Surface Unit Warfare |
| CASEVAC | Casualty Evacuation |
| ECS | Environmental Control System |
| EPR | Engine Pressure Ratio |
| FADEC | Full Authority Digital Engine Control |
| IGE | In Ground Effect |
| NFH | NATO Frigate Helicopter |
| MEDEVAC | Medical Evacuation |
| MRH | Multi-Role Helicopter (NH-90) |
| MTBF | Mean Time between Failure |
| OEI | One Engine Inoperable |
| OGE | Out of Ground Effect |
| RAST | Recovery Assist, Secure and Traverse |
| SAR | Search and Rescue |
| SEP | Systems Engineering Process |
| SFC | Specific Fuel Consumption |
| T | Temperature |
| TTH | Tactical Transport Helicopter |

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