A SYSTEM FRAMEWORK FOR THE DESIGN OF AN AVIONICS ARCHITECTURE WITH UPGRADE POTENTIAL – AVIONICS ARCHITECTURE ANALYSIS MODULE

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Abstract

The technological growth of 'avionics systems' has outpaced the service-life of the aircraft, resulting in avionics upgrade as a preferred cost-effective option to new design. Mid-life upgrade of "avionics systems" by state-of-the-art mission systems has been a challenging engineering task. The complexity of avionics upgrade process is due to the design rigidity of avionics systems architecture. An avionics architecture with growth potential is required to optimise avionics upgrade with state-of-the-art systems. In this paper, the overview of system framework for the development of avionics architecture with growth potential is presented, followed by the detailed discussion on the 'Avionics Architecture Analysis' (AAA) module. The AAA module considers various design parameters in identifying the architectural parameters of existing avionics.

1 Introduction

During the service life of military aircraft, advancements in avionics technology renders certain systems onboard either obsolete or with limited capability, compared to state-of-the-art systems. Mid-life upgrade of military aircraft, that includes insertion of advanced avionics systems in the "avionics architecture" is a cost-effective option to new design [1]. The major challenge in an avionics upgrade design process, is the integration of advanced system with systems onboard. The integration process is governed by the avionics architecture of the aircraft [2].

The architecture for military aircraft are based on a functional format. Flight control, navigation, identification friend or foe and communication are the common functional format [3]. The design rigidity of such an architecture format limits the degree to which integration can be achieved. The development of 'multi-functional avionics systems' coupled with architecture rigidity, has made avionics upgrade process an engineering challenge. A new design approach named – Integrated Modular Avionics (IMA) is being attempted to consider the current design drawbacks of avionics architecture and address the problem of technology insertion [4 & 5]. The principles on which these concepts are formulated are still premature and no major literature on the subject is in the public domain.

Rao, et al. [6] adopted a systems approach to develop a framework for the design of an avionics architecture with upgrade potential. – one that will holistically address all design parameters and constraints, including technological insertion. The architecture is on an 'open format', to provide in-built growth potential, and facilitate insertion of state-of-the-art systems in the architecture on a continuous basis, during the service life of the aircraft. The framework identified five modules for the architecture design. In this paper, the framework for the development of avionics architecture with upgrade potential is presented initially, followed by detailed discussion on the development of 'Avionics Architecture Analysis' (AAA) module.

2 System Methodology

A system methodology to study the operational needs and operational environment for deriving the mission requirements of military aircraft was developed by Sinha et al. [7 & 8]. Based on the derived mission requirements, a Mid Life Upgrade System (MLUS) was structured by Sinha et al. [7] to identify the system elements (components, attributes and relationships) and develop the system hierarchy [9]. The MLUS hierarchy aided the identification of state-of-the art mission systems for mid-life upgrade of in-service military aircraft [7 & 8]. The mission systems identified, included advanced avionics systems as replacement to obsolete systems on board, or as, additional systems to enhance mission capability. The insertion of these state-of-the-art avionics systems on board as part of the upgrade process, is governed by the "Avionics System Architecture" (ASA) - the platform on which rests all avionics systems.

The design structure of the ASA is based on the existent state-of-the-art technology during the design phase of ASA. As the ASA remains an integral part of the aircraft during the service life, the parameters on which the design was based, remains static. On the other hand, the avionics systems technology advancement continue resulting in new or modified design parameters. Hence, to facilitate the insertion of advanced systems, Rao, et al. [6] adopted a systems approach to develop a framework for the design of an avionics architecture with upgrade potential (ASA–UP) - one that focuses on the design parameters of future avionics systems.

The IMA concept and the methodology for mid-life up-grade analysis of military aircraft provides the foundation to formulate a research program on ASA-UP design methodology. The system methodology developed by Sinha et al [7 & 8] could be explored to identify future avionics systems. The methodology could then be further explored to identify the ASA-UP design parameter.

To develop a methodology that holistically [10] addresses an ASA-UP design, a system structure [7] for avionics upgrade is to be initially formulated. The system structure is to facilitate the identification of system elements based on the slated functions of the Avionics Upgrade System (AUS). Keeping the provisions of technological insertion as the focus, the functions of the AUS to be structured are as follows:

- Identify state-of-the art avionics systems;
- Formulate technological growth parameters;
- Identify avionics architecture parameters of the aircraft system; and
- Integrate growth and architecture parameters to identify the design parameters of ASA-UP.

The structure of the AUS formulated considering the above functions is presented in Figure 1.

3 System Framework

Having conceptualised the avionics upgrade process from a system perspective the framework for the design of an ASA-UP can be developed. The AUS structure identified the requirement of four components – two analysers, an integrator, a tester and validator – to aid the design of an ASA-UP. The components and their functions are as follows:

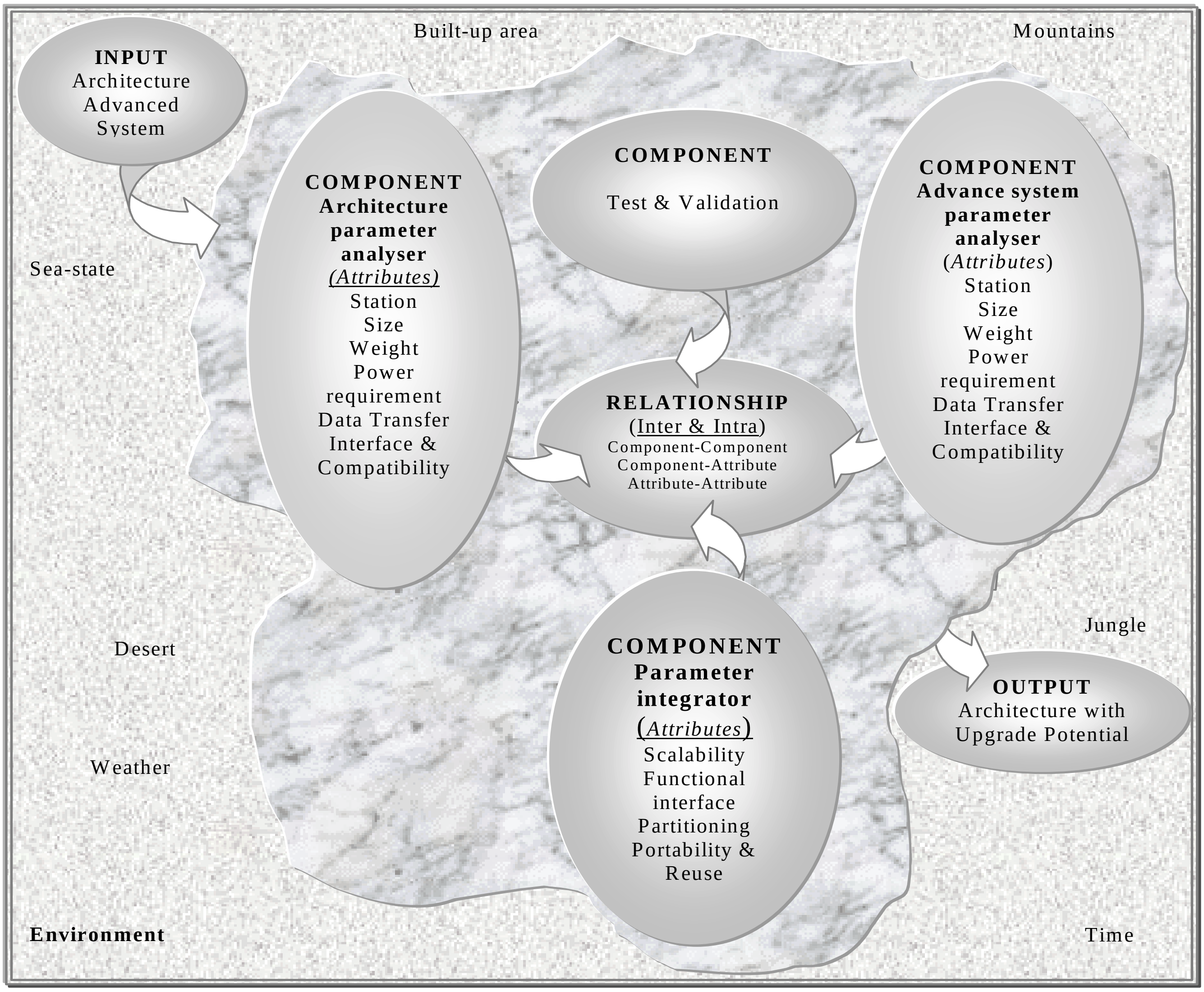
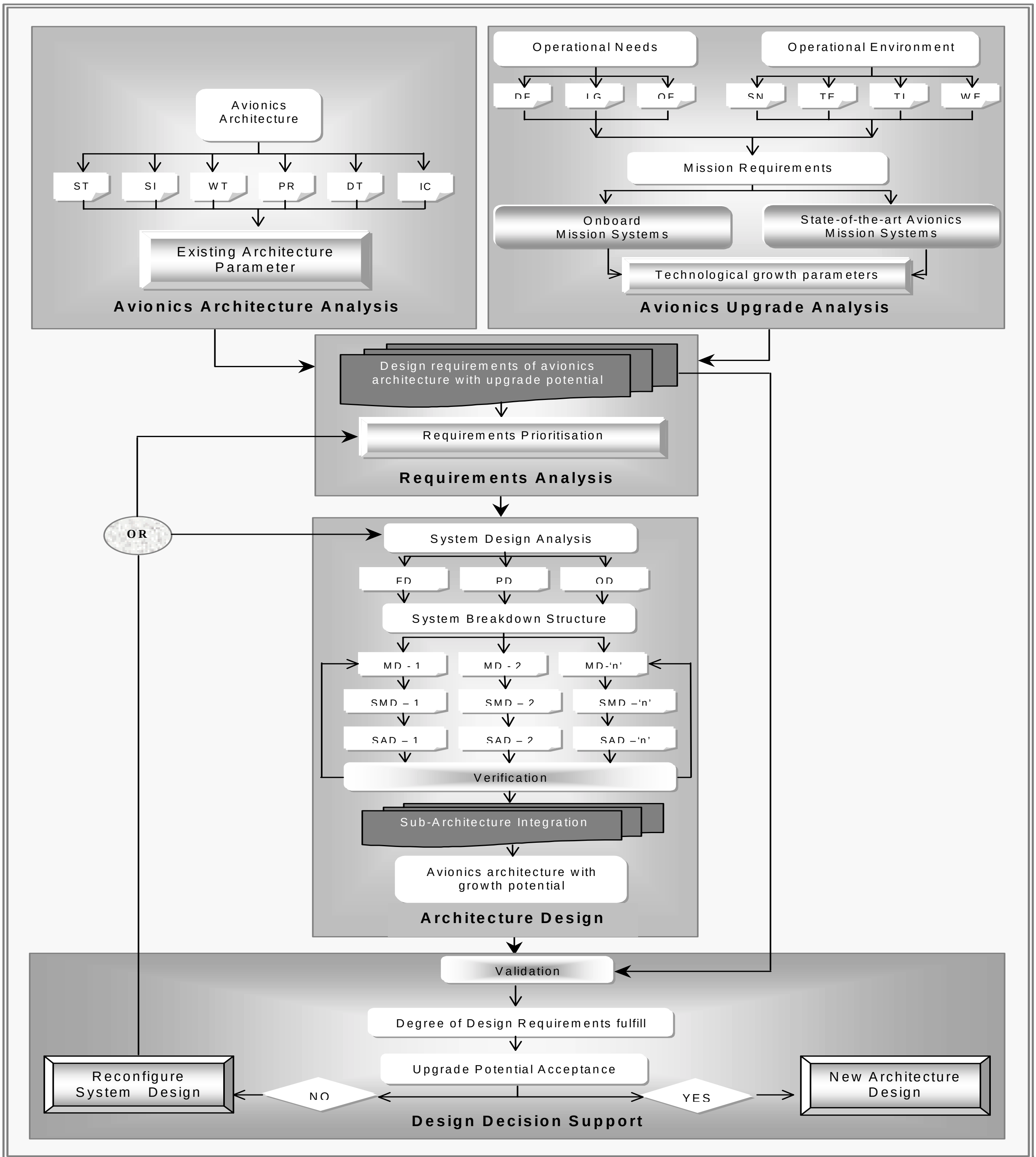


Figure 1. System Structure of an Avionics Upgrade System

- **Analysers:** To provide an analysis of the current architecture and advanced systems, and identify the architecture and technological growth parameters;
- **Integrator:** To integrate the architecture and technological growth parameters and update the design parameters for an ASA-UP; and
- **Tester & Validator:** To test and validate the ASA-UP design parameters for functionality, compatibility and performance.

With the above modules (components) and their functions identified, the system framework for the design of an avionics architecture with upgrade potential can be developed. The avionics architecture design framework developed by Rao, et al. [6] to facilitate upgrade, is presented in Figure 2 and consists of the following sub-design modules:

- **Avionics architecture analysis:** Identify parameters that govern architecture design;
- **Avionics upgrade analysis:** Identify technological growth parameters of future avionics systems;
- **Requirement analysis:** Identify design parameters of avionics architecture with growth potential;
- **Architecture design:** Design of an architecture with upgrade potential; and



Legends:

CS	:	Costs	DF	:	Defensive mission	DT	:	Data transfer
IC	:	Interference & compatibility	LG	:	Logistic mission	MP	:	Module parameters
OF	:	Offensive mission	PR	:	Power requirement	SAD	:	Sub-architecture design
SC	:	System capability	SF	:	System functionality	SI	:	Size
SMP	:	Sub-module parameters	SN	:	Situation	SP	:	System performance
ST	:	Station	TE	:	Terrain	TI	:	Time
WE	:	Weather	WT	:	Weight			

Figure 2. System Framework for the Design of an Avionic Architecture with Upgrade Potential

- **Design Decision Support:** Validate the degree to which the design requirements are met to support reconfiguration or acceptance of design.

3 Avionics Architecture Analysis

In the framework of ASA-UP, the existing avionics architecture was analysed by the 'Avionics Architecture Analysis' (AAA) module. To analyse the architectural parameters of existing avionics, the following main functions are slated for the AAA module:

- **Base Architecture Parameter (BAP)**: To analyse the design of the base parameters of avionics architectures, on which they need to be designed;
- **Existing Architectural Parameters (EAP):** To identify the existing architectural parameters on aircraft avionics; and
- **Parameter Integration (PI):** To integrate the design parameters, and identify the growth capability requirements of avionics architecture.

The BAP parameters are further studied to identify the functions in details, for holistic analysis of existing aircraft architectures. The detailed functions of BAP are as follows:

- **Architecture Design Analysis (ADA):** To analyse the avionics architectures on aircraft that are classified as centralised, federated, distributed, or modular architecture;
- **Avionics Packaging Analysis (APA):** To analyse the avionics physical design characteristics, by considering weight, dimension, interchangeability, maintenance, and power requirements;
- **Interface & Compatibility Analysis (ICA):** To analyse the design characteristics of the data bus, by considering bus standards used, protocols, security and safety, redundancy, and interfaces (connectors, loading, etc.); and
- **Avionics Software Analysis (ASA):** To analyse the avionics software by considering software platform, upgradability and security.

Having identified the required functions in detail, the system framework for AAA module is developed and is presented in Figure 3. The framework represents the sub-modules and the functional workflow of AAA module.

4 Results and Discussion

The system framework of AAA module identifies three main functions – (a) Base architecture parameter analysis; (b) Existing architectural parameter analysis; and (c) Parameter integration. The architecture parameter is further derived into four sub-functions to holistically analyse the existing avionics architecture. The output of the sub-module provides an avenue for the identification of baseline design requirements of ASA-UP.

5 Conclusion

System approach adopted for developing the framework for the design of AAA sub-module provides the avenue for a holistic analysis of the existing avionics architecture parameters. The sub-module analysis is on a multi-dimensional format that considers the architecture design, avionics packaging, interface and compatibility, and software that drive the aircraft avionics architecture.

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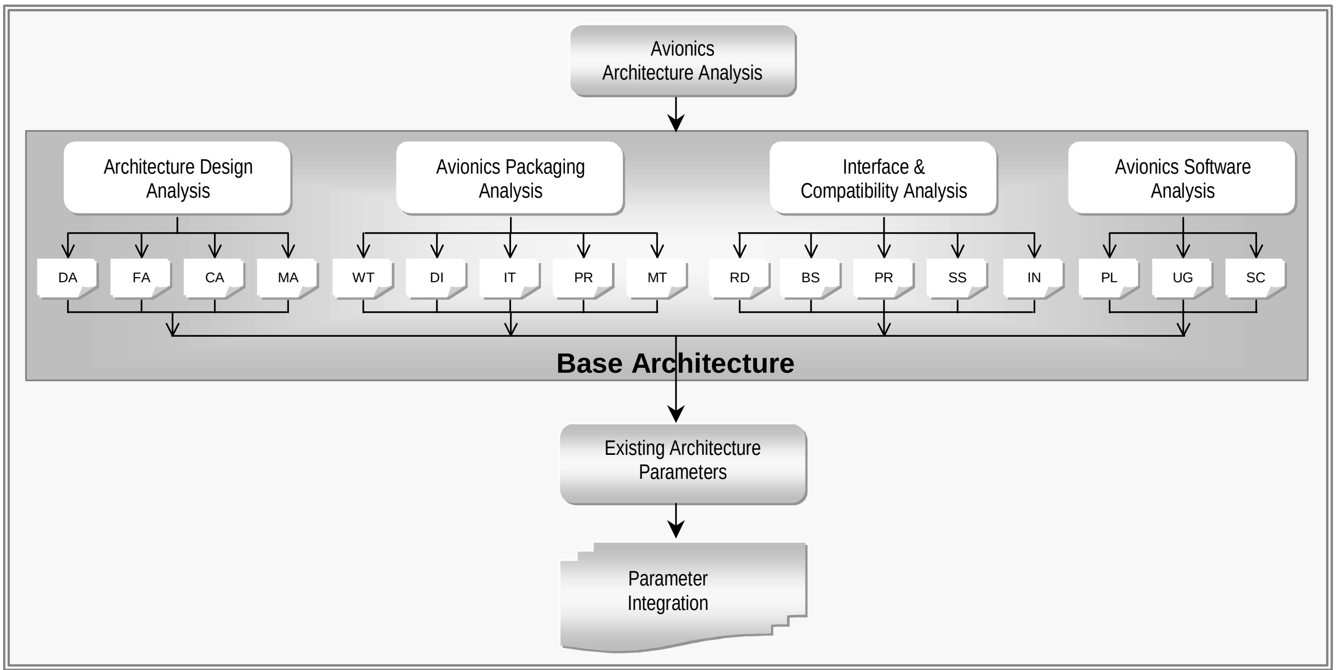

Legends:

BS	:	Bus standards	PL	:	Platform
CA	:	Centralised Architecture	PR	:	Power requirements
DA	:	Distributed Architecture	PR	:	Protocols
DI	:	Dimension	RD	:	Redundancy
FA	:	Federated Architecture	SC	:	Security
IN	:	Interfaces	SS	:	Security and safety
IT	:	Interchangeability	UG	:	Upgradability
MA	:	Modular Architecture	WT	:	Weight
MT	:	Maintenance			

Figure 3. Framework of an Avionics Architecture Analysis

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