PRELIMINARY STUDIES ON HEALTH AND USAGE MONITORING SYSTEM ARCHITECTURE FOR THE NH-90 ROTRCRAFT PLATFORM – FURTHER DEVELOPMENTS

Dipesh K Parekh[1] and Arvind K Sinha[1]

[1]The Sir Lawrence Wackett Centre for Aerospace Design Technology,
Royal Melbourne Institute of Technology,
GPO Box 2476V, Melbourne, Victoria, 3001, Australia.
Email: dipesh.parekh@rmit.edu.au

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Abstract

A Health and Usage Monitoring System (HUMS) provides the status of functionality and structural integrity for diagnosis and prognosis of the rotorcraft components. Consequently, a HUMS system provides the merits of automated monitoring and automated inspection. The implementation of HUMS systems has surged over the past decade leading to an improvement in safety and reduction of maintenance costs associated with rotorcraft fleet management. The growing need for safety enhancement and operational cost reduction of aging rotorcraft fleet has directly impacted HUMS design and development.

This paper aims to provide a discussion of the preliminary studies conducted on baseline HUMS architecture for the NH-90 rotorcraft platform. The development of a platform specific architecture will result in a HUMS *i*ntelligent *d*ata *m*anagement *t*ool (IDMT). Firstly, a comprehensive research methodology framework is proposed to contextualise the nature of the work undertaken. A systems approach is then adopted to develop a systems hierarchy in order to identify the key components of the total system at all levels. A system structure at the uppermost level is developed to identify the relationships and attributes. Having established a systems hierarchy and structure, a discussion pertaining to the baseline HUMS architecture is provided. Finally, the data management problem at hand is discussed in terms of the algorithm and a prototype *g*raphical *u*ser *i*nterface (GUI) which has been developed for the envisioned HUMS IDMT.

It is envisaged that the development of the HUMS IDMT will be integrated with the Fleet Management System (FMS) tool which is being concurrently developed. The resultant customised fleet management maintenance tool will aid the maintenance personnel via increasing efficiency of the current fleet management maintenance practices. Future work will focus on the development of specific capabilities for the HUMS IDMT. This research project is a collaborative research effort between The Sir Lawrence Wackett Centre for Aerospace Design Technology, Australian Aerospace Ltd, Army Aviation and Defence, Science & Technology Organisation (DSTO).

1. INTRODUCTION

A Health and Usage Monitoring System (HUMS) provides the status of functionality and structural integrity for diagnosis and prognosis of the rotorcraft components. Consequently, a HUMS system provides the merits of automated monitoring and automated inspection. The implementation of HUMS systems has surged over the past decade leading to an improvement in safety and reduction of maintenance costs associated with rotorcraft fleet management. The growing need for safety enhancement and operational cost reduction of aging rotorcraft fleet has directly impacted HUMS design and development.

The Sir Lawrence Wackett Centre for Aerospace Design Technology has collaborated with Australian Aerospace Ltd, Army Aviation and Defence, Science & Technology Organisation (DSTO) in order to cater for a current problem faced by the industry in relation to HUMS data management for the NH-90 rotorcraft platform. The NH-90 rotorcraft platform will perform a total of 19 missions with corresponding mission profiles. The usage and exceedance data gathered for a specific mission needs to be collected, analysed and evaluated in order to monitor the airworthiness and integrity of the NH-90 rotorcraft platform. Currently, the usage and exceedance information is retrieved manually, due to which an automation of the process is required.

This paper aims to provide a discussion of the preliminary studies conducted on baseline HUMS architecture for the NH-90 rotorcraft platform. The development of a platform specific architecture will result in a HUMS *i*ntelligent *d*ata *m*anagement *t*ool (IDMT). Firstly, a comprehensive research methodology framework is proposed to contextualise the nature of the work undertaken. A systems approach is then adopted to develop a systems hierarchy in order to identify the key components of the total system at all levels. A system structure at the uppermost level is developed to identify the relationships and attributes. Having established a systems hierarchy and a systems structure, a discussion pertaining to the baseline HUMS architecture is provided. Finally, the data management problem at hand is discussed in terms of the algorithm and a prototype *g*raphical *u*ser *i*nterface (GUI) which has been developed for the envisioned HUMS IDMT.

The development of the HUMS IDMT will be integrated with the Fleet Management System (FMS) tool which is being concurrently developed. The resultant customised fleet management maintenance tool will aid the maintenance personnel via increasing the efficiency of the current fleet management maintenance practices.

2. RESEARCH METHODOLOGY FRAMEWORK

The development of a customised HUMS architecture for the NH-90 rotorcraft platform requires a stringent methodological approach. In order to accomplish the required objectives, a research methodology framework has been formulated covering a time frame of three years. The proposed research methodology framework is illustrated in Figure 1.

The Sir Lawrence Wackett Centre for Aerospace Design Technology will be involved in the development of the HUMS architecture which will eventuate into the HUMS IDMT. Further industrial consultations will be provided by Australian Aerospace Ltd, Army Aviation and Defence, Science & Technology Organisation (DSTO). The development of a customised HUMS IDMT is structured in four stages with corresponding time to completion for each stage. The objectives and deliverables for each of the four stages are discussed below in detail:

Stage 1 (6 months): Helicopter Health and Usage Monitoring System needs of the Australian Defence Forces
The objective for this stage involves the determination of the present HUMS system needs and requirements of DSTO and Army Aviation as stipulated by Australian Defence Force (ADF) regulations. Additionally, it is vital to determine the present HUMS technology implemented by the NH-90 rotorcraft platform in order to outline the needs and requirements for the future as specified by Australian Aerospace.

The deliverable for this stage will involve documentation detailing the present and future HUMS requirements for NH-90 rotorcraft platform. Hence, the architectural requirements will be completed and can be utilised as the basis of designing the HUMS IDMT for Stage 2.

Stage 2 (8 months): Helicopter Health and Usage Monitoring System tool design
The objective for this stage involves the comparison of the mission profiles that need to be captured with the flight state recognition capability provided by existing maintenance management system (MMS) for the NH-90 rotorcraft platform.

The deliverable for this stage will involve the development of an algorithm enabling correlation between mission profiles and flight states based on the stipulated architectural requirements. This will result in the development of a customised HUMS IDMT which can be utilised by maintenance personnel. The development of HUMS IDMT will be documented and as such will form an important constituent of the deliverable for this stage.

Stage 3 (10 months): Health and Usage Monitoring System tool integration with Fleet Management System tool
The objective for this stage involves the integration of HUMS IDMT with FMS tool utilising the information from Stages 1 and 2 of the project.

The deliverable will involve documentation detailing the comprehensive system requirements specifications of the integrated HUMS IDMT and FMS tool.

Stage 4 (12 months): Test and validation of integrated Health and Usage Monitoring System tool and Fleet Management System Tool

The objective for this stage involves the utilisation of the integrated tool as per Stage 3 of the project to demonstrate simulation for NH-90 rotorcraft platform.

The deliverables for this stage will include: (i) Interface design and control document for the customised maintenance tool; (ii) Software test plan; (iii) Qualification plan; and (iv) Delivery of the qualified maintenance tool.

It is envisaged that the successful implementation of the aforementioned research methodology framework will result in: (i) HUMS IDMT; and (ii) FMS tool. The FMS tool is being developed concurrently with the HUMS IDMT. The complete integrated tool can be utilised by the structural integrity engineer and maintenance personnel for efficient NH-90 rotorcraft fleet management.

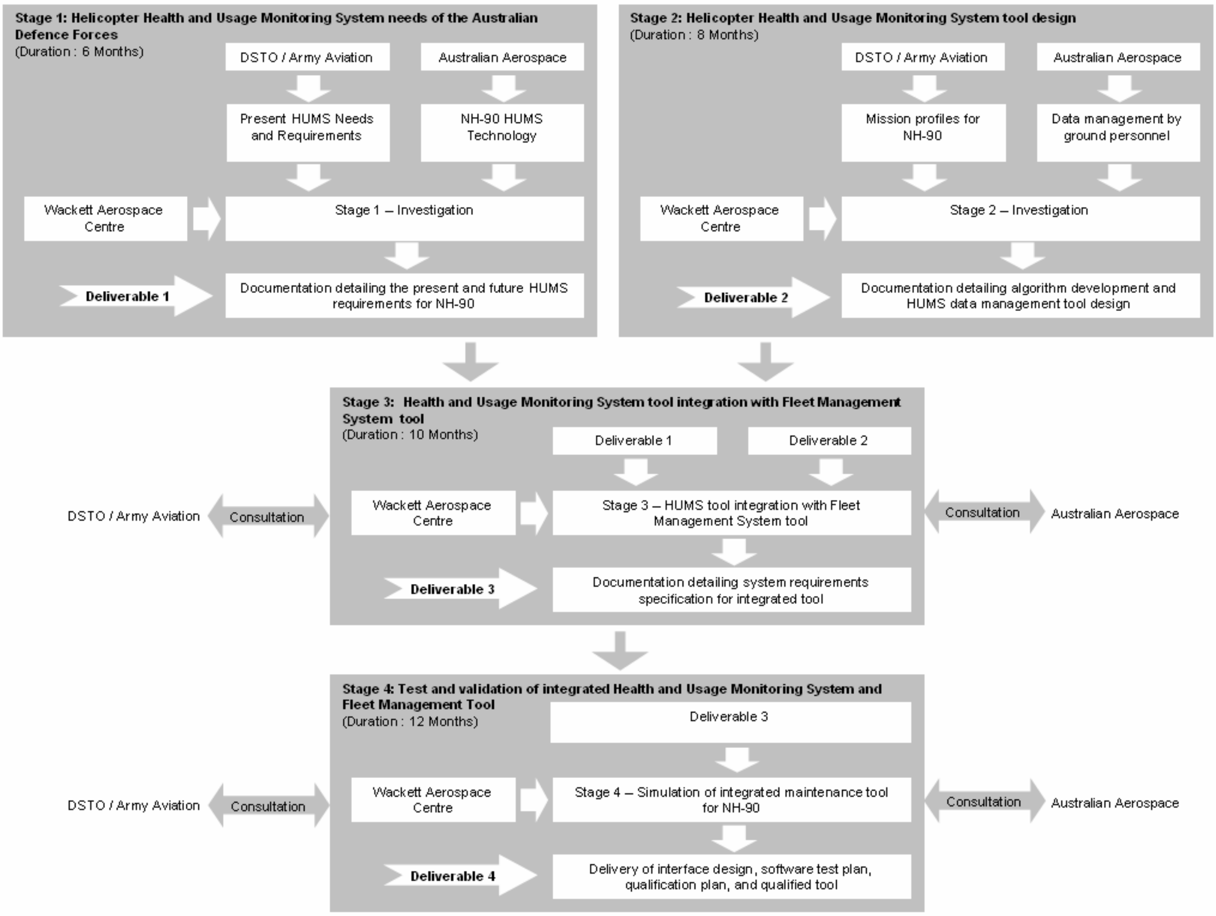

Figure 1: Research methodology framework

3. SYSTEM HIERARCHY AND ELEMENTS

A systems approach is adopted to develop the systems hierarchy in order to identify the key components of the total system. The definition of a system is provided by Sinha in [1] as follows: "*A system is composed of (i) components; (ii) attributes; and (iii) relationships. The components are also referred to as subsystems. The attributes are the functional characteristics of the components. 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 to as a system. The purpose of the system is achieved by the system elements and their corresponding attributes.*"

The total system is considered to comprise of the NH-90 rotorcraft fleet with the various subsystems located at lower hierarchical levels. Via establishing a systems concept of the various hierarchical levels, the attributes and relationships of the system components can be identified. Traditionally, a HUMS system would be considered to be a subsystem of a rotorcraft. However, in this instance, an individual NH-90 rotorcraft platform is considered to be a subsystem of the NH-90 rotorcraft fleet. Additionally, a HUMS system is located at the same level as an NH-90 rotorcraft platform as it forms a subsystem of both an individual NH-90 rotorcraft platform and the NH-90 rotorcraft fleet – total system.

3.1 Hierarchy Levels 1 to 3

The total system is at the top level of hierarchy whilst other subsystems and components are located at different levels of hierarchy. Each of these subsystems and components needs to be further investigated.

The NH-90 rotorcraft fleet comprises of HUMS system(s) and individual NH-90 platform(s) which form the subsystems of the next level in the hierarchy (Level 1). This paper focuses primarily on the HUMS systems and as such, a detailed systems hierarchy for NH-90 platform will require separate investigation. Within the HUMS system domain, there are aerial and ground systems – which form the next level of hierarchy (Level 2). Furthermore, since the focus of this paper is to lead to the development of an envisioned HUMS IDMT, it is anticipated that the tool will operate as part of the data management system – which forms the next level of hierarchy (Level 3). The system hierarchy from Level 1 to 3 is illustrated in Figure 2.

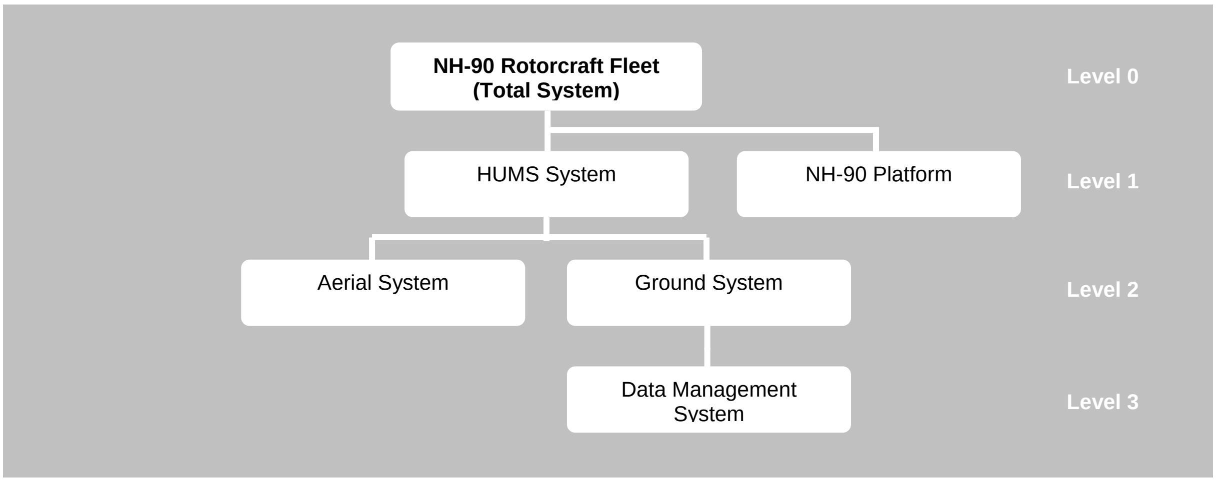

Figure 2: System hierarchy – Levels 1 to 3

3.2 System Elements – Level 1

The analysis of the system elements, that is, components, attributes, and relationships is based on the identification of subsystems of the total system. The two components identified at Level 1 are the NH-90 platform and the HUMS system. Subsequent analysis of the HUMS IDMT's logistics and support requirements for identification of the system attributes as an illustration is as follows:

- NH-90 Platform: The attributes of the platform can be characterised by the missions conducted by the platform. A total of 19 missions are to be conducted by a NH-90 platform. Each mission profile is unique depending on the type of mission conducted. The major categories of the missions are as follows:

    - Troop/cargo transportation;
    - Heliborne operations;
    - Search and rescue;
    - Medical evacuation;
    - Special operations;
    - Electronic warfare;
    - Airborne command post;
    - Parachuting;
    - Very important persona (VIP) transportation; and
    - Flight training

- HUMS System: A HUMS system comprises of an airborne system and a ground based system. The attributes of a HUMS system are as follows:

    - Engine performance assessment;
    - Rotor track and balance (RTB);
    - Absorber tuning;
    - Mechanical diagnostics;
    - Exceedance monitoring;
    - Usage monitoring; and
    - Ground station processing

3.3 System Structure – Level 1

Upon identifying the attributes of the components, the inputs, outputs, relationships and environment needs to be identified in order to develop a system structure. The environment may be classified as manmade and natural and may be further classified in detail at the next hierarchical levels.

The input to the system primarily comprises of the logistics and support doctrines whilst the output will be a customised HUMS IDMT. The relationships are inter and intra – component & component, component & attribute, and attribute & attribute. Figure 3 illustrates the system structure based on the identified system elements and the environment.

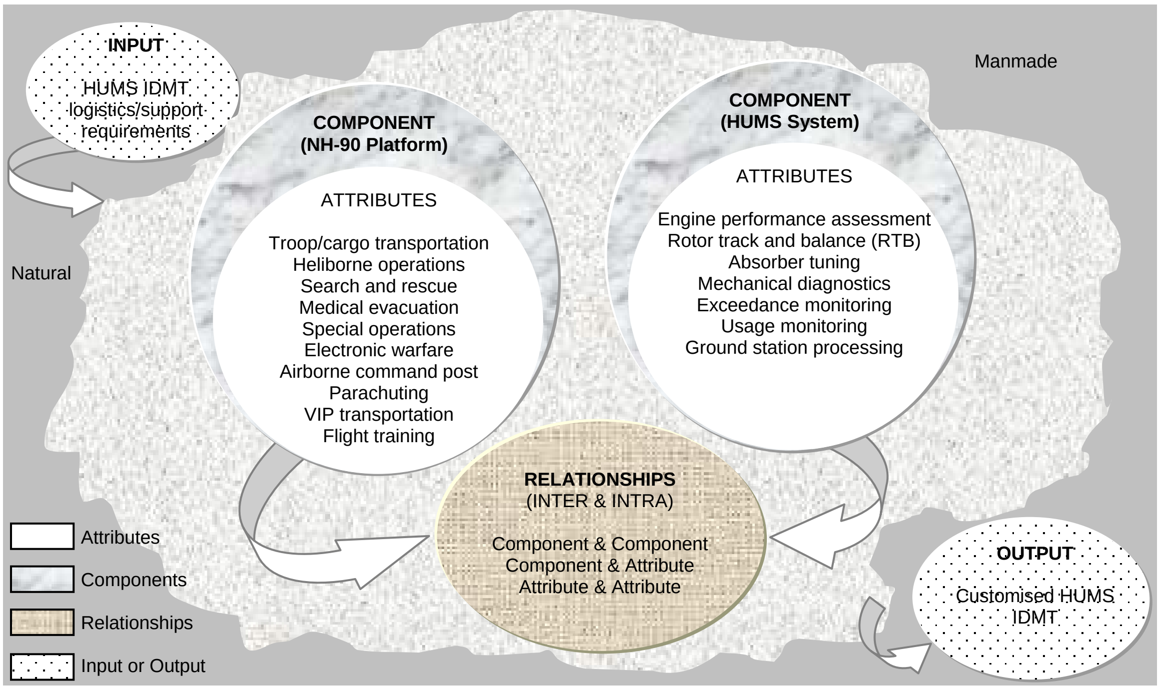

Figure 3: System structure – Level 1

4. HUMS ARCHITECTURE

4.1 Baseline HUMS System Architecture

In order to develop a HUMS IDMT which can integrate with existing systems, it is essential to determine the architecture of existing HUMS systems. However, due to the classified nature of the information pertaining to the HUMS system for the NH-90 rotorcraft platform, the discussions entailed in this paper revolves around a baseline HUMS architecture model based on pre-established HUMS systems model.

An architecture of a system aids to specify the components and the interaction amongst the components. The increase in application of HUMS for both military and commercial domains warrants a need for the design and evaluation of HUMS architectures. A prerequisite for evaluation of architectures is architectural specification. Architecture specification may include protocol specifications describing system behaviour and details of component interactions [2].

Figure 4 depicts a baseline HUMS architecture illustrating the distributed nature of HUMS system and its relationship to existing maintenance equipment. Typically, a HUMS system consists of an airborne system and a ground based system. Such an architecture enables efficient information and data exchange between the two systems and other ground based stations [3, 4].

The airborne system consists of the original helicopter fitted with additional HUMS equipment which involves hardware and instrumentation. A data transfer unit (DTU) is utilised to transfer both the raw and processed flight data to ground based system. The ground based system consists of a series of networked ground stations which are responsible for configuring flight specific analysis to support either pilot or maintainer queries.

Furthermore, the ground based system provides a large data set which can be utilised for trending, prognostics and planning. The ground stations form the primary user interface with the HUMS system. Generally, the ground station and existing maintenance system make extensive use of commercial-off-the-shelf (COTS) hardware and software [3, 4].

A great deal of consideration is given to the functional partitioning between: (i) The airborne system & ground based processing; and (ii) The integration of HUMS ground equipment with the operator's maintenance management system (MMS). A MMS is utilised by an operator for continuing airworthiness to: (i) Keep track of rotorcraft configuration; and (ii) Schedule maintenance actions which may include removal and replacement of rotorcraft components or assemblies [3].

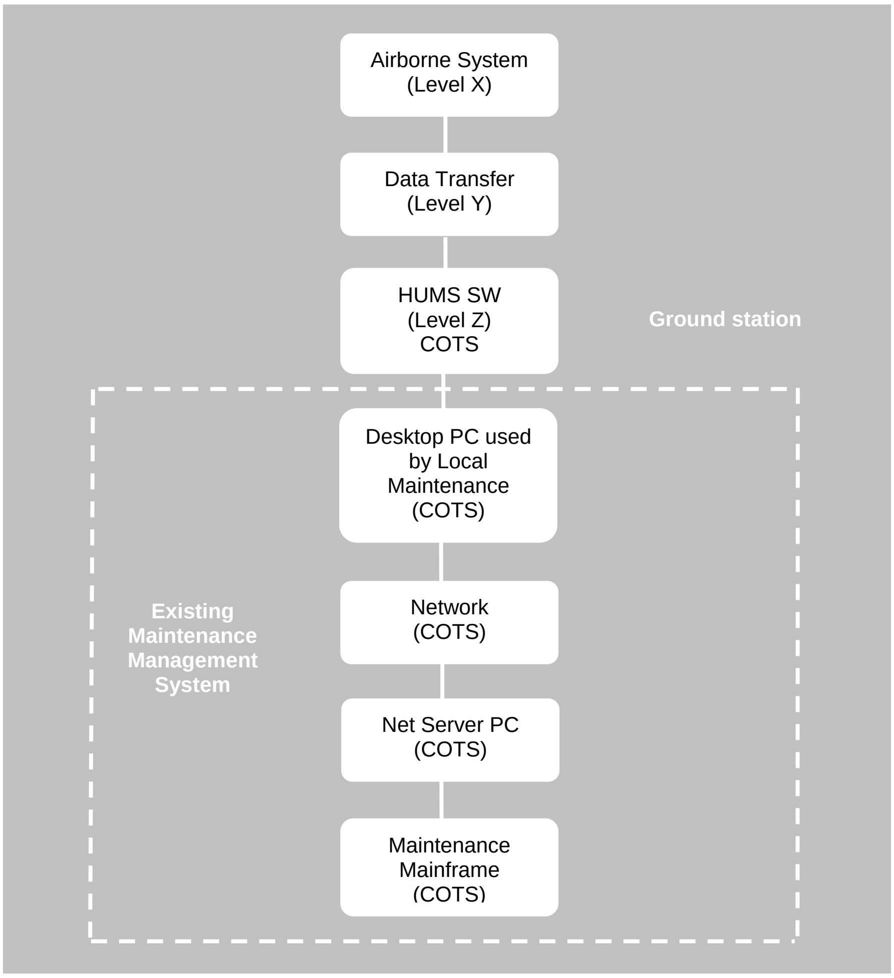

Figure 4: Baseline HUMS system architecture [3]

4.2 Open Systems Approach

The implementation of an open systems approach for HUMS systems is complicated due to the configuration control, flight safety and certification requirements. The onboard components of HUMS systems are required to pass stringent flight certification requirements which hinder the ability of multiple parties to upgrade the system regardless of the open system specification. The certification requirements for ground station are somewhat less stringent and thus provide an opportunity to fully implement an open systems approach [5]. Consequently, it is envisaged that the development of the customised HUMS IDMT will be certified at the ground station level.

It is essential to note the myriad number of advantages which can be incurred through the utilisation of an open systems architecture. A brief list of the advantages as specified by Brock is as follows [6]:

- Easier technology insertion;
- Increased competition;
- Incremental performance requirements;
- Improved interoperability;
- Faster fielding of systems;
- Reduced maintenance costs;
- Improved supply channels; and
- Extended equipment useful life

4.3 Architecture Design Process

In order to successfully develop the HUMS IDMT, it is useful to follow a defined software engineering process. Consequently, a three step architecture design process as defined by Gorton in [7] is to be implemented. The design process is illustrated in Figure 5. Briefly, the three steps involved in architecture design are:

- Architectural requirements: This involves the model of the requirements that will drive the architecture design. For the HUMS IDMT, this involves the determination of the functional and stakeholder requirements which will result in a documentation which explicitly states the architecture requirements.

- Architecture design: The stipulated architectural requirements act as inputs for the architecture design. During this stage, the structure and responsibilities of the components that will comprise the architecture are defined. The design stage will involve the selection of an established programming language in order to develop an algorithm. Major design decisions pertaining to the functionality of the envisioned HUMS IDMT must be considered at this stage.

- Validation: The design can be validated through prototype testing until all the desired functionalities, existing & future requirements are incorporated into the tool. Extensive use of Unified Modelling Language, UML v2.0, will be made to document both the structural and behavioural aspects of the HUMS IDMT.

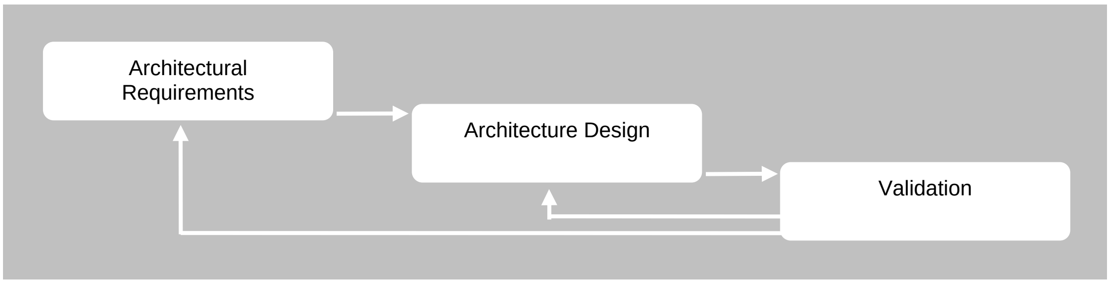

Figure 5: A three step architecture design process [7]

5. DATA MANAGEMENT ISSUES

5.1 Algorithm & Graphical User Interface (GUI) Development

As stated earlier, the NH-90 rotorcraft platform will perform a total of 19 missions with corresponding mission profiles. Consequently, the usage and exceedance data gathered for a specific mission needs to be collected, analysed and evaluated in order to monitor the airworthiness and integrity of the NH-90 rotorcraft platform. Currently, the usage and exceedance information is retrieved manually, due to which an automation of the process is required. Hence, the development of a HUMS IDMT will aid in the automation of the process.

At this stage, a fundamental understanding of the requirements of a HUMS IDMT has led to the development of a basic algorithm which has resulted in a prototype GUI. Figure 6 illustrates the basic GUI which provides the user with the option of selecting the FMS or HUMS tool. Future work efforts will focus on the the incorporation of the desired functionalities into the tool via meeting the refined requirements as stipulated by industrial collaborators.

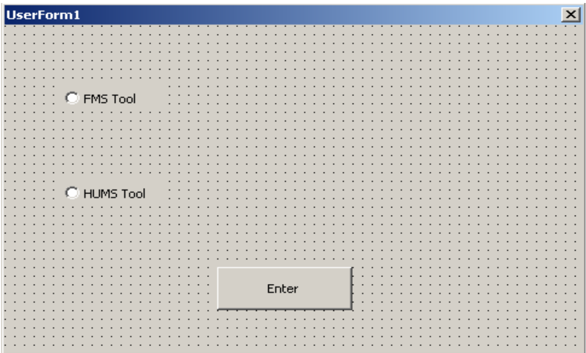

Figure 6: Prototype GUI development

6. DISCUSSION

In this paper, previous research efforts have been directed towards the development of a HUMS architecture which will eventuate into an envisioned software tool, namely, the HUMS IDMT. In order to aid the development process, a systems approach was adopted to identify the key components of the system and a system structure was established at the uppermost level (Level 1). The functionalities of the HUMS IDMT will be tested against the requirements stipulated by the industrial collaborators in an iterative manner to ensure that the final tool satisfies all the current and future requirements.

7. CONCLUDING REMARKS

Preliminary studies conducted revealed a baseline architecture for HUMS systems which will form the basis of the HUMS IDMT. The development of the tool will be guided by a comprehensive research methodology framework which has been formulated. As per the framework, four stages have been proposed with corresponding deliverables and timeframe.

An analysis of the system hierarchy and elements was also conducted via utilising a systems approach. The establishment of the system hierarchy aided in the identification of the key components of the total system at all levels. Additionally, a system structure was developed at the uppermost level (Level 1) in order to identify the relationships and attributes. The systems analysis establishes the location of the HUMS system and the HUMS IDMT within the total system – the NH-90 rotorcraft fleet.

The baseline HUMS architecture forms the basis of investigation in the absence of specific NH-90 rotorcraft information. As such, a basic description pertaining to the architecture was provided and the benefits of implementing an open systems approach were discussed. Furthermore, an outline of the architecture design process to be implemented for the development of the HUMS IDMT was also provided.

Lastly, the data management issues which need to be addressed were discussed. In order to counter these issues, an algorithm is being developed which will result in the HUMS IDMT. At this stage, a prototype GUI has been developed providing basic options for tool selection. Future work will focus on the development of specific capabilities for the HUMS IDMT. It is envisaged that the HUMS IDMT will be integrated with the FMS tool which is being developed concurrently. The resultant customised fleet management maintenance tool will aid the maintenance personnel via increasing the efficiency of the current fleet management maintenance practices.

8. REFERENCES

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