# A SYSTEM FRAMEWORK TO AUTOMATE DESIGN DECISION SUPPORT OF RE-CONFIGURABLE UAVS

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## Abstract

*Unmanned aerial vehicle (UAV) technology has now matured for certain missions, leading to further development of a more effective platform than manned aerial vehicle. The issues and challenges facing their design and development resulted in a large inventory of UAVs, placing logistic support challenges on the operators. To address the logistic challenges, the conceptual design of a multi-mission 'Re-configurable UAV' (RC-UAV) is being explored. In this paper, the framework for the automation of design process of RC-UAV is discussed. The framework considers the re-configurable design parameters as the key to automate the process.*

## 1 Introduction

Unmanned Aerial Vehicle (UAV) has proved its value in military operations recently, paving the way for technology acceptance towards further research and development. UAV technology has addressed several potential civil and military missions to enhance mission effectiveness and cost effectiveness. The technology developed has resulted in a large inventory of UAVs to meet the wide operational and environmental needs. Though the Issues and Challenges (I&C) were addressed [1], the large inventory has placed a logistic support challenge to the designers [2].

Sinha et al. [2] adopted a systems methodology to consecutively address the I&C and the large inventory. This resulted in the placement of a multi-mission UAV concept for consideration. The systems methodology addressed the I&C of project definition, technological maturity and operational effectiveness. From a systems perspective, the UAVs were classified as either in-support or in-combat; fixed-wing or rotary-wing based platform. The UAVs were further sub-classified based on the altitude of operation and the expected endurance.

To further address the multi-mission concept, Sinha et al. [3 & 4] provide an investigation on the concept of a Re-Configurable UAV (RC-UAV), to cover the varying range of payloads, endurance and altitude of operation. The results of the investigation indicate that the design process of RC-UAV involves highly complex engineering tasks. Additionally, the operational phase of the futuristic RC-UAV requires the reconfiguration process to be in timely manner. Thus to assists the designer in coping with the design complexity, a software-based application is required – one that can automate the engineering computations for time-based analysis.

In this paper, a system approach is adopted to formulate a framework for the development of an 'UAV Design Decision Support' (UAV-DDS). The framework of UAV-DDS provides the foundation for software development to automate re-configurable design parameters of RC-UAV.

## 2 System Methodology

The multi-mission RC-UAV is first viewed in a typical input-process-output configuration [5], to conceptualise it as a system for further analysis. The inputs are the base design parameters on which the conceptual design of the RC-UAV is to be developed. The required multi-mission capabilities are to be processed to provide a RC-UAV, as an output of the system. A systems perspective of the RC-UAV system in an input-process-output configuration is presented in Figure 1.

With the RC-UAV system configured, the next step is to identify the system elements – components, attributes and relationships [6]. The components are to be 'analysers' with attributes that address the functional characteristics of multi-mission, airframe and system effectiveness. The multi-mission characteristics of UAVs, are mainly governed by the payload, endurance and operating altitude. The airframe characteristics to be considered are fuselage extensions, changeable wings and tail units and alternative power units. System effectiveness, needs to be holistic; high mission effectiveness, enhanced flight performance, high reliability, low maintainability and low cost. The relationships between the components and attributes needs to be considered as inter and intra – components & components; components & attributes; and attributes & attributes. The operational environment ranges from different terrain, to weather and time of operation. The system structure of a multi-mission RC-UAV considering the system elements discussed, is presented in Figure 2.

The operation needs of the UAVs and its related mission requirements were investigated by Sinha et al. [2], to characterise the emerging technology. The resulting classification of the UAVs was in-support or in-combat; fixed-wing or rotary-wing based platform. The sub-classification was further explored into viable design technology groups, from a multi-mission perspective; for example, the multi-mission payloads are viewed from a fuselage extension point, and the endurance from a wing plan-form and variable on-board power. The resulting design technology groups from this exercise is presented in Table 1. The UAV system hierarchy based in I&C was developed by Sinha et al. [3]. The hierarchy is formulated on the design technology groups and then further sub-grouped according to the platform; fixed-wing or rotary-wing. The partial system hierarchy of a multi-mission RC-UAV system is presented in Figure 3.

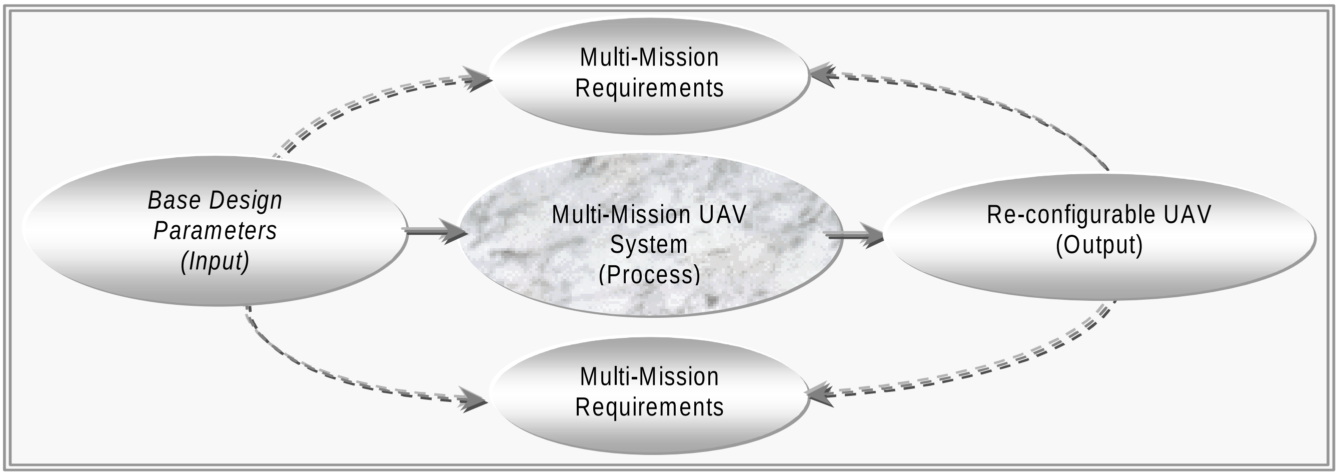

**Figure 1. System Perspective of a Re-configurable UAV System**

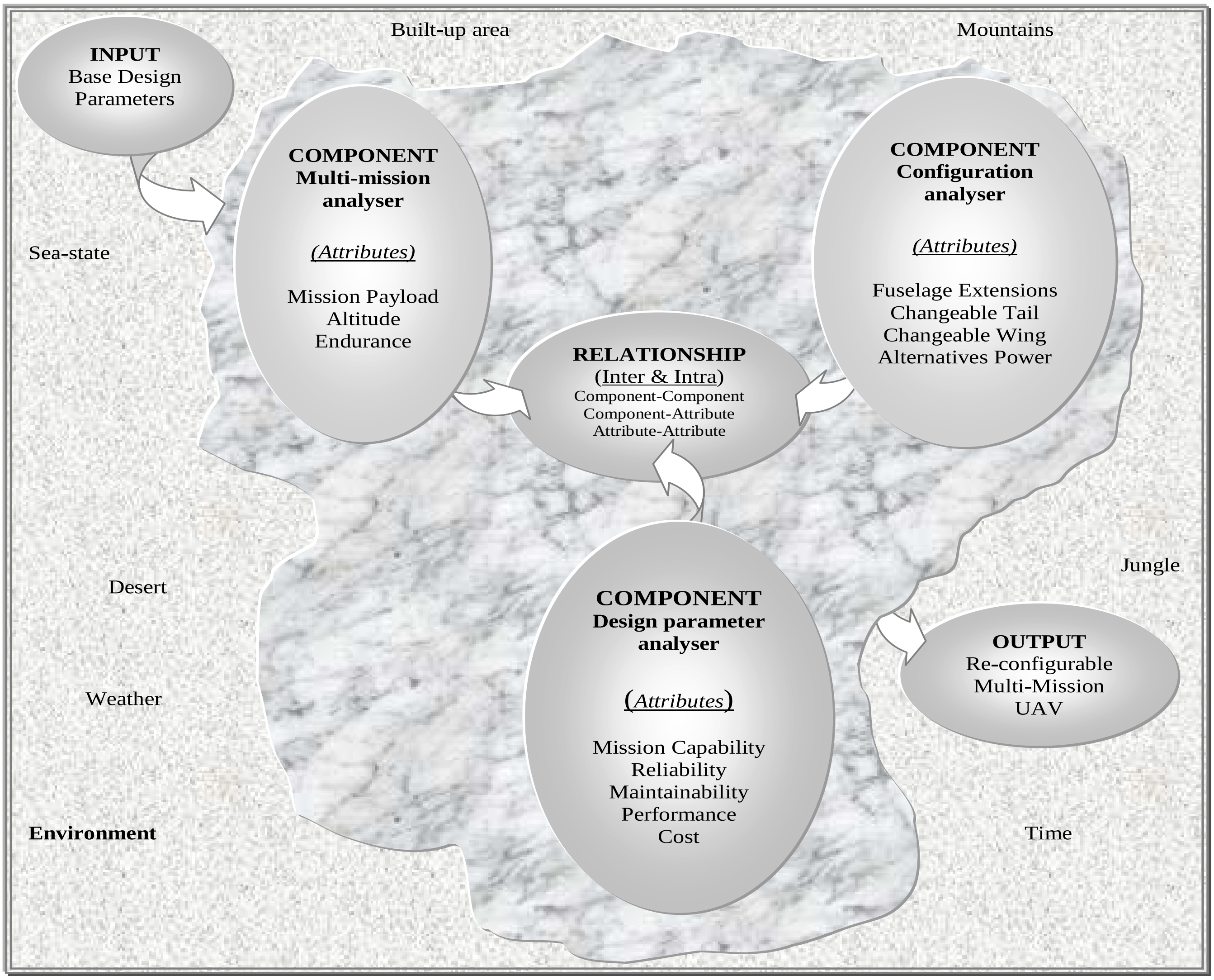

**Figure 2. System Structure of a Multi-Mission Re-configurable UAV System**

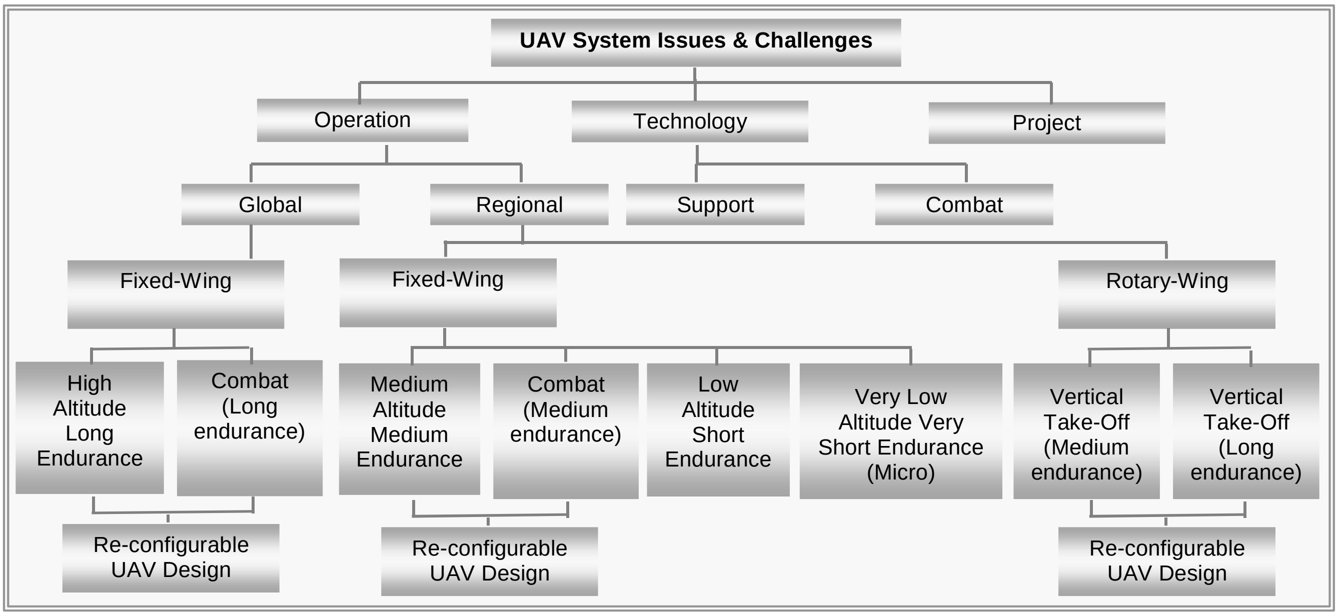

**Figure 3. Partial System Hierarchy of Multi-Mission Re-configurable UAV System**

Table 1. Multi-Mission Re-Configurable UAV Design Technology Groups

| **Operational Needs** | **Customers** | **Mission Requirements** | **Technology Classification** | **Characteristics** | **Multi-Mission Re-configurable UAV** |
|---|---|---|---|---|---|
| Global | Military | - Distance & large theater surveillance and reconnaissance;<br>- Monitor hostile emission; | Support UAV<br>*HALE*<br>*HALO* | Payloads: 1000 kg<br>Altitude: 19812 m<br>Endurance: 41 hr | Military<br>**HALE – HALO – UCAV(HL)**<br>Payloads: up to 1000 kg<br>Altitude: 4420 - 19812 m<br>Endurance: up to 41 hr<br>**MAME – UCAVs(MM)**<br>Payloads: 150 - 240 kg<br>Altitude: 4000 - 7620 m<br>Endurance: 4 - 25 hr<br>**VTUAV(LE) – VTUAV(ME)**<br>Payloads: 80-180 kg<br>Altitude: 3600 - 5000 m<br>Endurance: > 4 hr<br>Civil<br>**MAME - LALE**<br>Payloads: 45 – 67.5 kg<br>Altitude: 3660 - 4000 m<br>Endurance: 6 - 15 hr |
| | | - Destroy mobile missile launcher & time-critical targets; | *MAME* | Payloads: 204 kg<br>Altitude: 7620 m<br>Endurance: 25 hr | |
| | | - Communication with covert formation;<br>- Ballistic missile defence; and | Combat UAVs<br>*UCAVs (HL)* | Payloads: 1000 kg<br>Altitude: 4420 m<br>Endurance: 41 hr | |
| | | - Airborne early warning. | *UCAVs (MM)* | Payloads: 150 kg<br>Altitude: 4000 m<br>Endurance: >4 hr | |
| | Civil | - Meteorological monitoring;<br>- Disaster monitoring;<br>- Atmospheric telecommunication relay platform. | Support UAVs<br>*HALE*<br>*HALO* | Payloads: 330 kg<br>Altitude: 21336 m<br>Endurance: days | |
| | | | *MAME* | Payloads: 67.5 kg<br>Altitude: 4000 m<br>Endurance: 15 hr | |
| Regional | Military | - Precise targeting & terminal guidance; | Support UAVs:<br>*MAME* | Payloads: 204 kg<br>Altitude: 7620 m<br>Endurance: 25 hr | |
| | | - Force protection & battle management;<br>- Attack & suppress enemy ground targets;<br>- Combat Intelligence, Reconnaissance & Surveillance; | *LALE* | Payloads: 45 kg<br>Altitude: 3660 m<br>Endurance: 6 hr | |
| | | | *VTUAVs (LE)* | Payloads: 80 kg<br>Altitude: 5000 m<br>Endurance: ? hr | |
| | | | *VTUAVs (ME)* | Payloads: 180 kg<br>Altitude: 3600 m<br>Endurance: 4 hr | |
| | | - Battle damage assessment; | *VLAVLE (micro)* | Payloads: 0.45 kg<br>Altitude: 30 m<br>Endurance: 10 min | |
| | | - Communication relay;<br>- In-situ chemical/biological agent detection;<br>- Airborne early warning; | Combat UAVs<br>*UCAV (MM)* | Payloads: 1000 kg<br>Altitude: 4420 m<br>Endurance: 41 hr | |
| | | - Anti sub-marine & ship warfare;<br>- Electronic and information warfare; and<br>- Immediate vicinity surveillance & reconnaissance. | *UCAV (LL)* | Payloads: 150 kg<br>Altitude: 4000 m<br>Endurance: >4 hr | |

| | | | | | |
|---|---|---|---|---|---|
| | Civil | • Support Law enforcement;<br>• Search & Rescue;<br>• Relief Operation in Natural disaster;<br>• Customs tasks; and<br>• Media & entertainment. | Support UAVs<br>*LALE*<br>*VTUAVs* | Payloads: 45 kg<br>Altitude: 3660 m<br>Endurance: 6 hr<br>Payloads: 80 kg<br>Altitude: 5000 m<br>Endurance: 4 hr | |

***Abbreviation***

| | | | |
|---|---|---|---|
| HALE | High Altitude Long Endurance | UCAV(MM) | Unmanned Combat Aerial Vehicle (Medium Altitude Medium Endurance) |
| HALO | High Altitude Long Operation | | |
| LALE | Low Altitude Short Endurance | VLAVLE(Micro) | Very Low Altitude Very Low Endurance |
| MAME | Medium Altitude Medium Endurance | VTUAVs (LE) | Vertical Takeoff Unmanned Aerial Vehicle (Long Endurance) |
| UCAV(HL) | Unmanned Combat Aerial Vehicle (High Altitude Long Endurance) | VTUAVs (ME) | Vertical Takeoff Unmanned Aerial Vehicle (Medium Endurance) |

## 3 System Framework

Having investigated the concept of multi-mission RC-UAV from a systems perspective, the framework for the UAV-DDS is developed. The system framework of UAV-DDS comprises of nine sub-modules, which are formulated based on the components of the RC-UAV system structure – three analysers; and the functions of these modules are dictated by the attributes. The UAV-DDS sub-modules and their slated functions are as follows:

- **Man Machine Interface:** To provide user-system interaction;
- **Database:** To store and manage operational, mission systems and UAV data;
- **Mission Requirements Analysis:** To translate operational and environmental needs to mission requirements;
- **UAV Design Parameter Analysis:** To analyse the existing UAV system, and identify the re-configurable design parameters;
- **RC-UAV Baseline Requirements Identification:** To integrate the re-configurable UAV design parameters, and identify the baseline parameters for RC-UAV design;
- **Mission Payload Design:** To identify the mission systems based on their relative functional dependence and degree of contribution towards mission accomplishment;
- **Airframe Configuration Analysis:** To provide an integrated analysis on the fuselage extensions, wing plan-forms, tail units and alternative power plants;
- **System Effectiveness Analysis:** To provide an integrated analysis of the multi-mission capabilities, flight performance, reliability, maintainability and cost; and
- **Design Decision Support:** To evaluate the design acceptability of the RC-UAV from the perspective of system effectiveness.

With the modules and their functions identified the system framework to automate the design process of a RC-UAV is developed. The system framework for the development of UAV-DDS is presented in Figure 4. The framework represents the sub-modules integrated accordingly to the stipulated functions and the inputs/output requirements.

## 4 Results and Discussion

The development of system framework for UAV-DDS resulted in the identification of nine sub-modules. The framework is developed based on a comprehensive investigation into the design of RC-UAV. The sub-modules are designed to automate the design process of RC-UAV. The design process involves the identification of re-configurable parameters. It

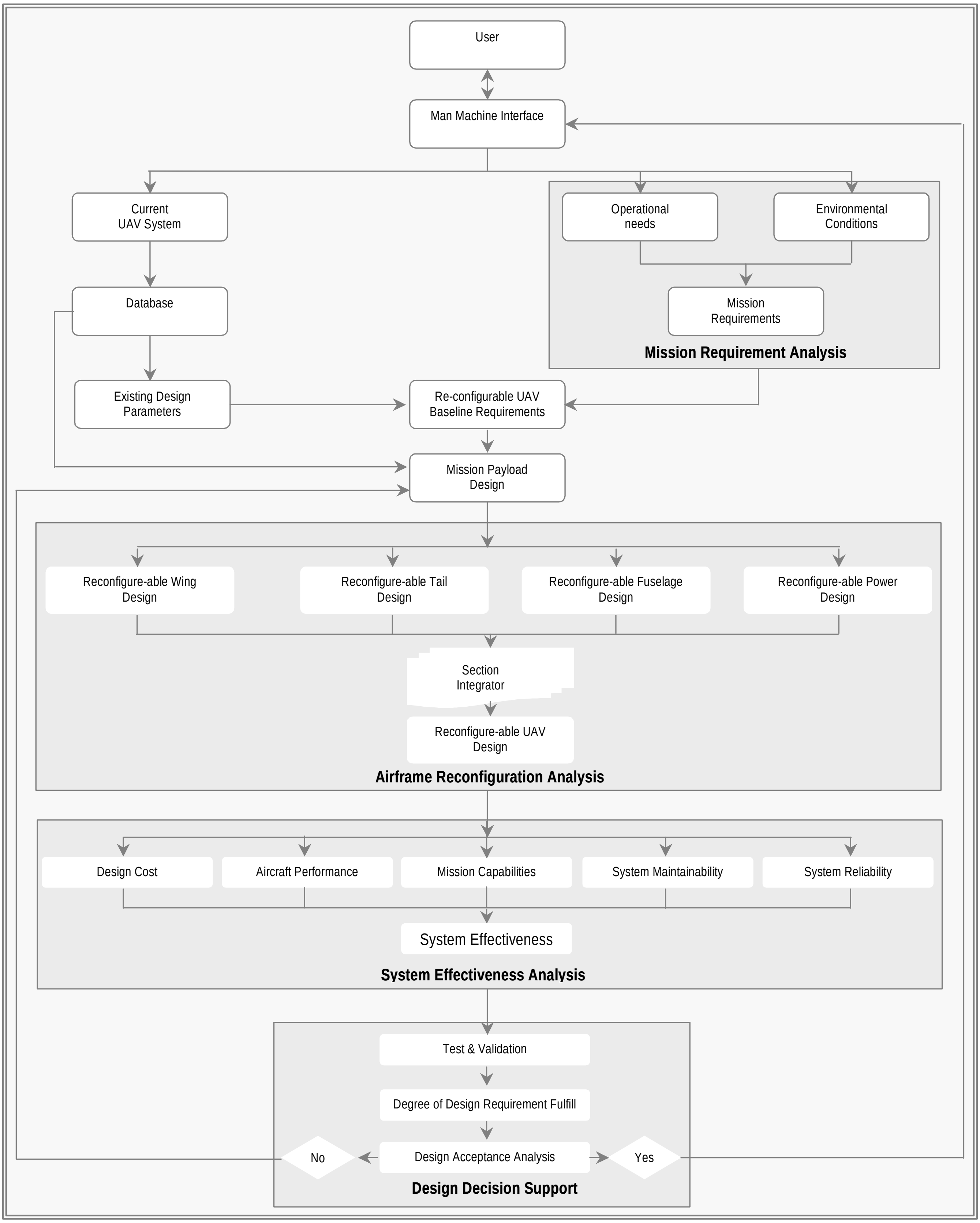

**Figure 4. System Framework of UAV Design Decision Support**

also includes system effectiveness studies for the development of a design decision support system.

## 5 Conclusion

System approach provides the avenue to develop the framework of UAV-DDS. The framework addresses the complexity of designing RC-UAV and the requirement for time-based reconfiguration process. The framework provides the base for the development of an automated RC-UAV design decision support.

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