An Investigation into the Adoption of Automation in the Aerospace Manufacturing Industry

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Abstract. Thus far, the aerospace industry has floundered in the uptake of automation compared to the automotive and high volume electronics manufacturing industries. This may partially be attributed to the lifecycle of many aerospace products whose components typically begin production at low to medium volumes. This environment often limits the adoption of automation, as well as proving to be an uncertain environment in which to base large capital investments. Following increases in demand, low volume processes are often found unsuitable for higher volume production, with potential re-design activities prevented by costly product qualification processes. Thus, manufacturers are forced to enable low volume processes to cope with high volume production, without product redesign for automated manufacturing, whilst remaining commercially competitive. This paper aims to investigate a world leading aerospace electronics company, to recommend an implementation framework for automation in the reduction of build cost and increase in production volume devoid of product redesign activities.

Keywords. Design for Automation, Industrial Robots, Flexible Production, Aerospace

1. Introduction

The aerospace and defence manufacturing industry has proven to be a difficult environment for the integration of automation. The nature of the business is an environment that necessitates steady incremental development, which does not readily facilitate radical change or instant capitalisation of innovation. Further to this, the demands on product performance and quality are extremely stringent, with highly skilled human centric roles during manufacture and assembly prominent in most organisations.

Process automation appears to be a logical step forward in an industry typically plagued by high relative labour costs, large variation in product demand and relatively high value, long lead time products. However, despite the obvious benefits that automation technologies appear to offer, the aerospace and defence industry currently remains as one of the least automated industries [1]. This circumstance is made more perplexing by the close observational relationship between aerospace and the automotive industry, typically the most automation dense organisations, with automotive operating systems such as the Toyota production system forming the foundations of many aerospace organisational *modus operandi*.

This project was undertaken at Collins Aerospace, Plymouth, UK – as part of an ongoing site wide capacity uplift program including the investigation into productivity improving machinery and automation technologies. A series of investigations, cost modelling and validation studies were undertaken, involving discussions with various engineering departments, shop floor employees, stakeholders and potential suppliers. At the projects culmination, a clear strategy was defined that directed the formation of an improvement engineering team, dedicated to the pursuit of identified objectives that would enable the organization to improve its performance. During this project, many obstacles were identified surrounding business improvement efforts surrounding automation both technologically and culturally as an organisation. During discussions with senior members of multiple aerospace organisations, it has come to light that the problems faced by Collins Aerospace are not unique – highlighting the need for a ubiquitous improvement strategy for the use in industry.

2. Research Background

As highlighted by El Souri *et al*. [2] in their investigation into improving organization defect knowledge management, the limited amount of current research into the use of design for manufacturing (DFM) techniques as an enabler to emergent technologies has undoubtedly acted to decelerate their uptake and limit their application. Adopting automation into the production process of a product, where neither have been specifically designed to facilitate its use, is therefore extremely difficult. In addition, products designed for manual production and assembly can often, by the limits of technology, be almost impossible to automate in a meaningful manner. This may be due to the requirements of complex motion, product sensitivity to force and quite simply: the lack of common sense when presented with symmetrical parts, complex geometries or unintuitive design or fastening requirements such as mixed adhesives.

Studies attempting to utilise standard 'off-the-shelf' automation for parts or systems not specifically designed for automation show that while practical uses may be achieved, they often necessitate bespoke tooling for part handling and are limited to very specific applications. An example of this is the study conducted by Björnsson *et al.* [3], who successfully applied automation in the manufacture of aerospace composite products. Their findings echoed the difficulties faced when attempting to modify existing product design in order to facilitate automation, and instead chose to identify discrete elements of production processes which could be improved on a micro-scale. Amongst their findings, a high emphasis was placed on the design of automated solutions that were able to perform flexibly in order to achieve meaningful application as well as a foreseeable return on investment.

Flexibility as a key attribute for automation in aerospace applications is also echoed by Drouot *et al.* [4], whose work in the development of a reconfigurable production environment for high accuracy, complex assembly aerospace components highlighted the potential for evolvable assembly systems. The concept advocated the use of reconfigurable automated cells able to adapt to production demand. Advances in automation technology such as rapid tool exchange, vision systems, force feedback handling and safe personal mobility have only strengthened the ability for automation to be applied in this manner.

Aside from automation equipment, the subject of cost justification and modelling for automation investment proves to be an elusive topic in the aerospace context. In a literature review conducted by Salmi *et al.* [5], it is noted that many manufacturers have learned through failure that automation is not guaranteed to translate into increased performance. The research performed aimed to support the development of cost estimation techniques, targeting variable levels of automation and assembly requirements to enhance successful investment. This has highlighted the requirement for cost modelling tailored to the variable nature unique to the aerospace manufacturing industry.

Considering aspects and issues related to concurrent engineering, automation of manufacturing and assembly issues need to be taken into account at the beginning stages of product design and development, including Computer Aided Process Planning (CAPP), Assembly Automation and Design for X. Today, companies are driven towards emerging design and product development technologies, including *Collaborative Design* and *Mass-customisation* [6], Additive Manufacturing and Cloud Manufacturing, towards Industry 4.0. The roles of automation in both Design and Manufacture becomes increasingly more important.

2.1. Findings of the Industrial Investigation

Over the course of the investigation, it was found that several elements influenced the difficulty of adopting automation into the Collins Aerospace design and manufacturing environment. These elements have been condensed and summarised into four key points that aim to define the difficulty of adopting automation into the organisation, so that potential solutions may be developed.

- ***Insufficiently 'Broad' Manufacturing Process Knowledge:***

  Many aerospace products are highly specialised and are developed in scientific environments by product specialists. This often results in products which are manufactured utilising the traditional methods that the company has established as a core competence, such as the use of hand soldering in the manufacture of electronic components. This greatly limits manufacturing innovation, and typically ties the organisation to the capabilities of a small number of processes that may be unsuitable for large volume or flexible production.

- ***Limited Design for Manufacture and Assembly and Design for Automation:***

  As previously mentioned, the lifecycle of aerospace products typically begin with low to medium production volumes. This acts to limit initial investment in design for high volume production and manufacturing flexibility, as design work is often concentrated on the development of reliably functional products for small to medium volume. Further to this, a product that is designed initially for manufacture utilising manual assembly (a dominant method in the investigated organisation), inevitably will not necessarily be suitable for subsequent automated manufacturing.

- ***Engineering Processes Become the Manufacturing Processes:***

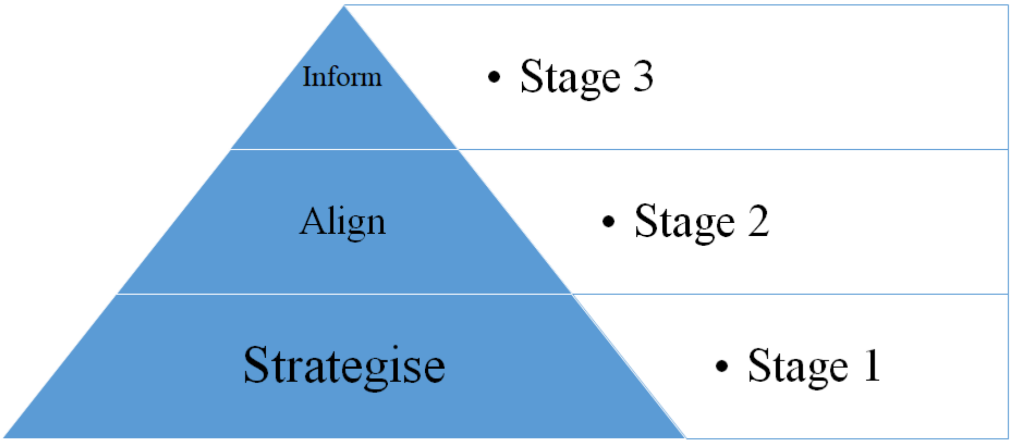
  With relatively low initial production volumes, as well as comparatively low design for manufacturability consideration when compared with automotive or mass production environments, it is often the case that the production methods considered during product development go on to become the product's actual manufacturing process. Though initially suitable in the beginning of the products lifecycle, it is found once production demands increase, the production processes are no longer suitable for higher volume production. This problem is typically solved with the up-scaling of production processes, whereby the initial process is simply made larger. Though this solution is often adequate to cope with larger product demand, it often leads to significant quality, labour and cost implications.

- ***The Barriers Preventing Redesign Activities:***

  As aforementioned, aerospace components often undergo rigorous product qualification trials due to the operating environment in which they are employed. These processes are often time consuming, expensive and require substantial investment of engineering labour hours. The option for later redesign then becomes almost an impossibility, as it is not cost effective to perform significant design changes and thus re-qualification trials often. Redesign is also often found to be resisted by the end user, who understandably does not wish to risk the failure of the product if a redesigned feature leads to an overlooked defect, potentially leading to product recall or catastrophic failure in use. Thus, the pressure for aerospace manufacturers to get the product right first time is extremely high.

3. Discussion and Conclusions

Based on the analysis of the investigation, it is proposed that a framework will be developed that enables aerospace manufacturers to make positive steps towards the adoption of automation. This is to include key factors such as designing for automation, relative product maturity and long term company strategy. Thus, an initial foundation in which to base an implementation framework is summarized and discussed below:



- *Stage 1 – 'Strategise'*: The initial stage of this framework will focus on the development of a long term organisational *automation strategy*. This will aim to identify the desired state the organisation wishes to achieve, and how this may be technologically realised. An essential objective of this stage is the identification of a *standard production sequence*, and the identification of *customisable and standard product elements*.

- *Stage 2 – 'Align'*: Once the organisational strategy has been developed, current deviants aim to be formally identified. This includes any aspect of the organisation / production process / product that does not adhere to the company long term strategy. Top level plans will then be identified to align the current state with the future state plan, with a mixture of short and long term projects.

- *Stage 3 – 'Inform'*: This stage aims to achieve continuing conformance to the long term strategy through the use of knowledge frameworks and organizational policy. With the aim of all future designs / projects / products automatically conforming to the future state plan.

Thus the above foundation model defines a theoretical concept to be pursued, that embodies the formulation of a long term organisational automation strategy. Each stage will require the development of a distinct set of tools, direction and definition of activities which will be developed by the author and will make use of current industrial tools where appropriate (eg: Lean Manufacturing, Cost Modelling, and Design for Manufacture). Therefore the fundamental aim will be to achieve a universal framework which may be applied by organisations wishing to implement automation in a structured and methodical manner to achieve long lasting benefits to productivity.

4. Summary

It can be observed that the complex nature of the aerospace manufacturing environment is a source of difficulty when attempting to design for, and integrate automation. Following the industrial investigation, the requirement for an organisational level framework has been identified. The sustainability of current automation frameworks aiming to employ flexible automation systems in the performance of discrete tasks without a greater organisation level strategy may be questioned as viable long term solutions, which in turn may cause greater levels of upheaval than benefit in this typically risk averse industry. It is proposed that a top level developmental strategy will aid manufacturers in performing a series of distinct activities which will align the organization with its desired future state, as well as ensure its lasting success. A prerequisite of this framework that has been recognised is that it must be able to be utilised at multiple points throughout existing product lifecycles, and must take into account factors such as product maturity, the type of available data, and the impetus for implementing automation. The proposed framework will aim to be developed and applied in practice, in order to evaluate its effectiveness, but also for the clarity of application so that it may be used universally as an implementation guide.

A primary aim of the industrial investigation conducted at Collins Aerospace Plymouth, was to achieve an in depth understanding of the nature, influencing factors and barriers faced by aerospace and defence manufacturers when attempting to initiate change and harness new technologies and innovative applications. The insight provided may stimulate research and technology developments that may aim to circumvent, alleviate or even eradicate these existing identified barriers as part of further research works in this context.

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