MISSION SYSTEMS IDENTIFICATION FOR THE UPGRADE DESIGN ANALYSIS OF ANTI-SUBMARINE MARITIME HELICOPTERS – AN UPDATE

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Abstract

The anti-submarine warfare mission effectiveness is mainly governed by the operational capabilities provided by the mission systems on board the military helicopter. A mid-life upgrade of existing helicopter with new on board mission systems is the only viable and cost-effective option to enhance mission effectiveness and overcome the technology upgrade demand. The design of payload to upgrade mission effectiveness of the helicopter with mission systems identified is complex being a major analytical and iterative process.

To achieve time-based design analysis and robust design decision in an upgrade design an "Intelligent Decision Support System (IDSS)" is being developed to simulate the automation of mid-life upgrade process. This paper presents the detailed description of Mission Systems Identification sub-process customised for specific mission and of a designated helicopter make and model.

Introduction

The anti-submarine warfare mission effectiveness is mainly governed by the operational capabilities provided by the mission systems on board the military helicopter. However the littoral airborne ASW operations have widened the threat dimensions demanding the state-of-the-art helicopter borne ASW mission systems to enhance operational capabilities for cueing, searching, targeting, and neutralising submarines. The significant advancements in helicopter mission systems, due to improved material, capable electronics and enhanced methods of fabrication outpace the service life of the helicopter. A mid-life upgrade of existing helicopter with new on board mission systems is the only viable and cost-effective option to enhance mission effectiveness and overcome the technology upgrade demand **(Ref 8)**.

A research on "upgrade analysis for design decision" by Sinha et al **(Ref 10, 11, 12 & 13)** adopted a system approach considering operational and environmental needs to identify state-of-the-art mission systems for aircraft upgrade. The result was formulation of a generic "Mid-Life Upgrade System (MLUS)". Kusumo et al **(Ref 5 & 6)** developed an automation framework for the design of an "Integrated Decision Support System (IDSS)" that simulated the MLUS to provide time-based analysis.

As most other existing design environment the automation framework by Kusumo et al **(Ref 5 & 6)** is built around the assumption that a single user will build and perform the engineering trade study. The design of payload with mission systems identified that are specific to ASW is complex being a major analytical and iterative process. To achieve the time-based design analysis and robust design decision in an upgrade design it is required to develop an "Intelligent Decision Support System (IDSS)" customised for specific mission and of a designated helicopter make and model considering the following multi-dimensional aspects: a) complete spectrum of operational needs and operational environment for the; b) state-of-the-art mission systems; c) cost of ownership; and d) effective implementation of the mid-life upgrade program.

Jonnalagadda et al **(Ref 2, 3 & 4)** revisited the automation framework and presented the framework for the "Intelligent Decision Support System" representing a collaborative design analysis environment to consider the aforementioned multi-dimensional aspects.

This paper, presents the detailed description of the Mission Systems Identifier (MSI) sub-module. The function of the MSI sub-module is to identify the ideal mission systems for upgrade of anti-submarine maritime helicopter. The mission systems being identified are for the Seahawk (S-70-B-2) helicopter.

Intelligent Decision Support System Framework

The automation framework developed by Jonnalagadda et al **(Ref 2, 3 & 4)** identified the following functions for the "Intelligent Decision Support System" designed for upgrade design analysis of anti-submarine maritime helicopters:

- Provide user input facility to different sources of data for the upgrade design analysis;
- Integrate various ASW missions and provide a common tactical picture for specific helicopter model;
- Convert the operational and environmental data obtained from various sources or systems to operational and environmental needs;
- Derive the ASW mission requirements from operational and environment need;
- Identify state-of-the-art mission systems and their attributes to meet the derived ASW mission requirements;
- Evaluate the relative degree of contribution of the mission systems to the mission success;
- Design the mission payload based on aforementioned evaluation;
- Provide a holistic analysis of the ASW maritime helicopter upgrade options considering mission capability; flight performance; reliability; maintainability and cost as parameters;
- Integrate the results of the holistic analysis to verify and validate the system effectiveness of the upgrade option;
- Present the optimal design option for upgrade decision;
- Test the robustness of the upgrade decision; and
- Provide a baseline for future upgrade decisions.

Based on the functions identified for the "Intelligent Decision Support System" the framework is divided into five modules. The complete automation framework is presented in (**Figure 1**):

- **Man-machine interface**: To facilitate user-system interaction for input and view the output of the upgrade design analysis;
- **In-service helicopter**: Contains the design details of the helicopter subjected to the upgrade design analysis including the on-board mission systems;
- **Anti-submarine mission requirements**: Contains the anti-submarine mission requirements based on the operational and environmental needs;
- **Mission systems technology**: Contains functional details of mission systems that provide enhanced anti-submarine mission capability; and
- **Knowledgebase**: Contains the computing methodology to integrate mission systems into the in-service helicopter, analyse and present an optimum upgrade design option for anti-submarine warfare. The sub modules for the "Knowledgebase" are listed below:
  a. **Mission systems identifier**: Identify the mission systems stored in the database that meet the defined ASW mission requirements also stored in the database;
  b. **Mission payload design**: Prioritise mission systems based on their relative dependency and degree of operational effectiveness;
  c. **Design parametric analysis**: Evaluates the degree to which ideal mission systems selected for upgrade meet the design parameters (mission capability, flight performance, maintainability, reliability, and cost);
  d. **Verification and Validation:** Evaluate the 'system effectiveness' through the integration of the design parameter analysis of the upgrade and select an optimal upgrade option;
  e. **Database:** Store and manage operational, mission requirements, mission systems and in-service helicopter data;
  f. **Knowledge Base**: Contains the collection of the rules or methodologies that are necessary for the upgrade design analysis;
  g. **Design robustness**: Test the robustness of the design decision against temporal uncertainties;
  h. **Coordinator**: Coordinate with various modules in the "Knowledgebase" for external interaction and perform upgrade design analysis; and missions,
  i. **Design baseline**: Maintain a baseline of the optimised configuration for future upgrades.

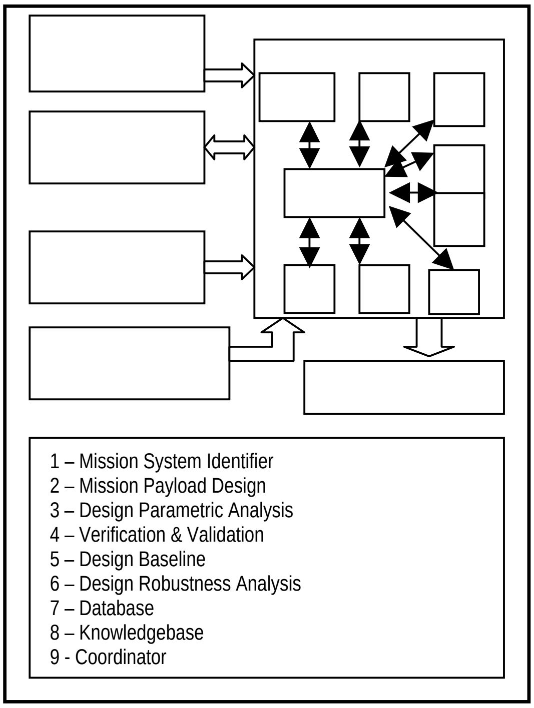

Figure 1: Intelligent Decision Support System for upgrade design analysis of anti-submarine maritime helicopter.

Mission System Identifier Sub-Module

The “Mission System Identifier – Sub-module” is a semi-autonomous agent that identifies the ideal mission systems for upgrade of the selected in-service helicopter. With this aim the sources and sinks for the “Mission System Identifier – Sub-module” were studied. The module being semi-autonomous interacts with the “Coordinator” either for the input or to provide the output. The “Coordinator” initiates the action for “Mission System Identification” once it has the required input. The following is the input:

- **Anti-submarine mission profile:** The “Mission Profile” contains Crew Information, Information before warm-up such as mission category, operating weight, fuel weight, date, time, temperature etc. The mission profile also contains information regarding each segment such as warm-up, takeoff, hover, climb, descent, and land. This profile is provided by the Pilot/Mission Commander from the Man-machine Interface and is stored in the “Database”. Each segment inturn has the threats or interference encountered.
- **Mission systems technology:** A set of mission systems given as input from the “Mission Systems Technology” module. The mission systems are categorised according to the operational and environmental requirements, which are based on the functional characteristics of the mission systems. These systems are latest in the industry. This is provided by the manufacturer of the Mission systems technology and stored in the database. The weight, speed, volume, height, docking station, date of manufacturing, mean time between failure (MTTB), mean time to repair (MTTR), cost and the multiple mission requirements a particular mission system satisfies are recorded.
- **ASW mission requirements:** The operational and environmental conditions are extracted from the stored mission profile to generate the anti-submarine warfare mission requirements by ARM. The requirements are grouped in hierarchy. These requirements need to be stored in the database for the “Mission System Identifier – Sub-module”; and
- **In-service helicopter:** This module contains design details of the helicopter being considered for the upgrade is the input. This includes on-board mission systems in addition to many more design variables with respect to the airframe.

The output is a set of mission systems and their functional characteristics that are to be considered for the mission payload design.

With the inputs and outputs to the “Mission Systems Identifier” clearly identified a methodology is needed to process the inputs. The use case diagram presented in **(Figure 2)** shows the user-system interaction with respect to “Mission Systems Identifier Sub-module” and complete process. Only the analyst and Pilot/Mission Commander interacting with the MSI agent are shown in the figure for brevity.

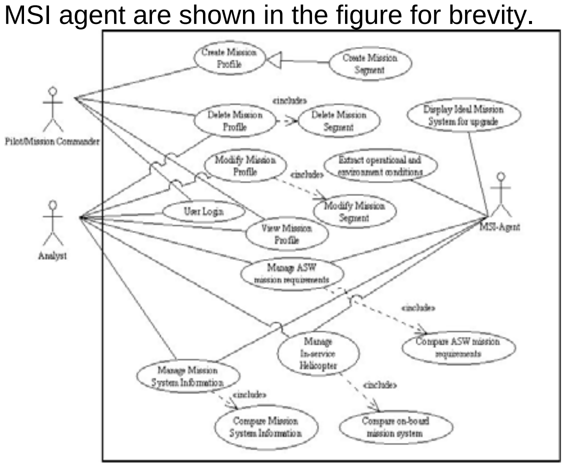

Figure 2: Use case Diagram for Mission System Identifier- Sub-module

The operational and environmental needs input by the Pilot/Mission Commander through the mission profile and stored in database are extracted by the “Coordinator” to establish a link with the ASW mission requirements stored in the “data base”. The mission systems stored in the database with the input from the manufacturer and categorised according to the functional characteristics. A mission system may satisfy more than one requirement. For example a navigation system is required for both offensive and defensive ASW operations. Now the mission systems are identified through comparison process. The set of mission systems are then compared with the on-board systems stored in the database through the In-service helicopter module to specifically identify the ideal mission systems for upgrade.

Simulation

The simulation software program for the "Intelligent Decision Support System" named "Intelligent Decision Support System Software" (IDSSS) has been developed. The software is completely web-based allowing different sources of input to participate in the upgrade design analysis process from remote locations. The man-machine interface has been developed using ASP.NET®. The current version of the "IDSSS" works with Internet Explorer ® version 6.0 or above. Other browsers have not been tested. The mission profile is a standard web page. This database has been built in Microsoft Access® and is shown in (**Figure 3**).

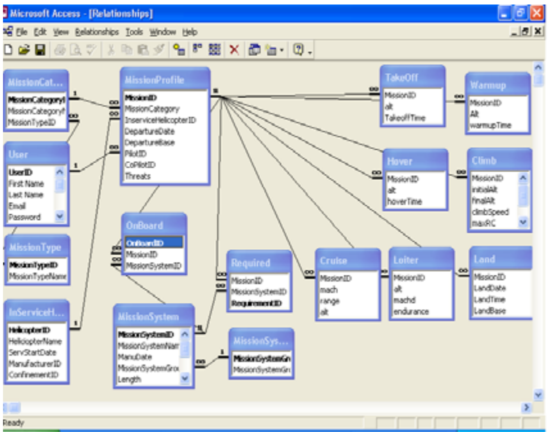

Figure 3: Snapshot of the database created in MS-Access®

The selection and listing of the mission systems has been accomplished through simple Structured Query Language (SQL) statements, which retrieve data from the database. One or more of the ideal mission systems can be part of the payload already on the in-service helicopter for a particular mission. The following is the scenario based description of the user system interaction for the "IDSSS".

The user enters the website for the "IDSSS" with the help of a web browser. The screen layout is shown in the (Figure 4).

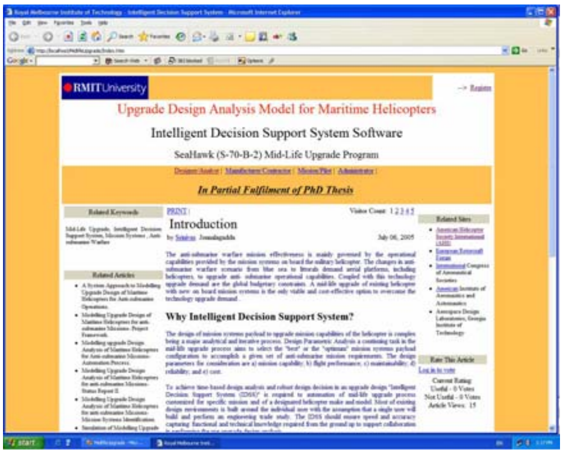

Figure 4: Home Page for IDSSS

The home page has links for different user to either login or register to enter the site. Each registered user is redirected to a different web page once he identifies as pilot or analyst or manufacturer. There is only one administrator for the IDSS who has overall control. The snapshots of the registration and login pages are presented in (**Figure 5 & 6**).

Figure 5: Registration Page for different users in IDSSS

Figure 6: Login Page Analyst in IDSSS

Based on the user type a particular user is directed to his menu page. As an example menu for Analyst would have project management utilities such as creating an in-service helicopter configuration, opening an existing configuration. Creation, deletion and modification of ASW mission requirements etc. The (Figure 7) is the snapshot for the aforementioned option.

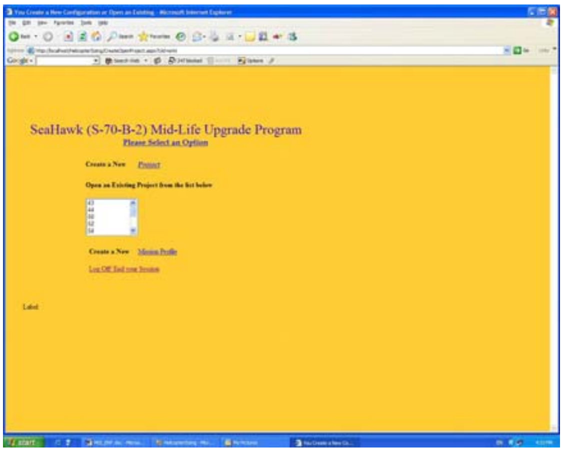

Figure 7: Project Manager Screen for Analyst

The in-service helicopter details are entered by the analyst as shown in (**Figures 8 & 9**).

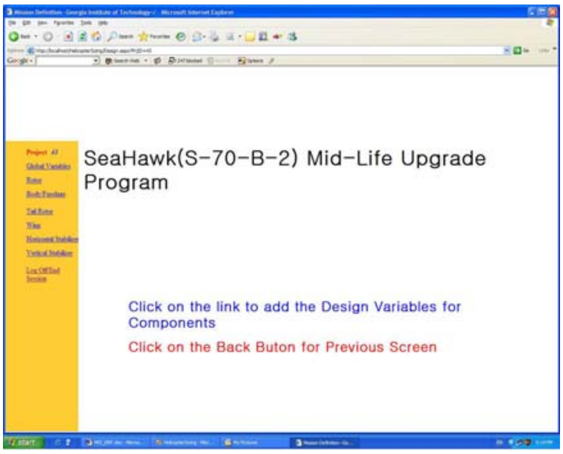

Figure 8: In-service helicopter details

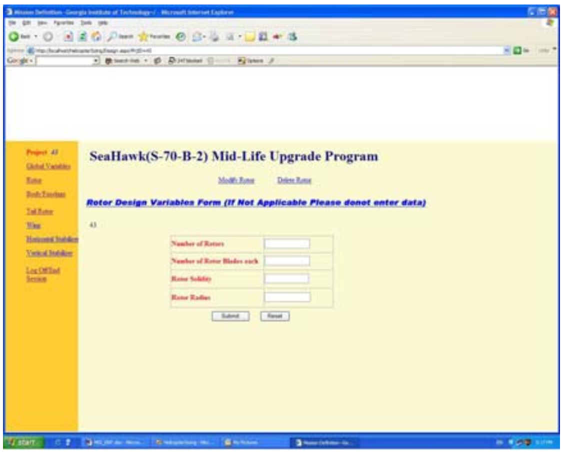

Figure 9: In-service helicopter (ob-board MS)

In case of the pilot/ mission commander the mission profile creation, modification and deletion of the mission profile are the primary options. Figures 10 & 11 present the snapshots of the web pages a pilot/ mission commander uses.

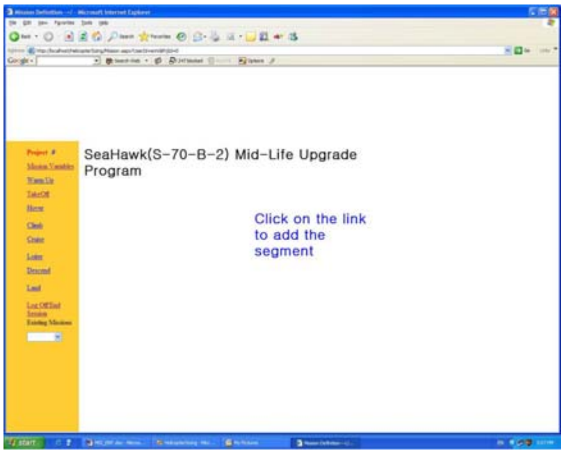

Figure 10: Mission Profile Main Page

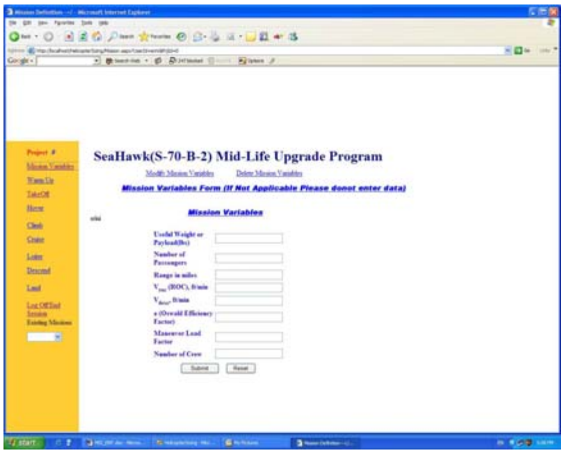

Figure 11: Mission Profile Main Page

Similar web pages exist for the manufacturer to login and input data for the state-of-the-art mission system into the database base on the existing ASW mission requirements.

With all the data available a process needs to be developed to identify ideal mission systems for upgrade. Algorithms were developed to compare and identify mission system that match the required capability, compare them with the on-board mission systems to prepare the list of ideal mission systems for mission payload.

Results and Discussion

The automation of the upgrade design analysis process for Seahawk (S-70-B-2) for mission system identification by developing the "IDSSS" fulfilled the following objectives:

- Provide user input facility to different sources of data for the upgrade design analysis;
- Integrate various ASW missions and provide a common tactical picture for specific helicopter model;
- Convert the operational and environmental data obtained from various sources or systems to operational and environmental needs;
- Derive the ASW mission requirements from operational and environment need;
- Identify state-of-the-art mission systems and their attributes to meet the derived ASW mission requirements;

The (Figure 12) represents the final step in the Mission Systems Identification and a complete description table and its attributes follows the figure.

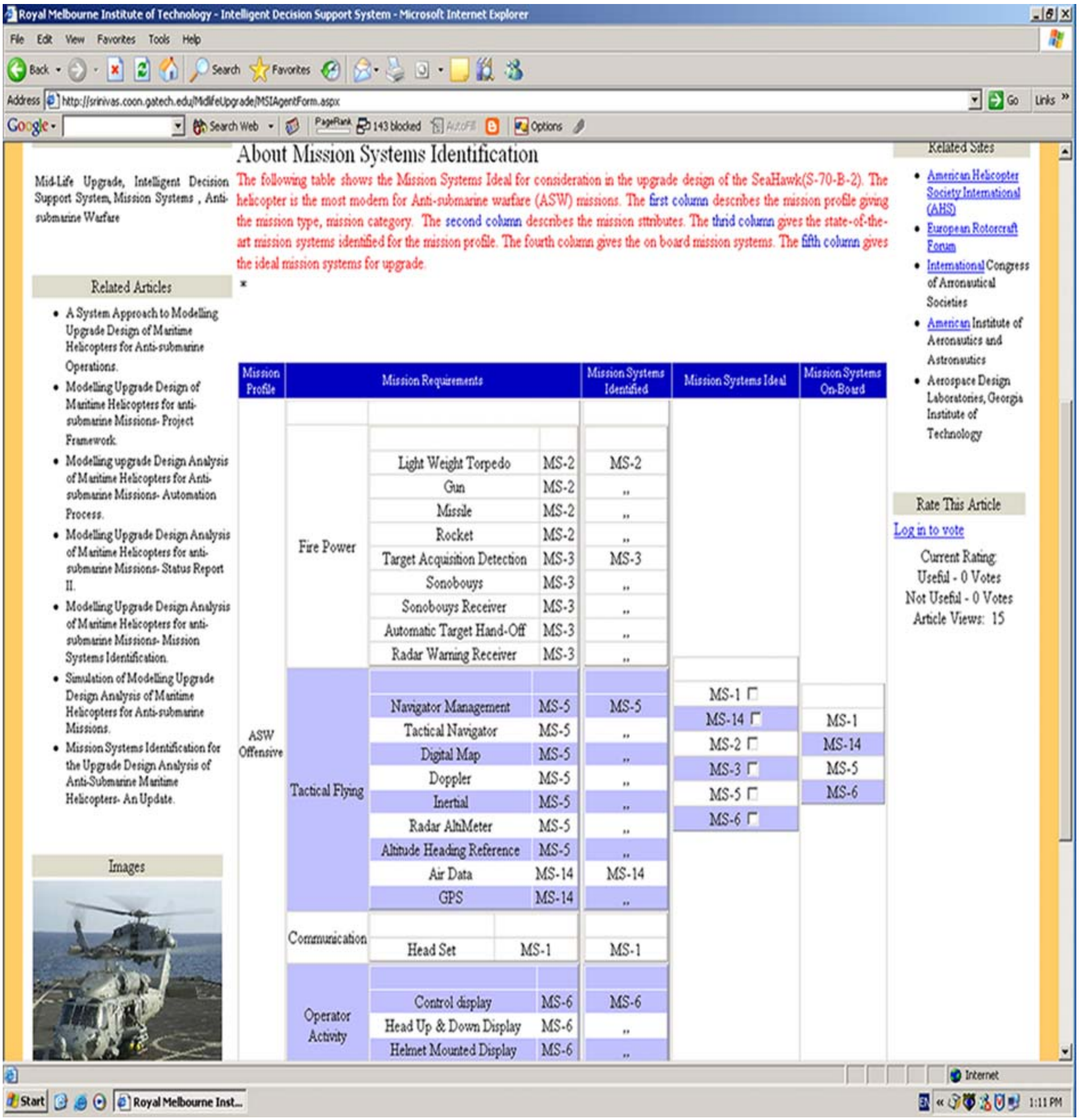

Figure 12: Snapshot of results of Mission System Identifier Agent Listing Ideal Mission Systems for Upgrade

Based on the mission profile given by the pilot/ mission commander the mission category and mission type are selected for a particular helicopter mission. In the (**Figure 12**) the first column displays such a mission profile. The mission category which is offensive, defensive or logistic support is the input for selection of mission requirements. These are displayed in the second column and are sub-divided into operational and environmental requirements. The environmental conditions are **sea state, time, weather and threats**. These are extracted from the mission profile. The operational requirements are listed from the knowledgebase for example **fire power, operator activity, communication, tactical flying,** etc. These are displayed in the second column. The component-wise requirements for an operational condition are listed in the third column. For example Tactical flying requires Navigator management, Digital map, Doppler, Inertial, Radar Altimeter, Altitude Heading Reference, Air Data, and Global Positioning System (GPS). This is the matched mission capability requirement in terms state-of-the-art mission systems. These components or the mission systems belong to different groups. In the (Figure 12) while Light Weight Torpedo, Gun, Missile, Rocket belong to Armament Group designated as (MS-2), Sonobouys, Sonobouys Receiver, Automatic Target Hand-Off, Radar Warning Receiver belong to Fire Control Group designated as (MS-3). Both of these are required for fire Power and become Mission Systems Identified. These are compared with the mission systems or components and their groups are displayed in the last column. Assuming that a particular helicopter has Communication (MS-1), Network-Enable (MS-14), Navigation (MS-5) and Observation (MS-6) on-board the ideal mission systems are listed as the difference between mission systems identified and the mission systems on-board. The ideal mission system groups are provided with a checkbox in each row. The Analyst selects from the ideal mission systems mission payload design and further analysis.

Conclusion

The automation process for mission systems identification for upgrade is the base for the upgrade design analysis. The process is based primarily on categorization of mission requirements and mission systems from mission profile created and the database of mission onboard and required mission systems. The web centric architecture with completely object-oriented approach used in the process is systematic and can benefit in a) knowledge retention and reuse; b) better utilization of computing resources; c) standardization of the design method.

References

1. Aiyappan R. *Knowledge Driven Automation*. http://www.expresscomputeronline.com/20021223/tech1.shtml, 2002, access date: 23/02/2004.

2. Jonnalagadda S, Sinha A K, Hoffmann P, and Scharge D P. Modelling Upgrade Design of Maritime Helicopters for Anti-submarine Missions- Project Framework. *Proceedings of the 60th Annual Forum and Technological Display of American Helicopter Society*, Baltimore, MD, 08-10 June, 2004.

3. Jonnalagadda S, sinha A K, Hoffmann P, and Schrage D P. Modelling upgrade Design Analysis of Maritime Helicopters for Anti-submarine Missions- Automation Process. Proceedings of the 22nd International Council of Aeronautical Societies (ICAS), 2004, Yokohoma, Japan, 29 – 31 August, 2004.

4. Jonnalagadda S, Sinha A K, Hoffmann P, and Schrage D P. Modelling Upgrade Design Analysis of Maritime Helicopters for anti-submarine Missions- Status Report II. Proceedings of the 30th European Rotorcraft Forum, Marsellies, France, 14-16 September, 2004.

5. Kusumo R and Sinha A K. Common Development Tools For An Integrated Decision support System for Mid-Life Upgrade Analysis. *22nd Congress of the International Council of the Aeronautical Sciences*, 613, 613.1-613.8, Toronto, Canada, 8-13 September, 2002.

6. Kusumo R and Sinha A K. Mission Systems Identification Sub-Model of an Integrated Decision Support System for Mid-Life Upgrade of Maritime Helicopters. American Helicopter Society 57th Annual Forum, Washington DC, USA, 9-11 May, 2001.

7. Morgan J. Anti-Submarine Warfare-A Phoenix for the Future. http://www.chinfo.navy.mil/navpalib/cno/n87/usw/autumn98/anti.htm, 1998, access date: 16/04/2003.

8. Mulholland D. USAF puts upgrades before platforms, *Jane's Defence Weekly*, Vol. 35, i.23, pp.5, 2000.

9. Roth B A, and Marvis D N, *A Stochastic Approach to Designing Affordable*, *Environmentally Acceptable Systems,* www.asdl.gatech.edu, 2002.

10. Sinha A K, Kam B H, and Wood L A. A Comparative Analysis of Decision Support Systems for Helicopter Multi-Mission Modifications. *First International Seminar on the Development and Utilization of Helicopters in South Asia Pacific*, Bangalore, India, 1995.

11. Sinha A K, Kam B H, Wood L A, & Caterson J. Toward a Compromise Solution for Helicopter Multi-Mission Modification Decisions. *Proceedings of 52nd Annual Forum and Technology Display of American Helicopter Society*, Washington, D C, U.S.A, 4-6 June 1996.

12. Sinha A K, Bil C, and Scott M L, Design of Payloads for Mid-life Upgrade of Maritime Helicopters: Stage I, II, III and IV. *Proceedings of 3rd Australian Pacific Vertiflite Conference on Helicopter Technology*, Canberra, A.C.T, 12-14 July 2000a.

13. Sinha A K, Bil C, and Scott M L. Design of Payloads for Mid-life Upgrade of Maritime Helicopters: Stage V and VI. *International Conference on Systems Thinking in Management*, Melbourne, Victoria, 8-10 November 2000b.

14. Scott W, Hongman K, Mullins J and Sobieszczanski-Sobieski J., A Web Centric Architecture for Deploying Multi-Disciplinary Engineering Design Process, American Institute of Aeronautics and Astronautics; www.phoenix-it.com; access date: 30-November-2004.