MODELLING UPGRADE DESIGN OF MARITIME HELICOPTERS FOR ANTI-SUBMARINE MISSIONS – AUTOMATION PROCESS

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Abstract

The current face of global conflict has shifted maritime missions from blue sea to littoral waters, adding further complexity to the role of maritime helicopters. Future global crisis and conflicts in littorals will require aerial platforms, including helicopters, to possess enhanced anti-submarine capabilities in order to counter the increased submarine threat. The design and manufacture of new aircraft with enhanced capabilities is highly expensive and time consuming. A mid-life upgrade of existing platforms with new on-board systems is generally the preferred option for enhancing mission capability. The pre-upgrade design analysis process is intricate and iterative. Software tools, that ensue the speed and accuracy of this process need developing. This paper addresses the application of an automation framework for modelling the upgrade design of maritime helicopters for anti-submarine missions.

1 Introduction

In future global crisis and conflicts the prevalent submarine threat present in littorals will require aerial platforms, including helicopters, to possess enhanced anti-submarine capabilities [6]. However, the inherent uncertainty in projecting the future anti-submarine mission environment requires synergic integration of state-of-the-art onboard mission systems capable of operating in both littoral and blue sea environments [3].

The design and manufacture of new aircraft capable of defeating these future threats is highly expensive and time consuming. A mid-life upgrade of existing platforms with new on-board systems is generally the preferred option for enhancing mission capability and overcoming new threats [7].

The integration of state-of-the-art mission systems to enhance anti-submarine capabilities is challenging. The trade-off between established in-service technologies and advanced technologies is complex and requires detailed synthesis for the formalisation of a coherent whole [8].

Knowledge-based applications are now an essential component of most new aerospace development programs to reduce non-recurring development time by incorporating product or process specific design requirements into computer programs [13]. To achieve optimum integration of mission systems in an upgrade design, it is essential to capture functional and technical knowledge and to automate the design and manufacturing processes [1].

Sinha et al. [9, 10, 11 & 12] adopted a systems approach to address the mid-life upgrade process for mission capability enhancement. This was conceptualised as an 'input-process-output' configuration which considered the disparate design parameters - mission capability, flight performance, reliability, maintainability and cost. A framework to automate the upgrade design methodology was also developed and was addressed by Kusumo et al. [4 & 5]; through an Integrated Decision Support System (IDSS). The IDSS comprised of sub-modules synergistically integrated for user-system interaction and mission system analysis [5].

Jonnalagadda et al. [2] presented an initial automation framework based on the concept of Sinha et al. [9, 10, 11 & 12] and Kusumo et al. [4 & 5]. The automation framework description included the description of the baseline modules. Each module was self-contained using distributed system paradigm providing input to the knowledge base for design decision support.

This paper, presents the automation framework as applied in the development of a model to address the mid-life upgrade for anti-submarine capability enhancement for a robust upgrade design option. Covered are the mid-life upgrade systems methodology and the automation process.

2 Mid-Life Upgrade Systems Methodology

The generic "mid-life upgrade system" developed by Sinha et al. [9, 10, 11 & 12] and automation framework by Kusumo et al. [4 & 5] are presented in Fig.1 and Fig. 2 respectively.

The mid-life upgrade system identifies the integration of missions through decision support system to formulate a mission equipment package for upgrade. The airframe to be upgraded is then analysed on the basis of several design parameters: a) mission capability; b) flight performance; c) maintainability; d) reliability; and e) cost. A multi parameter evaluation graph is then proposed for identification of an optimal upgrade design.

Automation framework of the aforementioned mid-life upgrade system identified modules for the following: a) mission system identification; b) mission payload design; c) multi-parameter analysis; and d) decision support and e) robustness. The input command and output was through a man-machine interface. A database provided inputs for all computations.

The mid-life upgrade system and its proposed automation are revisited from a system perspective to develop an upgrade system structure to enhance anti-submarine capabilities. The system configuration is as 'input-process-output' configuration. Three components of the system identified to address the following functional characteristics (attributes): a) Man-Machine Interface – User inputs and machine codes; b) Mission System-Attack, counterattack, reconnaissance and surveillance; and c) In-Service Helicopter-Mission capability, flight performance and logistic support. The environment of the operation is to address the threat, time of operation, weather and the sea state.

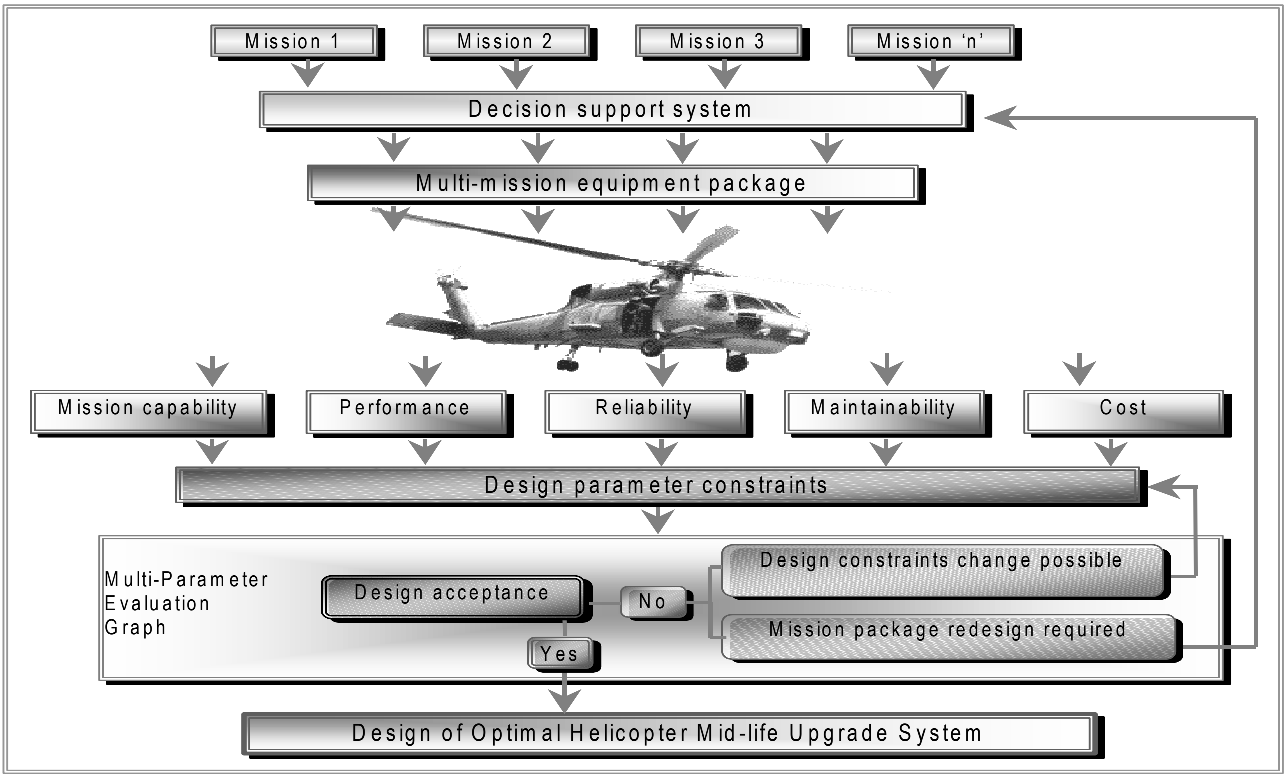

Fig. 1. Mid-Life Upgrade System [12]

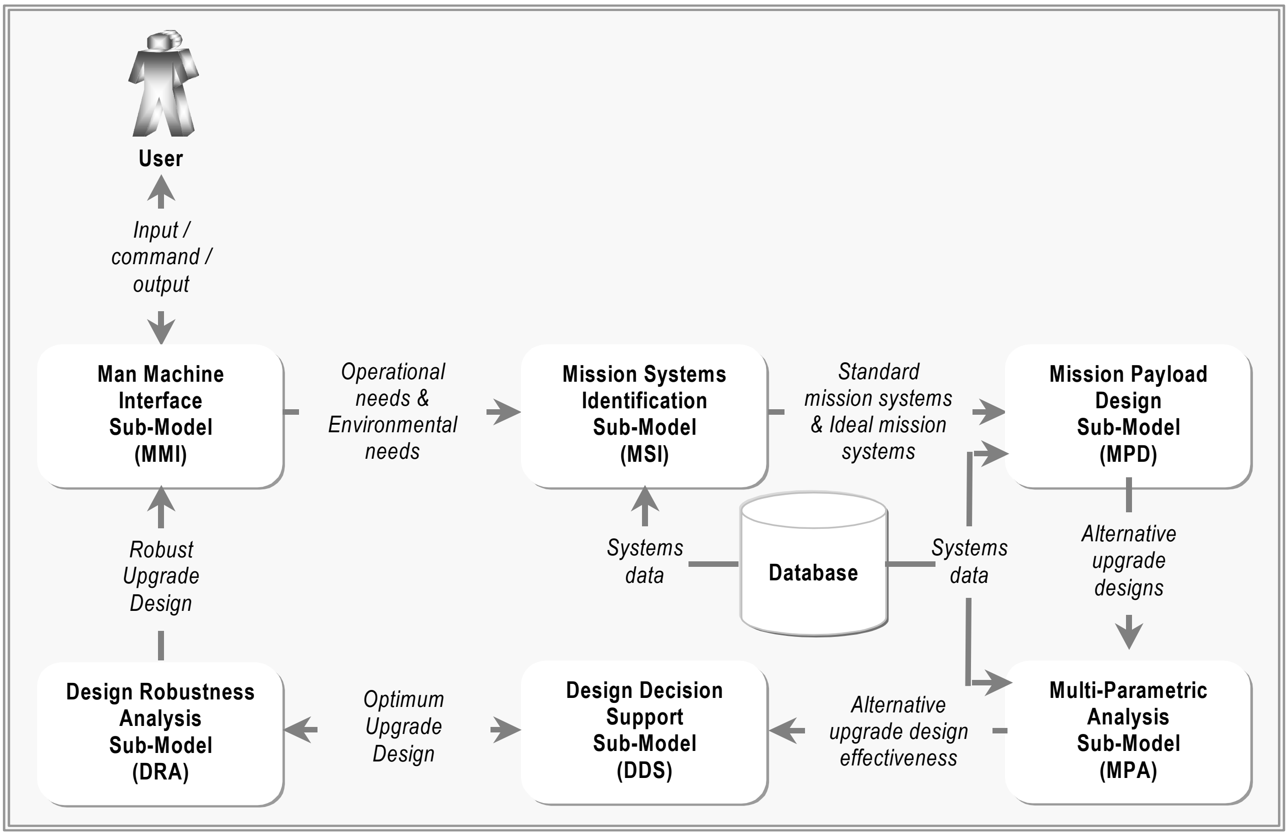

Fig. 2. Framework of an Integrated Decision Support System for automation of the Mid-life Upgrade [4]

3 Automation Process

The automation model of Jonnalagadda et al. [2] is presented in Fig. 3. The mid-life upgrade of maritime helicopters for anti-submarine missions comprised of the five baseline modules, which can be either integrated or distributed to form an intelligent decision support system presented in Fig. 4:

1. **In-Service Helicopter module (IHM):** Provides design details of the selected in-service maritime helicopter to be upgraded.
2. **Anti-submarine mission requirements module (ARM):** Determines mission requirements based upon operational needs and the operational environment.
3. **Knowledge base module:** Computing methodology and integration of the state-of-the art mission systems by implementing reuse of relevant information to produce optimum upgrade design option.
4. **Mission systems technology module (MST):** Provides functional characteristics of system technologies offering improved anti-submarine mission capability.
5. **Man-Machine Interface module (MMI):** The Man-Machine Interface provides user system interaction.

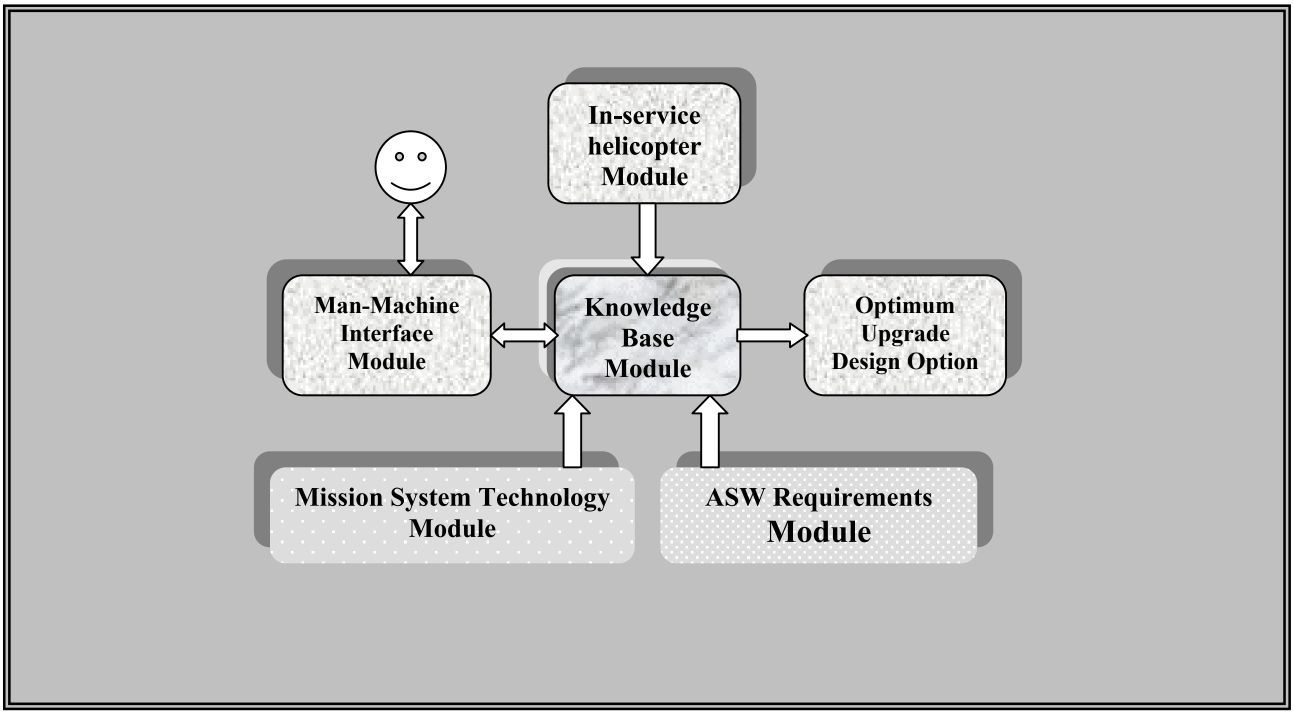

Fig. 3. Automation Process To Enhance Anti-Submarine Capabilities Through Mid-Life Upgrade [2]

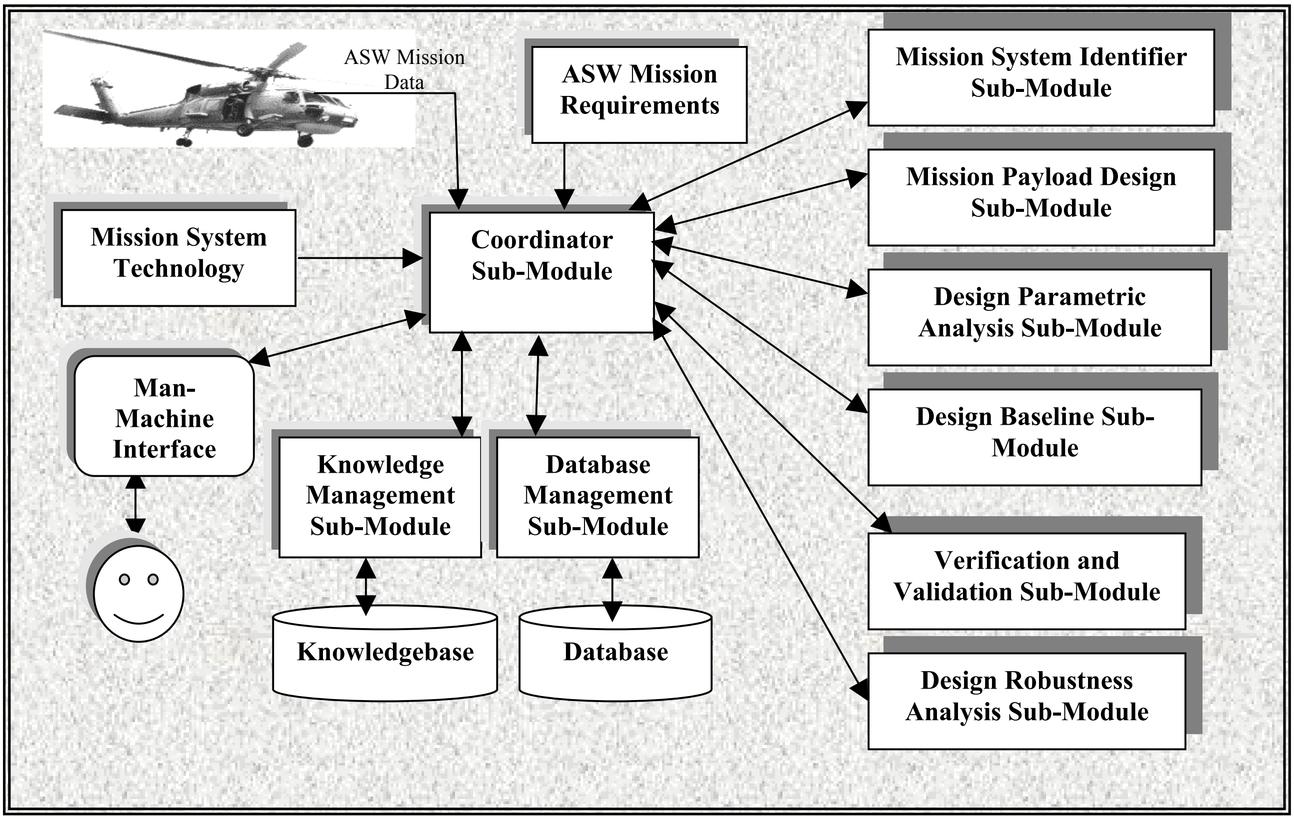

Fig.4. Framework for Intelligent Decision Support System To Enhance Anti-Submarine Mission Capabilities

3.1 In-Service Helicopter Module

The In-Service Helicopter Module (IHM) represents the design details of the selected aircraft to be upgraded. The design details for consideration in the upgrade process are flight performance, mission capability and logistic support. The onboard database which is in the form of mission data recorder and data link are the sources for the design parameters. The relevant anti-submarine mission data based on previous mission knowledge is extracted from the onboard database. The initial set of parameters form the design baseline for mission systems identification. The sub-modules in the in-service maritime helicopter are as follows:

- **Onboard Database sub-module:** Collects data developed during the mission. The database accepts the following data from the crew, Data Transfer Device, Data Link, Sensors and Computers:
    - Data defined as a part of the mission planning process;
    - Data used by the crew to interpret the situation; and
    - Data collected on the health and status of the system.
- **Knowledge base interface sub-module:** Transfers data generated about a mission from onboard database the knowledgebase through Knowledge base interface.

3.2 Anti-Submarine Requirements Module

The Anti-Submarine Mission Requirements Module (ARM) manages the mission requirements which drive the upgrade design process. The automation of the anti-submarine mission requirements analysis process encompasses defining the anti-submarine mission operational scenario and comparing the design parameters against the current capabilities from the In-Service Helicopter Module to extract the required capabilities a) flight performance; b) mission capability; and c) logistic support. The scenario considers operational environment and operational needs as attributes. The operational environment is to address a) the threat; b) time of operation; c) weather and d) the sea state. Effort is to make the operational environment dynamic either user selected or simulated values to form inputs for anti-submarine mission requirements generation. The operational needs considered are a) attack & counterattack and b) reconnaissance & surveillance. The anti-submarine mission requirements are shown in Table 1.

3.3 Knowledge Base Module

The Knowledge Base Module identifies the state-of-the-art mission systems from the defined operational and environmental needs provided by the anti-submarine mission requirements module. It is also responsible for the mission systems integration into the in-service helicopter and the evaluation of alternative upgraded helicopter designs. The sub-modules are identified are:

- **Knowledge Management sub-module:** Creates, collects and processes knowledge required for achieving different goals.
- **Database Management sub-module:** Store and manages operational, environment and mission systems data received from the Onboard Database.
- **Design Baseline sub-module:** Maintains a baseline once the optimum upgrade design option is generated. The initial design constraints identified will form the first baseline. The further baselines are dependent upon choice of mission systems integrated by the user.
- **Mission System Identifier sub-module:** Compares the functional characteristic of the mission system from MST, the translated anti-submarine mission requirements from the ARM, IHM and identifies ideal mission systems for the mid-life upgrade. These are stored in the database. The output will be the ideal mission systems for mission payload design.
- **Mission Payload Design sub-module:** Integrate ideal mission systems and design alternative mission payloads according to the priority based on their relative functional dependence and degree of contribution in mission success.
- **Design Parametric Analysis sub-module:** Performs unit level sub-system test with the alternative mission payloads for acceptance of disparate design parameters- flight performance, mission capability, maintainability, reliability and cost.
- **Verification and Validation sub-module:** Performs both unit level and system verification and validation after integration for the system effectiveness of the upgraded design option.
- **Design Robustness Analysis sub-module:** Tests the robustness of the design decision against temporal uncertainties [5].
- **Coordinator sub-module:** Refines, interpret and present to the agents and other sub-modules the relevant information to perform the required task.

3.4 Mission Systems Technology Module (MST)

The Mission Systems Technology Module provides functional characteristics of system technologies offering improved anti-submarine mission capabilities. The design parameters of system technologies are dependent operational needs and the environmental needs generated from the AMR. The design parameters are integrated for verification and validation. These are a set of ideal mission systems designed with the support of knowledge from the knowledge base and are stored for reuse. The operational needs as mentioned are a) attack & counterattack; and b) reconnaissance & surveillance. The environmental needs are a) all weather; b) sea state; c) round-the-clock operation; and d) threat. These are presented in Table 1.

<table>
<tr><th colspan="2">Inputs</th><th>Anti-Submarine Mission Requirements (Attributes)</th><th colspan="2">Output</th></tr>
<tr><td rowspan="14">Operational Needs</td><td rowspan="8">Attack & Counterattack</td><td>Armament</td><td rowspan="8">Attack & Counterattack Sub-Mission Capability</td><td rowspan="25">Anti-Submarine Mission Capability</td></tr>
<tr><td>Observation</td></tr>
<tr><td>Navigation</td></tr>
<tr><td>Communication</td></tr>
<tr><td>Self Attack</td></tr>
<tr><td>Knowledgebase</td></tr>
<tr><td>Crew Activity</td></tr>
<tr><td>Fire Power</td></tr>
<tr><td rowspan="6">Reconnaissance & Surveillance</td><td>Situation Awareness</td><td rowspan="6">Reconnaissance & Surveillance Sub-Mission Capability</td></tr>
<tr><td>Communication</td></tr>
<tr><td>Navigation</td></tr>
<tr><td>Crew Activity</td></tr>
<tr><td>Armament</td></tr>
<tr><td>Survivability</td></tr>
<tr><td rowspan="11">Environment Needs</td><td rowspan="3">Threat</td><td>Armament</td><td rowspan="3">All Threat</td></tr>
<tr><td>Observation</td></tr>
<tr><td>Survivability</td></tr>
<tr><td rowspan="5">Weather</td><td>Tropical</td><td rowspan="5">All Weather</td></tr>
<tr><td>Hot Weather & Desert</td></tr>
<tr><td>Cold Weather</td></tr>
<tr><td>Thunderstorms & Turbulence</td></tr>
<tr><td>Snow</td></tr>
<tr><td rowspan="3">Time of Operation</td><td>Day</td><td rowspan="3">Round-the-Clock</td></tr>
<tr><td>Day/ Night</td></tr>
<tr><td>Night</td></tr>
</table>

Table.1. Inputs, Mission Requirements And Outputs Of Mid-Life Upgrade System For Anti-Submarine Missions

4 Results and Discussion

A comprehensive framework has been developed to model robust timely upgrade design of maritime helicopters for anti-submarine missions. The framework was conceptualized as a system for holistic analysis. The automation process viewed as 'input-process-output' configuration performs the following:

a) Mission analysis;
b) Anti-Submarine requirements specification;
c) Functional analysis;
d) Design;
e) Synthesis;
f) Verification and Validation; and
g) Design robustness analysis.

Each sub-module has its feedback mechanism reducing the iteration time.

5 Conclusions

The automation framework provides a holistic analysis for the enhancement of anti-submarine mission capabilities of maritime helicopters. The successful development could be used for other missions.

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