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Simulation based Life Cycle Cost Modelling as a Decision Support Tool

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This paper summarizes the work that has been carried out as part of the FLAVIIR project, a 5 year research program looking at technologies for future unmanned air vehicles. This is a UK EPSRC funded project sponsored by BAE systems. A framework is presented in which a life cycle cost model can be integrated into the design process to facilitate the comparison between different configurations. The architecture to estimate the life cycle cost and the associated models are described. The acquisition costs are estimated using a hierarchical structure and a discrete simulation model is used to estimate the maintenance and operation costs. It is then demonstrated how the framework can be used to evaluate the cost penalty of different design concepts.

I. Introduction

In the past, technology has been the dominant driver in the design process, but there has always been a demand for cost reduction in the aircraft industry to satisfy the customer's needs. It is widely believed that typically 70% of the total avoidable cost is controllable at conceptual design phase [1]. Thus, there has been a realization by the aircraft producers that cost reduction needs to be tackled at this stage.

Life cycle cost (LCC) is increasingly being used when making procurement decisions or to assess the competitiveness of a product design. The LCC is concerned with the overall cost of a product from its conception up to, and including, its disposal. Asiedu and Gu [2] divide the total product cost or LCC into four distinctive phases: (1) research and development costs; (2) production and construction costs; (3) operations and maintenance costs; and (4) retirement and disposal costs. This is of interest when an estimate is to be used in a performance trade-off study of a process or activity [3]. Engineering costing within aircraft design should have a more directly influential role, for example as part of an integrated process that is embedded within a multidisciplinary systems modeling architecture. Differential product evaluation with regards to cost, technology, reliability and maintainability is important for a better product design. Because cost is not known in advance of production, a cost estimation system is required. Scanlan *et al* have identified the need for detailed and reliable cost information for the optimization of a product design [4]. The challenge is to look into all of the aspects of cost and to link these into the design decision making process at the conceptual stage. A design-oriented capability can be used to implement product changes that reduce cost.

II. Cost Engineering

Cost engineering can be described as the application of scientific and engineering principles and techniques to problems of cost estimation and cost control. An overview of the state of the art and future trends in the field of cost estimation is given by Layer [5]. A wide range of studies have been performed on the estimation of manufacturing costs. But, the efforts of most of these studies are concentrated on a particular aspect of manufacturing. Ben-Arieh estimates the manufacturing cost focusing on the costs for set-up, machining and raw material costs [6]. Similarly, Stockton elaborates the development of time estimating models for advanced composite manufacturing processes [7]. Studies have also been performed on estimating the manufacturing costs from design specifications. Rehman describes a method for modeling manufacturing costs throughout the design phase of a product's life-cycle, from conceptual to detail design [8]. A framework for estimating manufacturing cost from geometric design data is outlined by Wei [9] and a model designed to estimate process cost directly from the design specifications has been developed by Kulkarni [10].

Cost is an important attribute of any product and is a prime factor in the engineering design process. Dean is well known for promoting considerations for design to cost within NASA [11]. Curran et al present a typical generic model of a cost estimating tool which can be used within the design domain [1]. Bao *et al* demonstrate the use of process-based manufacturing and assembly cost models in a traditional performance focused multidisciplinary design and optimization (MDO) process [12]. Gantois *et al* also present a multilevel MDO process implemented through a hierarchical system with cost at the top level and apply the method to a civil aircraft wing to achieve a minimum cost design [13]. These multi-disciplinary design studies are performed by taking only the manufacturing costs into account. But, life-cycle cost models are needed when an estimate is to be used in a performance trade-off study of a process or activity.

Operational costs should also be included in a performance trade-off study of a product design. Simulation models can assist in accurate estimation of the operation and maintenance costs compared to analytical models, which can not provide

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