COST MANAGEMENT AND ACCOUNTING METHODS TO SUPPORT LEAN AEROSPACE ENTERPRISES

October 2003
"Cost mgmt is not confined to cost reduction, but covers enterprise-wide activities across different departments aimed at improving overall profitability performance. This involves target costing, capital investment planning, cost maintenance and cost improvement (kaizen costing)"

(Murman et al, 2003, p 103)
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Executive Summary

The ultimate aim of introducing lean principles and practices into the aerospace industry is to reduce total acquisition costs. This requires a cost management focus across product life-cycles and through the aerospace supply chain. In addition, lean manufacturing efforts need to be underpinned by appropriate product costing, operational control and continuous improvement methodologies.

This report, produced by the UK Lean Aerospace Initiative (UK LAI)\(^1\), illustrates how costing, accounting and measurement systems can be developed to support lean aerospace enterprises. The report describes a variety of tools and techniques that can be used during the New Product Introduction and Manufacturing phases. It also describes how some of these approaches can be extended to the supply chain in order to maximise cost reduction opportunities.

The report concludes that the greatest opportunities for cost reduction exist at the earliest stages of New Product Introduction and, therefore, a greater emphasis needs to be placed on techniques such as Target Costing and Life-cycle Costing in order to drive total cost reduction. It is vital that suppliers are engaged at the earliest possible stage in order that the competitive pressures are transmitted through the supply chain. This is particularly important in light of the increasing trend towards total care packages and risk/ revenue sharing partnering arrangements.

Although there is less opportunity to reduce costs at the Manufacturing stage, it is important that costing, accounting and measurement systems are aligned with lean thinking – complementing value stream organisation, supporting pull and flow production, and driving continuous improvement.

\(^1\) The UK Lean Aerospace Initiative (UK LAI) is a part of the SBAC Competitiveness Challenge (CC) which has set out to support member companies in meeting their improvement objectives. This is being delivered under programme management from the Society of British Aerospace Companies (SBAC) and supported by a leading University group consisting of Warwick, Bath, Cranfield and Nottingham. Funding for this programme has been provided by EPSRC and SBAC member companies.
The implementation of the recommendations contained in this report requires radical changes to the role of accountants and finance personnel within aerospace organisations, a review of the education and training requirements for management accountants and high level commitment from senior management and financial directors.
1. INTRODUCTION

1.1 Cost Management for the Lean Aerospace Enterprise

The UK Lean Aerospace Initiative (UK LAI) was established in 1998 to improve the competitiveness of the UK aerospace industry through the promotion of lean principles and practices. Adopting a lean approach promised significant improvements in productivity, quality and delivery, resulting ultimately in substantial cost savings. Although many aerospace companies have introduced lean working practices, there has been considerable difficulty in demonstrating the financial benefits derived from lean initiatives and correlating operational improvements to improved financial performance at the enterprise level. In addition, lean initiatives have often been undertaken without a rigorous consideration of the accounting and costing tools that are needed to ensure decisions are taken with the full financial consequences in mind. Aerospace companies have also expressed concerns that traditional costing and accounting methods may actually conflict with the objectives of lean initiatives. Moreover, to further increase competitiveness in the UK aerospace industry and reduce costs, the latest vision for the future of the UK aerospace industry calls for an increased emphasis on the application of lean practices, not just in the piecemeal way that it has often been applied to date, but in a more integrated manner that encompasses whole product life-cycles and value chains (AeIGT, 2003). It is clear, therefore, that it is now critically important for the industry to examine its management accounting and costing processes with a view to improving the way they support lean initiatives.

As a result, the UK Lean Aerospace Initiative has undertaken an in-depth study into appropriate costing and accounting methods for aerospace companies that are applying lean principles. This study investigates the value of existing research in this field and develops a research framework specific to the requirements of the aerospace industry. This framework emphasises the life-cycle and value stream perspectives that are becoming more important to the aerospace sector as total care packages begin to be more widely used. Numerous costing and accounting tools, techniques and approaches are examined and their compatibility with lean ideas is analysed. Their value at different phases of the life-cycle and at different levels of the value stream is discussed.

This report aims to encourage the use of costing and accounting techniques that support lean principles. The authors are very aware that the industry does not consist of one homogeneous type of enterprise. The needs of prime contractors have different emphases
from the needs of systems suppliers and small component providers. Moreover, the industry produces a variety of end-products ranging from small commercial aircraft and helicopters to defence related helicopters, fighter aircraft, “jumbo” passenger planes, space vehicles and major research programmes. We do try to take account of some of these differences in places in this report where recommendations are made on lean accounting for the aerospace industry. We conclude, however, that, despite this operational complexity, the basic lean accounting principles that we propose do have a wide degree of applicability throughout the industry provided that there is a due moderation of emphasis in different aerospace contexts. Nevertheless, although we do make clear distinctions between the needs of prime contractors and smaller systems and component providers, it is impossible in a report like this, to provide specific answers that will suit every aerospace company context. Hence, each company should use this report to focus on the issues that it, itself, should be addressing in order to align cost management and management accounting with lean strategies and operations. Each company needs to consider carefully how far the accounting tools and processes that we recommend are applicable in its own specific context.

1.2 Methodology

An extensive literature search has been undertaken in order to understand the appropriate cost management and accounting approaches that need to be adopted by aerospace companies that are implementing lean principles and practices. Initially, this report examines the introduction of lean practices to the aerospace industry over the past decade and identifies the main driver, that of total cost reduction. However, despite cost reduction objectives, there is limited existing research linking costing and management accounting advances to the requirements of lean enterprises. This report outlines the potential problems that traditional cost and management accounting methods may cause as companies continue to adopt lean practices. It also examines the developing “lean accounting” research that exists and highlights its limitations with regard to developing appropriate management accounting methods for lean aerospace enterprises. The report also identifies how existing research may be built upon to satisfy the needs of the aerospace industry. Throughout the report, extensive reference is made to tools and techniques promoted by the management accounting literature. In addition, the report draws heavily on the literature available relating to lean thinking, lean enterprise and value stream concepts, as well as supply chain management and operations management.
For the duration of this research programme, a collaborative research style has been adopted whereby industrial sponsors have been involved in an on-going manner with research developments. This was believed to be appropriate as there is limited research available in this field and, therefore, the learning process could be accelerated for all stakeholders through collaboration. In addition, it enables faster dissemination and implementation of research findings. A joint academic-industrial Working Group was established within the UK Lean Aerospace Initiative in order to guide the research direction, ensure relevance to the aerospace industry and enable industry characteristics and requirements to be incorporated. Representatives of fifteen aerospace companies have been involved in the Working Group to date. These companies have validated the research findings at each stage and have had the opportunity to provide feedback and input to finalise this report. In addition, the collaborative approach has included on-site semi-structured interviews, questionnaire surveys and case study material to support the research activity.

1.3 Structure of the Report

This report begins by outlining the origin of lean principles and practices in the aerospace sector. Section 2 presents an historical overview of how lean principles and practices have been introduced to the aerospace sector over the past decade. It also identifies the main driver associated with the transfer of lean ideas from the automotive sector to the aerospace sector – the prevention of continued cost escalation on aircraft programmes in the face of declining military budgets and falling passenger demand. The current aerospace climate further reinforces the need to gain additional benefits from lean initiatives in order to improve productivity and competitiveness. The United States, the European Union and the United Kingdom have all produced reports on the future of aerospace calling for improvements in quality, delivery and process excellence in addition to reductions in product lead times and total cost. However, despite expectations that lean initiatives would deliver significant financial and non-financial benefits, firms have had considerable difficulty in showing how operational improvements have led to improved financial performance. In addition, accounting literature over the last decade or so has suggested a range of ways to approach cost reduction, but no one method has proved to be universally dominant as a systematic way of supporting lean strategies.

UK Lean Aerospace Initiative member companies have also expressed concern regarding the appropriateness of traditional costing and accounting methods. It is believed that traditional costing and accounting methods may actually drive behaviours that conflict with
lean thinking. Section 3 describes some of the problems that may arise as a result of traditional costing and accounting methods. It analyses these approaches and outlines the research framework that has been adopted by the UK Lean Aerospace Initiative in order to suggest an aerospace-specific solution. This framework adopts both life-cycle and value stream perspectives.

Section 4 presents costing and accounting methods suitable for the New Product Introduction phase. Tools and techniques such as Target Costing and Life-cycle Costing are described and their compatibility with lean thinking are examined.

Sections 5 - 8 investigate the costing and accounting requirements for the Manufacturing stage. These sections analyse the requirements for product costing and overhead allocation, operational monitoring and control, and costing for continuous improvement in lean aerospace enterprises. Tools and techniques such as Activity-based Costing, Time-based Costing, Value Stream Costing, Throughput Accounting, Cost of Quality and Kaizen Costing are examined. In addition, the use of non-financial measures for operational control is discussed.

Section 9 examines the need for cost management to extend beyond individual firms to the entire value stream. Supply Chain and Inter-organisational Cost Management approaches are described, in addition to techniques such as Supply Chain Target Costing and Supply Chain Kaizen Costing.

Section 10 presents the conclusions of this report. The findings are summarised and recommendations are made regarding the steps that can be taken to implement cost management and accounting methods that align with lean thinking in aerospace companies.
2. LEAN IN AEROSPACE

2.1 The Changing Global Aerospace Environment

In the early 1990’s, the foundations of the global aerospace industry were rocked to the core by two major factors.

1. The end of the Cold War prompted drastic reductions in defence procurement budgets resulting in reduced military markets. The defence industry could no longer justify the cost-plus mentality that characterised the Cold War era and faced the challenge of seeking new markets (AW&ST, 1992; Interavia, 1999b).

2. Passenger demand fell suddenly following the Gulf War, forcing airlines to cancel or postpone civil aircraft orders. This followed a period where civil aircraft had been running at unprecedented high levels. The inability of the industry to respond to unexpected changes in demand was reflected by long lead times (AW&ST, 1999b).

These events signalled radical changes for the global aerospace industry. There was now over-capacity in the market and profits were declining (Cosentino, 1999). This was further compounded in Europe by unfavourable dollar exchange rates (AECMA, 1996). Global competition was on the increase as the major players were forced to seek business outside their traditional markets.

The situation faced by one of the major aero-engine manufacturers, Pratt & Whitney, highlights the challenges for the entire industry at that time (Womack and Jones, 1996). June 1991 was the peak month of production volume in Pratt & Whitney’s history. The company went from a profitable state to a loss-making situation in the space of a year. The end of the Cold War meant that its military engine business was uncertain. The boom in commercial engines was on a downward cycle and subsequently dropped to a low in 1993. Airlines were seeking low-cost rather than high-performance engines. The spares business also took a nosedive as airlines cut costs by repairing rather replacing parts.

2.2 The Lean Response

The US response to the new aerospace business environment was to transfer lean ideas from the automotive sector to the aerospace industry. The US Lean Aerospace Initiative (US LAI) was “born out of practicality and necessity as declining defence procurement budgets collided with military industrial over-capacity prompting a demand for ‘cheaper, faster, and
The US LAI was formally launched in 1993 when the US Air Force (USAF), Massachusetts Institute of Technology (MIT), major aerospace defence companies and the labour unions joined forces in an effort to revolutionise the industry. Organisations involved included Boeing, Raytheon, Lockheed Martin, the US Department of Defence, TRW (now Goodrich), Pratt & Whitney, Hughes and Aerojet. The aim of the US LAI is “to deliver military aerospace products at significantly reduced costs and cycle time while meeting or exceeding performance expectations and enhancing the effectiveness of [the US] workforce” (http://lean.mit.edu).

“Lean enterprise” became the new buzzword on the F-22 advanced tactical fighter programme where Lockheed Martin, Pratt & Whitney, Boeing and the USAF were working together to reduce costs and improve quality using lean production techniques following a US Department of Defence review (Flight International, 1993; Interavia, 1994). The USAF had high expectations of lean manufacturing. It believed that this approach would give the industry the best chance of surviving the budget challenges ahead and that the results in military aircraft production would be more dramatic than those seen in automotive. A 50% improvement in performance measures such as cost, cycle time and quality was expected as a result of introducing lean manufacturing (AW&ST, 1993).

By the mid-1990’s, a huge amount of rationalisation had taken place in the US aerospace industry. Surviving companies enjoyed healthy profit margins despite falling production rates and the US aerospace industry had been transformed into one of the most competitive aerospace industries in the world. It is believed that this transformation was in part due to the adoption of lean manufacturing techniques (Interavia, 1995).

In Europe, this revolutionary culture change was much slower (Interavia, 1994; 1995). In 1993, Airbus began to examine how it could develop a more flexible, efficient manufacturing system which would allow rapid changes in capacity requirements and significant lead time reduction while maintaining quality and on-time delivery (Flight International, 1999b). The UK, however, was remarkably quick to embrace lean manufacturing. The process of integrating the UK aerospace industry into British Aerospace (now BAE Systems) happened ahead of the rest of Europe, giving the UK an advantage. In addition, the influence of Honda in the Rover Group (owned by British Aerospace until 1994) was evident in changes made at specific British Aerospace sites, namely, Woodford, Warton and Samlesbury (Interavia, 1995; 1996). However, although some European companies had adopted competitive manufacturing methods, each country was pursuing its own approach. There was a call for a
shared European culture focused on productivity and cost-reduction and a sense of urgency regarding European aerospace industry restructuring (Interavia, 1996).

2.3 Increasingly Intense Global Competition

Competition continued to intensify in the mid-1990’s, with Boeing and Airbus fighting for dominance in new markets and military contracts becoming increasingly rare. Although the US aerospace industry was experiencing an increase in profits, companies were being warned that “cleaner inventories, shorter cycle times and downsizing [were] no substitute for integrated processes and design, lean manufacturing and assembly, and just-in-time delivery” (AW&ST, 1996a). The European Aerospace Association, AECMA, also acknowledged increased competition and the continuing drive for cost-reduction and increased efficiencies (AECMA, 1996). Industry actions recommended by AECMA included:

- **Efficiency Improvement to Achieve Cost and Lead-time Reductions**
  1. continue to reinforce activities for the development of lean organisations in engineering, production, customer support and administration
  2. continue to reorganise activities and procedures to reduce lead times and cycle times
  3. dedicate research and technology efforts to develop new engineering and manufacturing techniques aimed at the reduction of costs and lead times.

- **Improve the Operation of the Supply Chain**
  1. rationalise the supply chain, e.g. by packaging equipment orders into sub-system orders from single companies
  2. create long-term partnerships globally through technology sharing arrangements as well as risk sharing
  3. improve the involvement of SMEs in the supply chain”.

The European Commission also emphasised “sustaining growth and competitiveness against increasingly intense world competition” in its report *The European Aerospace Industry – Meeting the Global Challenge* (European Commission, 1997). This was further supported by a Key Action in the *Fifth Framework for Research, Technology and Development* entitled *New Perspectives for Aeronautics* which stressed the need for the “integration of technologies for new-generation aircraft in order to reduce design, production and operating costs” (European Commission, 1999).
In the UK, the share of the global aerospace market was declining and funding for aerospace R&D had been reduced at the time the Department of Trade and Industry launched the Foresight Technology Programme in 1995. This was taken on board by the UK aerospace industry in order to recover market share, improve competitiveness, remain a net exporting industry, develop cheaper, more efficient technologies and foster a world class industry (Marshall, 1999).

2.4 The Global Lean Aerospace Revolution

It was really the late-1990s before the impact of the US LAI began to be recognised and successes were promoted (AW&ST, 1997). The Lean Enterprise Model, developed at MIT, had been adapted by the USAF for the military aerospace manufacturing environment. Pilot programmes were also established with Hughes Missile Systems, Lockheed Martin, McDonnell Douglas and Northrop Grumman. Lockheed Martin reported reduced costs on the F-16 aircraft programme and cost savings of $4b on the F-22 programme due to the adoption of lean manufacturing techniques (Flight International, 1998; Interavia, 1999a).

According to Lockheed Martin Aeronautical Systems President, Tom Burbage, “the lean movement is the difference between success and failure, the difference between life and death to a company like this. And it’s not only something you need to do on the factory floor, it cuts across the entire enterprise” (AW&ST, 1999a). Boeing was also using lean techniques to combat declining margins and reduce costs, setting itself ambitious targets of improving quality by 50% per year, increasing productivity by 2% per month and reducing lead times by 90%. In the electronics sector, Rockwell Collins was setting itself similar targets – 35% improvement in productivity by 2000, 40-50% reduction in WIP, 40-50% reduction in product cycle times, 25% reduction in floor space and business growth in excess of 30% (AW&ST, 1998).

BAE Systems’ (formerly British Aerospace) Samlesbury site became the company’s flagship manufacturing site, believing that lean manufacturing was central to controlling costs on the Eurofighter programme. However, BAE Systems perceived the aerospace industry to be 10-15 years behind the automotive sector in implementing lean ideas (Flight International, 1998).

In April 1998, the Society of British Aerospace Companies (SBAC) launched the UK Lean Aerospace Initiative (UK LAI) as part of its Competitiveness Challenge agenda. This initiative was aimed at spreading lean practices throughout the UK aerospace industry in order to
improve competitiveness in the global aerospace market. The UK LAI is a partnership between industry, academia and the UK government and also has close links with the US LAI.

Lockheed Martin declared 1999 the “year of lean” (Interavia, 1999b) and the following excerpt shows just how strongly lean ideas had taken hold in the aerospace sector:

“The aerospace industry is in the grip of a revolution. Its name is “lean” and its guiding principle is the elimination of waste from the production cycle. The revolution is moving out of the prototyping shops and on to the assembly lines, with dramatic results – and none too soon. The automotive industry has been lean for years. In aerospace, avionics and engine manufacturers embraced lean thinking long before the airframe makers. Now airframers are moving fast to catch up. Their motivation is the promise of faster development, better quality and lower cost” (Flight International, 1999a). This lean revolution may be explained by the characteristics of the current aerospace industry environment:

“No longer driven by technology and performance criteria alone, aerospace companies worldwide are challenged by ever-spiralling investment costs, forcing them to gear research and development funds to win-win projects and markets, to drive up manufacturing efficiency to unprecedented levels and relentlessly pursue risk-sharing partners across the globe. If the financial squeeze does not halt technological progress by an industry increasingly shaped by highly cost-conscious civil and military markets, it will certainly steer it in more conservative directions. Equally, though, it will challenge companies to apply their creativity and innovation to generating higher levels of engineering efficiency, improving both performance and reliability” (Flight International, 2000a).

2.5 Facing the Future

The global aerospace industry has been badly affected by the terrorist attacks in the U.S. on 11 September 2001. This incident accelerated the cyclical downturn, causing a significant fall in passenger traffic and subsequently leading to aircraft order cancellations and a decline in demand. Both the U.S. and Europe have acknowledged that the aerospace industry is entering a critical phase. In the U.S., a Presidential Commission was set up to address the concerns of the aerospace industry and make recommendations for the future (AIA, 2000; US Presidential Commission, 2002). This was mirrored by the European STAR 21 report – Strategic Aerospace Review for the 21st Century (European Commission, 2002). The UK Department of Trade and Industry launched the Aerospace Innovation and Growth Team (AeIGT) during 2002 to agree a vision and strategy for the future of the industry, which is
second in size only to the US. The AeIGT report reinforces the commitment of UK aerospace companies to lean principles and practices in the drive to improve productivity and competitiveness (AeIGT, 2003). The AeIGT vision for 2022 calls for “world class productivity within key UK companies, derived from sustained process improvement programmes”.

3. COST MANAGEMENT AND ACCOUNTING FOR THE LEAN ENTERPRISE

3.1 Introduction

The adoption of lean principles and practices within the aerospace industry was initially heavily focused in the manufacturing area. As companies have become more proficient in carrying out lean activities in manufacturing, they have extended these ideas to other parts of their organisations and throughout their supply chains. It is now widely recognised within the aerospace community that an holistic, enterprise-wide view is critical to achieve the potentially significant total product cost savings (Murman et al, 2002; AelGT, 2003).

Despite the major drive for cost reduction within the aerospace sector, there have been difficulties in identifying how cost management and accounting practices can support the lean enterprise. There are many documented cases of successful lean activities across a variety of industries (Womack and Jones, 1996; Liker, 1998; Henderson and Larco, 1999). However, cost savings data usually relate to specific lean activities that cannot be scaled-up to enterprise level or correlated to bottom-line performance improvement (Primost, 2001; Cook and Graser, 2001; Ruffa and Peroziello, 2000).

UK Lean Aerospace Initiative (UK LAI) member companies are, however, concerned that traditional costing and accounting systems are not necessarily appropriate to support efforts to apply lean principles throughout the aerospace supply chain. Cost management and accounting systems need to reflect the lean business model that is being promoted in the aerospace industry.

This section describes briefly the problems associated with the continued use of traditional accounting systems in lean environments. Current thinking related to accounting for the lean enterprise is examined and the limitations associated with existing research in this area are highlighted. The section concludes by describing the research approach that has been adopted by the UK Lean Aerospace Initiative to investigate the most appropriate costing, accounting and financial methods to support and drive lean principles and practices in the aerospace industry.
3.2 Problems with Traditional Management Accounting

Kaplan (1988) highlights some of the limitations of traditional costing systems, stating that operating costs are reported too late and are too aggregated to benefit production supervisors. In addition, he argues that managers often have to use, for product mix and product closure decision purposes, product cost estimates that focus on the least important cost component – direct labour - and exclude specific product related expenses involved in designing, marketing, distributing and servicing goods. While his view has not been without challenge, Kaplan (1988) argues that cost systems have been designed primarily to satisfy the financial accounting requirements for inventory valuation, thus ignoring the information required to promote operating efficiencies and the measure product costs. Kaplan (1988) claims that in the situation where senior managers insist on one “official” system, the demands of the financial reporting function invariably win.

Cooper (1995) identifies the four most prominent causes of the misrepresentation of product costs calculated in traditional cost accounting systems. These are:

1. the failure to use direct costing where it is economically feasible
2. the failure to segregate overhead costs into unique cost pools, making it more difficult to associate overhead costs with specific products
3. the failure to apply appropriate cost allocation bases resulting in distorted product costs
4. the failure to penetrate beyond a gross margin analysis to include the costs of marketing, distribution and administration in product cost calculations.

Cooper also highlights the symptoms of an obsolete cost system:

- Difficult-to-produce products exhibit high profit margins even though they do not command a premium price
- Product margins cannot be easily explained
- Results of competitive bids are hard to explain

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2 One needs to be careful with this statement. Direct costing (where only all variable costs are treated as product costs and where fixed costs are treated as costs of the period irrespective of how many products are produced) does have benefits for some types of decision and analysis. But for other types of decision, focusing on just direct costs will lead to incorrect analyses. Moreover, following Kaplan’s insights on Activity Based Costing and, quite separate, developments in organising manufacturing on a cell basis (both addressed later in this report), it is often by no means clear that a division of all costs into just two types of cost behaviour (i.e. just variable or fixed) is either correct or serves all decision needs. Furthermore, one must beware calling for one single concept of accounting. Different classes of decisions need different cost information. We discuss this further in Sections 5-8.
• High volume products are apparently being priced by competitors at unrealistically low levels
• When a decision is made to outsource parts or components, which have been previously made in-house, and the suppliers' bids are considerably lower than expected
• When customers show little reaction to price increase or if competitors quickly match price increases
• When profit margins appear to be unrelated to the company's core competencies.

As a result, an unthinking use of traditional management accounting approaches is now seen as dangerous.

Supporting the arguments of Kaplan and Cooper, Maskell (1996) also summarises the problems with traditional management accounting as follows:

• Lack of relevance to manufacturing strategy, daily control of the business and product pricing decisions
• Cost distortions caused by an inaccurate understanding of cost patterns, by not distinguishing direct and indirect costs properly and by apportioning overheads incorrectly
• Inflexible, too late to be useful
• Incompatible with lean manufacturing approaches because capital projects are assessed incorrectly, the emphasis is on machine and labour efficiencies, large batch sizes are encouraged, managers are encouraged to continue with wasteful activities and obsolete systems are maintained
• Inappropriate links to the financial accounting system cause confusion and make cost and management accounting less useful.

3.3 Aligning Accounting with Lean Thinking

Much has been written about the problems associated with traditional management accounting and the need for change. However, the nature of these changes is the subject of continuing debate (Ahlstrom and Karlsson, 1996). The key question is "what kind of management accounting system would cause our [employees] to do the right (lean) thing?" (Womack and Jones, 1996).
3.3.1 A management accounting profile that supports manufacturing excellence

There is limited literature directly related to accounting for the lean enterprise (Ward, 2001) and a few case studies have enabled researchers to develop a profile of companies that successfully align accounting systems with lean principles (Jenson et al, 1996). This profile is outlined below and identifies both the characteristics of companies that align their accounting systems with lean thinking and some of the practices they engage in as a result.

1. Integrate the business and manufacturing cultures
   • Companies must demonstrate that they have achieved a world-class level of competitiveness within their manufacturing operations and have integrated quality management, waste reduction and productivity enhancement methods throughout the organisation.
   • Finance and accounting conducts itself in the same spirit as their manufacturing counterparts by decreasing their reporting cycle times; improving transaction processing accuracy; eliminating unnecessary transaction processing and financial reporting.
   • The accounting department is measured in Quality, Cost, Delivery (QCD) terms.

2. Recognise lean manufacturing and its effect on management accounting measurements
   • Methods used to measure the efficiency of productive capital utilisation should be re-evaluated in the light of cellular, continuous flow manufacturing.
   • Reduced cycle times diminish the justification for detailed in-process transactional tracking. In many cases, the processing of such data lags behind the physical flow of the product.
   • Backflushing is used whereby the resource consumption of a finished good is computed ex post facto using the Bill of Materials to relieve raw material inventory and standard conversion times to apply overhead to the product.
   • Recording in-process transactions can actually create perverse incentives leading to local optimisation. If a department can generate credit through transfers rather than customer shipments, it has the incentive to build excess inventory or build assemblies that are easier to build and generate credit faster.
   • The focus on efficiency measures is at the cell level. The only meaningful utilisation concern will be at each cell bottleneck.
   • Adhering to the pull production concept, excess time is used by cell employees to pursue continuous improvement activities rather than build excess inventory.
3. **Emphasise continuous accounting improvement**
   - The accounting department has the same continuous improvement mandate as production areas.
   - Finance personnel aim to continually reduce cycle times for reporting and month end closing.
   - Cause and effect analysis of credit memorandums and other transaction errors is conducted.
   - Partnering with outside firms is engaged in to reduce the complexity of transaction processing, reduce the volume of paper handling and the resulting transaction costs.
   - Mistake-proofing of accounting processes is pursued.
   - Measures such as response time are implemented to improve the performance of the accounting department in returning bid quotations to customers.

4. **Strive to eliminate accounting waste**
   - Companies strive to eliminate accounting activities that either promote dysfunctional behaviour within the organisation or fail to lead to higher quality products or more efficient production processes.
   - Accounting systems are streamlined to minimise potential coding errors, computer storage space and processing time.
   - Companies focus on reducing the time spent on immaterial adjustments or unnecessary precision of accounting estimates, especially if these cause major delays.
   - Expense accounting is simplified through automation and reducing paper document processing.
   - Invoices are consolidated and arrangements are made with vendors to reduce the volume of cheques which require processing.
   - Alternatives to paper handling are explored and procedures and controls are re-evaluated.
   - Unnecessary reports, controls and procedures are removed.
   - Up-to-date accounting methods are used.
   - There is a move away from historical analysis to the study of linkages between production processes and financial results. This provides more forward-looking information.
5. **Encourage a pro-active management accounting culture**

- Management accountants actively integrate business and manufacturing cultures by providing future-oriented support and decision-making information that is relevant in light of a lean manufacturing approach.
- Accountants provide an education role and have direct involvement with the shop floor. They know the core business and production processes, assist cells to develop measures and provide training in the use of data systems. They also raise the level of financial understanding within the organisation e.g. so that engineers can better understand the financial implications of design decisions.
- Innovative management accounting practices are most often driven by and run parallel to innovative manufacturing practice.

This profile provides a valuable insight into the type of management accounting changes that may be required in order to support a lean enterprise. It also identifies how lean tools and techniques can be applied within the finance and accounting area itself to promote continuous improvement. Also, as the profile is based on a series of case studies across a number of industries, it is evident that some companies are implementing these ideas in practice and that they are relevant to those companies adopting lean ideas. Moreover, this profile may motivate companies to improve their methods of costing and accounting to support lean principles and also examine ways of applying lean ideas in the finance area. It may, therefore, be very useful for Finance Directors and Chief Accountants who want a checklist to commence a review of their management accounting systems. Unfortunately, for our purposes in considering methods of costing and accounting to support lean aerospace enterprises, however, this profile has limitations. While making some specific proposals, Jenson et al’s many exhortations are often expressed in quite general terms. There is nothing wrong with what is advocated, but it does not, in our view, probe sufficiently the detailed cost information needed to support lean manufacturing operations. More importantly for satisfying our remit, it is crucial to consider cost management and accounting issues from a life-cycle perspective. The characteristics of the aerospace industry – huge investment requirements, long product development cycles and long product in-service lives – make this essential. The profile offered by Jenson et al emphasises accounting in the manufacturing stage and, therefore, does not include costing, accounting and financial issues for other stages of the life-cycle. In addition, its focus is internal. It does mention partnering for the purposes of outsourcing finance tasks, but does not include issues related to cost management throughout the supply chain. Both life-cycle and supply chain issues are
important elements that need to be addressed when examining cost management issues for the aerospace sector as well as a more detailed consideration of appropriate cost concepts for different types of decision that need to be made to support lean manufacturing.

3.3.2 A diagnostic questionnaire to evaluate progress towards Lean Accounting

Maskell (1996) recommends that the accounting systems should be systematically simplified as the company implements lean manufacturing techniques and ideas – “Eliminate everything in the accounting systems that is not value-added – which is almost everything”. To apply his thinking in practice, Maskell (1996) developed an Accounting Questionnaire that can be used as a diagnostic tool to identify changes a company may want to make to its accounting methods to support world-class manufacturing practices (see Appendices 1 & 2). This questionnaire is based on a capability maturity model and uses categories from traditional to world-class. The questionnaire seeks to identify where the company's current status in relation to accounting practices and highlight opportunities for improvement. The UK Lean Aerospace Initiative has undertaken a preliminary study of several companies in the aerospace industry using Maskell’s questionnaire as a means of assessing how far companies in the industry had moved in modernising its accounting systems (Crute et al, 2003).

The questionnaire proved to be a useful diagnostic tool to identify whether or not an organisation is moving away from traditional accounting practices towards world-class practices. However, this is done from an accounting perspective and does not, either explicitly or closely, relate changes in accounting practice to changes needed for lean operations. In addition, it is assumed that there is a linear progression through the traditional and intermediate categories of accounting development to arrive at world-class status. The research conducted by the UK Lean Aerospace Initiative shows that this is not necessarily the case with organisations displaying elements of traditional, intermediate and/or world-class simultaneously for specific accounting practices.

The most important finding from this preliminary research is that although respondents were in most cases aware of the direction their company wished to take regarding the implementation of lean operational practices, they were unclear about the direction that accounting practices should take to support lean ideas, especially given the differential needs of the aerospace industry.
3.3.3 *Lean accounting model*

Maskell (1998) sets the following world class targets for lean accounting (Maskell, 1998):

- 70% of accounting people located in operations
- 50% of accounting people’s time devoted to improvement
- budgets at a high level only, no detailed budgets
- control process through activity outputs
- no detailed cost collection of labour hours
- consistent balanced and focused performance measurement throughout the company
- all information widely and easily available to all
- use benchmarking and “lean perfection” to set targets
- establish product, assembly and part target costs from market view of value.

In order to achieve these targets, Maskell (1996, 1998) has developed a 4-Step Lean Accounting Maturity Model that suggests the changes that should be made to accounting systems as lean principles are adopted. Table 1 provides a summary version of this model. The full version can be found in Appendix 3.

### Table 1: Maskell’s 4-Step Lean Accounting Maturity Model

<table>
<thead>
<tr>
<th>Maturity Steps</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Low-hanging fruit</td>
<td>Maintains current accounting and control methods but eliminates obvious waste within the processes (e.g. reducing detailed labour reporting and variance reporting, reducing the number of cost centres, simplifying accounting processes)</td>
</tr>
<tr>
<td>2. Removing transactions</td>
<td>Eliminates much of the detailed shop-floor tracking as lead times reduce and WIP becomes immaterial; eliminates unnecessary cost and financial reporting</td>
</tr>
</tbody>
</table>

3 The UK LAI research in this area began prior to the publication of the more recent 2002 version of the questionnaire and, therefore, the 1996 version was used.
<table>
<thead>
<tr>
<th>3. Eliminating waste</th>
<th>Company operations no longer need to be in step with accounting periods; month ends are irrelevant to the sale of products, manufacture or distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Lean accounting</td>
<td>Move to minimal transactions – production completion or product shipment transactions are used to backflush all the relevant information through the control systems</td>
</tr>
</tbody>
</table>

In contrast to the Accounting Questionnaire, Maskell’s 4-Step Lean Accounting Maturity Model (1996, 1998) proposes the changes that can be made in accounting methods in parallel with lean changes that are being implemented in other areas of the organisation. As a result, it is a valuable tool for identifying when it may be appropriate to introduce changes to the costing, accounting and measurement systems. It also recommends what accounting changes should be made as lean practices become more embedded within the organisation. However, there is no guidance as to what specific accounting changes should be made to support each type of decision and it is still assumed that companies would move through the four steps in a linear fashion.

In a similar manner to the Jenson et al (1996) profile described above, Maskell’s model primarily focuses on manufacturing and the elimination of accounting wastes. This is a valuable starting point. Just as lean ideas have been heavily adopted initially in the manufacturing area, it is natural that costing and accounting methods to support lean manufacturing should be developed as a first step. However, within the aerospace industry, there is a drive to spread lean principles and practices beyond the manufacturing areas and across the entire enterprise. Therefore, costing, accounting and measurement systems must reflect the lean enterprise rather than focusing primarily on the manufacturing area. Also, an emphasis on the elimination of wasteful finance and accounting tasks is useful. It encourages cost reduction and value enhancement in an administrative area. In addition, it provides good training to finance personnel who will then be in a better position to support other areas in their efforts to implement lean practices, tools and techniques. However, a detailed audit of the information needs of individual companies may be required in order to identify what is value-added, non-value-added or waste in terms of finance and accounting tasks.
In addition, as Maskell’s ideas have evolved, he has referred to various different accounting approaches and techniques that should be used to support world-class and lean practices. He refers, either implicitly or explicitly, to activity-based costing and management, the theory of constraints and throughput accounting, target costing and value stream costing. However, his exhortations, like those of Jenson et al are general in nature. It is often unclear how these approaches are to be used and in what context they should be used. It also appears to be assumed that all these approaches are compatible both with lean ideas and also with each other. Maskell’s proposals are, however, developing on a continuing basis and his most recent ideas do centre more explicitly on the concept of costing and accounting methods to support lean value streams (Maskell and Baggaley, 2002). Value Stream Costing is now being more heavily emphasised than Activity-based Costing (ABC)4. This represents a valuable evolution of thinking in this area and will be addressed in more detail throughout this report.

In summary, Maskell (1996, 1998, 2002b) has developed a generic, theoretical model of Lean Accounting and has also provided a diagnostic tool for industry that has some value in initiating thinking despite the limitations we found. We fully acknowledge that thinking in this field is at a developmental stage and that there is no accepted consensus as to how to move forward. As a result, Maskell’s work is inevitably incomplete and still evolving. Although Maskell’s questionnaires and model complement the case study findings of Jenson et al (1996), there is not much evidence to date that his ideas are being adopted and implemented in practice – especially in aerospace companies. In addition, there are questions regarding the applicability of a generic model to all companies and all industries.

Despite these limitations, the combination of Maskell’s work and the profile developed by Jenson et al (1996) stand out amongst the very few accountants attempting to relate accounting directly to lean thinking. Their proposals provide one basis from which to investigate costing and accounting methods to support lean enterprises and helped us in developing our initial thinking about the needs of the aerospace industry. However, we felt that, while generally relevant, they provided an insufficiently focused basis for giving direct and specific advice to that industry.

4 Approaches such as Activity-based Costing and Value Stream Costing will be addressed in more detail in Section 6. Moreover, the principles of ABC are not necessarily redundant if Value Stream accounting is adopted.
3.4 Costing and Accounting for Lean Aerospace Enterprises

Organisations that adopt lean manufacturing principles view their operations in an holistic manner. For any specific product, a lean approach emphasises all the steps required to produce that product, from beginning to end. This sequence of events is known as the value stream, as value is added at the various stages. Womack and Jones (1996) define the value stream as “the set of all the specific actions required to bring a specific product through the three critical management tasks of any business: the problem-solving task running from concept through detailed design and engineering to production launch, the information management task running from order-taking through detailed scheduling to delivery, and the physical transformation task proceeding from raw materials to a finished product in the hands of the customer”.

Within the aerospace industry, programmes are viewed as core value streams and the most elemental units of aerospace business activity (Murman et al, 2002). Murman et al (2002) describe these value streams as being:

- a collection of activities that produce a particular product, system or service that is delivered to the customer and generates revenue
- encompassing the full range of life-cycle processes
- being accountable for cost, schedule and performance.

Murman et al (2002, p116) also state:

“Lean principles must be understood and implemented in the context of aerospace products for which the link between design, manufacturing and sustainment has far-reaching implications in terms of life-cycle affordability and delivery of best value to customers and other stakeholders”.

It is clear, therefore, that cost management and accounting methods that support lean principles in aerospace⁵ must also take a life-cycle approach into consideration. Furthermore, in the aerospace context, where a high proportion of costs reside in the supply chain, an extended value stream approach also needs to be considered. Consequently, the research that has been undertaken by the UK Lean Aerospace Initiative has examined the cost management and accounting issues in an holistic manner. The literature review has identified existing costing and management accounting approaches, tools and techniques

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⁵ And we would also add in many other industries too.
developed in recent decades and considered how appropriate they are for aerospace companies adopting lean principles. We took into account that different tools and techniques may be appropriate at different stages of the product life-cycle, through the extended value stream and for a variety of decision purposes. Figure 1 illustrates the research framework that has been adopted. Our research decided to address the cost management and accounting needs to support lean thinking in three separate dimensions: New Product Introduction, Manufacturing and the Extended Value Stream. In order to attempt some distinction between accounting needs for different types of decision within the Manufacturing dimension, the differential needs of product costing, ongoing operations monitoring and control and achieving continuous improvement are considered. The report highlights how we believe that the accounting tools and techniques developed in recent decades and listed under each main section and subsection in Figure 1 serve each of these separate purposes. As each section and subsection identified in Figure 1 is addressed, the general nature of the relevant tools and techniques to each section will be described before considering their relevance in an aerospace setting.

**Figure 1: Research framework**

<table>
<thead>
<tr>
<th>New Product Introduction</th>
<th>Manufacturing</th>
<th>Extended Value Stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life-cycle costing</td>
<td><strong>Product costing and overhead allocation</strong></td>
<td>Activity-based costing for internal supply chains</td>
</tr>
<tr>
<td>Target costing</td>
<td>• Activity-based costing (ABC)</td>
<td>Supply chain target costing</td>
</tr>
<tr>
<td></td>
<td>• Product costing in cellular environments</td>
<td>Supply chain kaizen costing</td>
</tr>
<tr>
<td></td>
<td>• Time-based costing</td>
<td>Total cost of ownership</td>
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<tr>
<td></td>
<td>• Value stream costing</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Operational control</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Non-financial performance measures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Value stream box scores</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Throughput accounting</td>
<td></td>
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<tr>
<td></td>
<td>• Backflushing</td>
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</tr>
<tr>
<td></td>
<td><strong>Costing for continuous improvement</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Benchmarking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Kaizen costing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• ABC and cost reduction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cost of waste and waste indices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cost of quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Inventory reduction</td>
<td></td>
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</tbody>
</table>

**LEAN ACCOUNTING APPLICABLE TO EACH PHASE AND DECISION TYPE**
3.5 Summary

There is considerable concern that traditional costing and accounting systems are not necessarily appropriate to support efforts to apply lean principles. This section referred to the problems that can result from the use of traditional costing and accounting systems. Full absorption costing can lead to distortions in product costs and measures such as labour productivity and machine utilisation can motivate behaviours that conflict with a lean philosophy.

While there have been many proposals for ways in which accounting could undertake analyses to support cost reduction or improve product costing, there has been little research that has attempted to relate this specifically to the requirements of lean enterprises. This section outlined the pioneering contributions made in this field by Maskell (1996, 1998, 2002) and Jenson et al (1996). Maskell (1996, 1998, 2002) provides a useful diagnostic tool that enables companies to identify the changes to costing and accounting systems that they might consider as they adopt lean principles and also proposes a Lean Accounting model that recommends the appropriate stage to make these changes. The case study work carried out by Jenson et al (1996), and the resulting profile of companies that are successful in creating management accounting systems that support manufacturing excellence, provides evidence that companies are attempting to adapt their costing and accounting systems to reflect the adoption of lean manufacturing.

With regard to the applicability of the Maskell and Jenson et al research approach to the aerospace industry, there are some limitations. The main conclusion from the UK Lean Aerospace Initiative survey is that although companies may know the direction they are taking with regard to the implementation of lean practices, they are unclear about the direction that accounting practices should take to support lean ideas.

That research also places a heavy emphasis on costing and accounting at the manufacturing stage and on the elimination of waste within the accounting function itself rather than specification of what is needed as output from accountants to enable operational managers to act in a lean manner. While that is a good basis to begin looking at making changes to the costing and systems, a broader perspective is required for the aerospace industry. The huge levels of investment required during the new product introduction phase combined with long lead times and long product lives indicates that a life-cycle approach is required for both programme and cost management. In addition, as over 70% of materials
are bought out at the prime contractor level (Cook and Graser, 2001; Murman et al, 2002),
cost management in the extended value stream is a vital element in the reduction of total
value stream costs.

This report will now look in detail at cost management and accounting for New Product
Introduction, Manufacturing and Extended Value Streams.
4. COST MANAGEMENT FOR LEAN NEW PRODUCT INTRODUCTION

4.1 Introduction

The aerospace industry is characterised by long development cycles and produces products and systems that can often be in service for more than 25 years. It is also estimated that up to 80% of total costs can be built in at the detailed design stage as illustrated in Figure 2 (Fabrycky, 1991).

**Figure 2: Life-cycle Costs**

![Life-cycle Costs](source: Fabrycky, 1991)

This view is supported by research conducted by the US Lean Aerospace Initiative (Murman et al, 2000, 2002). Murman et al (2000) draw on the experiences of many aerospace programmes that *indicate that the ability to influence the life-cycle costs of a product or system is greatest in its earliest stages, and rapidly diminishes as detailed design is executed*.

This is further reinforced by Murman et al (2002, p204-205):

*“Decisions made early in the program life-cycle have the greatest impact on eventual capability – cost, schedule and availability. Although the expenditure of resources in early program phases is small, this is the time when the greatest leverage exists. Decisions about the product architecture and the key design features made in the conceptual and preliminary*
design phases lock in two-thirds of the eventual cost of the product, even though these costs will not actually be incurred until the production phase”.

There is, therefore, an opportunity to reduce total costs significantly during the New Product Introduction stage (Yoshikawa et al, 1993).

The UK Lean Aerospace Initiative defines the New Product Introduction process in aerospace as “a number of key processes that are performed in sequences but with overlapping activities/ processes and integration, depending on the nature of the development strategy, including:

1. **Product life-cycle processes** – define and develop business and product strategy; select and plan product portfolios; define and develop requirements; carry out full concept design; carry out detail design; prototype and validate product (1st production article); enable transition to full-scale production
2. **Supporting processes** – programme management; capability/ technology acquisition; supply chain development and management” (Haque, 2001).

Lean approaches (or approaches compatible with lean) can be employed within New Product Introduction, aimed at reducing total costs over the life of a product, increasing quality and shortening product development cycle times. These include:

- Integrated Project Teams (IPTs)
- Concurrent engineering
- Set-based concurrent engineering
- Quality function deployment
- Use of advanced design technologies e.g. CATIA
- Design for manufacture
- Design for sustainability
- Design for best value life-cycle
- Design to cost⁶.

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⁶ Further information on lean tools and techniques for New Product Introduction can be found on the Lean Aerospace CD-ROM available from the Society of British Aerospace Companies (SBAC). Please contact UK LAI Administrator on 0207-2271026.
However, the use of these approaches may result in increased costs being incurred at the New Product Introduction stage in order to reduce costs at later stages of the life-cycle – the “pay now, save later” concept. For example, it has been estimated that the use of IPTs in the US military aircraft industry could add 10-20% to the initial design costs (Cook and Graser, 2001). Therefore, New Product Introduction costs cannot be looked at in isolation but must be viewed from a value stream point of view.

This section examines the two main costing and accounting approaches that can be used at the New Product Introduction stage, (1) Life-cycle Costing (also known as Whole Life Costing) and (2) Target Costing. These are valuable mechanisms for reducing whole life costs. Also addressed are methods for the control of costs within the New Product Introduction phase.

4.2 Life-cycle Costing (Whole Life Costing)

4.2.1 What is it?
Within the aerospace industry, it is recognised that it is no longer appropriate to purchase equipment based solely on procurement cost. There is an increased emphasis on total acquisition costs and life-cycle costing is a method that supports this thinking. Life-cycle costing is an active management tool used during the New Product Introduction phase which attempts to capture all the costs associated with a major capital asset, such as an aircraft, over its life-cycle, including research and development; production; operation, maintenance and support; and phase-out and disposal. It assigns expected costs to each separate phase of the life-cycle to arrive at total life-cycle costs for a new product or system. Where the life-cycle is long, the projected costs of different alternatives may be discounted to present values to make valid cost comparisons.

In effect, there should be two related Present Value models: one showing the customer’s perspective where all costs that the customer is expected to incur are set down by each phase of the life-cycle and discounted to a present value of all costs. This would incorporate any share of development costs the customer will bear, the capital good price, subsequent operating costs including the prices paid for spare parts, MRO (maintenance, repair and overhaul) and modifications during the in-service phase. From the aircraft assembler’s perspective, there will also be a Net Present Value model. This will include the present value of all costs through each life-cycle stage less the present value of all revenues expected to be generated from the sale of the capital goods (i.e. the aircraft) and also from the after-
market. For more recent contractual developments where assemblers are expected to provide services (e.g. passenger miles) on demand, rather than aircraft per se, the assembler’s Net Present Value model will incorporate all capital and operating costs and the revenue stream that it expects to generate from future sales of services.

Life-cycle costing, therefore, provides an understanding of the cost and revenue implications of equipment both before and after entry into service. It can be used to inform engineering decision-making and cost monitoring over the life of the product. Both the US Department of Defence and the UK Ministry of Defence emphasise affordability throughout the life-cycle. The UK Ministry of Defence defines Whole-life Costing as "the continuous process of forecasting, recording and managing costs throughout the life of an equipment with the specific aim of optimising its whole-life costs and military output" (UK MoD, 2002).

4.2.2 How is it done?
As discussed previously, the vast majority of costs related to a major capital good are committed by the end of the detailed design stage. However, this is the stage where there is the least knowledge about the operation of the product in-service and, therefore, there are significant challenges related to developing a life-cycle cost profile.

Future cost estimates require judgements concerning costs that may or may not be based on past experience. They can be derived from expert opinion, cost estimating relationships (commonly used in the construction and insurance industries) or known cost factors and data.

There are three methods of estimating life-cycle costs:
1. Parametric estimates – based on the relationships between costs and the factors that determine the costs e.g. weight, performance; involves statistical analysis
2. Comparative estimates – based on the historic behaviour of similar existing products, with adjustments made for differences
3. Detailed estimates – detailed costs are built up from the Bill of Materials and from production process information.

The three methods are appropriate at different stages of the New Product Introduction process, with parametric and comparative estimates being more appropriate at the planning and concept stage and detailed estimates being more appropriate at the detailed design stage as additional knowledge is built up about the product.
Cost data can be sourced from:

- existing databases;
- product planning data;
- supplier documentation and data;
- engineering test and field data; and
- financial and accounting data.

It is essential that those estimating costs for each stage of the life-cycle have a very clear idea of what are the relevant cost concepts to use at each stage. This will entail:

- A careful and separate assessment of (1) conceptual development and design costs, (2) the cost of manufacturing parts and assembling the capital asset, (3) the operating costs associated with that asset, including as a subset the revenues and costs associated with the after-sales market for this asset, and (4) disposal costs at the end of the product’s life.

- Avoidance of inaccurate cost predictions for the after-market production phase based on multiplying historic full product costs by expected units to be produced where those costs incorporate general overhead cost allocations based on direct labour or another similar volume measure. Where they are of significant magnitude, estimation of indirect costs (production overheads) should be based upon a consideration of the factors that drive increased overhead in manufacture using basic concepts derived from Activity-based costing (See Section 6 for a detailed explanation). In addition, direct labour should not necessarily be treated as a strictly variable cost.

- No overhead should be included in production overheads for development or design costs or other non-production stage costs as such costs will be included in the cost estimates for the relevant stage of the life cycle model.

- Direct and separate estimates should be made of maintenance and running costs and these should be assigned to their correct stage of the life cycle model and not included in product overhead in manufacturing the main capital asset. Estimating such costs may well be difficult where upgrades are expected at as yet unknown times in the product life cycle. There is, however, no alternative to making one or two alternate assumptions as to when these might occur and what approximate effect they may have on costs (both product change costs and running costs) at later stages of the life cycle.

- Estimates should also be made of selling, distribution, marketing and administration costs for each product / product group and assigned to their correct life cycle stage. For
life cycle costing, they should not be incorporated into product cost, as advocated by Activity-based Costing for product mix decision purposes as this might then lead to them being erroneously included in the incorrect time phase in the life-cycle model.

- No financing costs should be included in product overheads if the costs over the whole life cycle are made comparable using discounted cash flow (DCF) which takes account of the costs of finance in the DCF calculation.
- The cost predictions should not include any calculations for depreciation as calculated for the financial accounts. The full capital and revenue costs will already be captured in the life cycle calculations. Accounting depreciation is needed only to provide an annual allocation of the capital cost to the P&L Account in calculating annual profit.

### 4.2.3 Benefits

Life-cycle costing:

- Provides a method for managing costs and revenues over the life of a product.
- Informs decisions regarding the allocation of scarce resources.
- Enables the evaluation of alternatives, both inter-system comparisons (comparison between products from different suppliers) and intra-system comparisons (comparison between different design configurations of the same product).
- Provides additional information for capital investment decisions.
- Highlights the economic impact of design decisions.
- Enables understanding of product behaviour over the life-cycles (Life-cycle cost profiling).
- Identifies high cost contributors and, therefore, highlights opportunities for cost reduction.
- Forms the basis for sensitivity analysis, trade-off analysis and risk analysis.

### 4.2.4 Limitations

- Life-cycle cost analyses present major challenges with regard to data collection and consistency. Hence, they are inherently inaccurate. Information may need to be drawn from different sources and, therefore, contain inconsistencies or be in different formats. There may also be difficulties accessing data sources. In addition, the analysis only provides a snapshot of later costs and revenues from the after-market as seen at the outset of the project and many of these costs are likely to change as a consequence of events.
• Reliance on historic cost data from existing products may not provide a valid basis for predicting the cost behaviour of future products.

• Cost data may need to be adjusted to reflect improvements due to learning. However, as the aerospace industry is characterised by low production runs, it may be possible to be in a state of continuous learning. This is particularly true where modifications and changes to requirements are made during the product life cycle. A RAND Corporation study (Cook and Graser, 2001) supports this by suggesting that learning curves be renamed continuous improvement curves.

• If a traditional cost estimating approach (a detailed “bottom-up” approach) is followed, it could be argued that mistakes made at detailed level may be multiplied up in the totals. This essentially results from the inappropriate allocation of overheads to products and, consequently, inaccurate product costs being specified for the manufacturing stage. To avoid this, the cost estimators should have a very clear understanding of the correct cost concepts to use for life cycle analysis as listed above.

The principle limitation is, therefore, the difficulty in predicting costs and revenues of later stages of the life-cycle. But, if one is to choose between alternative designs on the basis of costs over the full life of the asset, estimates of future costs have to be made however difficult that may be. This should incorporate an expected rate of learning if continuing improvement is the norm. Also, magnitudes of likely error can be assigned to the more uncertain elements of cost and the expected (i.e. the mean of those distributions in a statistical sense) costs used in the cost estimations. The cost ranking of the options (or the decision whether to go ahead or not where there is no range of options) should then be examined to ensure that deviations of costs within their likely range would not radically alter the ranking (or go/no-go decision).

4.2.5 Compatibility with lean ideas

In the aerospace environment, where through-life support is becoming more important, life-cycle costing provides essential customer value. Life-cycle costing and the subsequent decision-making is driven by customer value. The life-cycle approach becomes an important tool for satisfying customer needs and making realistic investment decisions for the business. Consequently, life-cycle costing is broadly compatible with lean ideas. It takes an holistic approach, including all stages of the life-cycle from initial concept and design to phase-out and disposal. This coincides with the value stream view held by lean proponents. It is a multi-disciplinary exercise and incorporates data from a wide variety of stakeholders.
Life-cycle analysis, based on life-cycle cost data, can be used to identify opportunities for cost reduction and continuous improvement.

However, life-cycle analysis does not set out explicitly to reduce costs although this may ultimately be one of the outcomes. It sets out to estimate costs that will be incurred given the technology and the production and operating methods that will be used. In addition, it focuses heavily on cost estimation for all stages of the life-cycle, taking place at the design stage as it is assumed that the majority of costs can be influenced at this stage. This may discourage an on-going focus on cost reduction at the later stages. Also, there is a danger that life-cycle costs collected and/or estimated at the outset may not be updated as circumstances change over the life of the product. The life-cycle analysis may be compiled by engineering personnel and used for up-front decisions but not shared with others along the value stream. While many stakeholders provide data to produce the life-cycle cost analysis, they may not have access to the completed analysis to assist with their own process improvement and cost reduction exercises at the later stages of the life-cycle. There is an even higher probability that this will be the case when many different organisations are involved in the value stream over the product life-cycle.

Life-cycle costing stresses that capital acquisition costs should not be the sole guideline for procurement policy. Similarly it will stress, from the producer’s viewpoint, that the sale should be based on the comparison of total costs with total sales throughout the aircraft’s life and not just on the sale price of the aircraft and the initial cost of producing it. By incorporating the full costs and revenues of the asset over its lifespan, more reliable comparisons can be made between competing products or whether to go ahead or not with the project. Moreover, full life cycle costs enable choices to be made between capital outlay and running costs. Often increased capital costs can be accepted if that brings about lower operating costs later in the project. Without full life cycle costs, the lowest capital cost project may be preferred even though it will have a higher (discounted) life cycle cost.

As stated earlier, however, the decision to base capital asset choice decisions on full life cycle costs does not, in itself, provide a mechanism for cost reduction. The following technique to be described, namely target costing, does. Target costing can be directed only at providing a given product at a given market price, but, if coupled with life-cycle costing, it can be used to target a desired combination of capital cost and subsequent running costs. For a comprehensive cost analysis to support lean thinking at the new product introduction stage, one, therefore, needs a combination of both life-cycle costing and target costing.
4.3 Target Costing

4.3.1 What is it?
Japanese companies have long recognised that it is in the New Product Introduction stage that there is the greatest opportunity for reducing total product cost (Hiromoto, 1998). The aim is to design cost out and design value in at the earliest possible stage. The Japanese take a disciplined approach to cost reduction in the design stage, known as Target Costing. Target costing is viewed as the most important development to support the commitment to low-cost production (Sakurai and Scarborough, 1997). Target costing is a multi-disciplinary tool for reducing total costs. As such, it is not a management cost control tool in the traditional sense. It is applied at the planning and design stages of new products with the involvement of R&D, engineering, production, marketing and finance, with engineering being viewed as the key discipline. It is believed that target costing is more suitable in the multi-product, small-production-run firm than in the few-product, large-production-run firm (Monden and Hamada, 1991). This would imply that target costing is appropriate in the aerospace industry.

Yoshikawa et al (1993) define target costing as “the process established to set and support the attainment of cost levels, usually expressed as product costs, which will contribute effectively to the achievement of an organisation’s planned financial performance. The target cost itself can be viewed as the maximum allowable cost at a particular point in time, usually specified by reference to the successive stages in the product life cycle”.

Target costing involves:
1. First, planning a specific product that satisfies customers’ needs and establishing the target cost from the target profit and targeted sales price of the new product.
2. Once the target cost is set, realising that target cost by using successive stages of value engineering and a comparison of target costs with achieved costs (Monden and Hamada, 1991).

There are two forms of target costing (Yoshikawa et al, 1993; Monden and Hamada, 1991):
1. Genka kikaku - Cost reduction in the development and design phase or, for the purposes of this report, “target costing”
2. Genka kaizen - cost reduction in the manufacturing phase or, for the purposes of this report, “kaizen costing”.
In the West, however, it has become normal to speak of just *Genku kikaku* as target costing, with kaizen costing separate. Then target costing and kaizen costing, when linked together, constitute the total cost management system of Japanese companies. Total cost management in this context implies cost management in all phases of the product life-cycle (Yoshikawa et al, 1993). When we use the term target costing in this report, we shall mean just *Genku kikaku*.

This section of our report focuses on cost reduction in the development and design phase. Cost reduction in the manufacturing phase (kaizen costing) will be examined in more detail in Section 8. Target Costing can also be extended to the supply chain and this will be further discussed in Section 9.

### 4.3.2 How is it done?

Target costing is undertaken by working backwards from the market-driven target price. This target price is the price required for market success, regardless of whether or not that price is supported by current manufacturing practices. Cost reduction activities (both internally and throughout the supply chain) continue until the target cost is achieved or all parties realise it is not possible to achieve it and both market and product plans have to be radically amended. This is known as the Subtraction Method (Yoshikawa et al, 1993).

Cooper and Slagmulder (1997) identify the three steps involved:

1. Set the target selling price based on market conditions
2. Set the target profit margin
3. Set the allowable cost by subtracting the target profit margin from the target selling price.

Cooper and Slagmulder (1997) also propose a set of questions to enable companies to identify whether or not genuine target costing is being undertaken. These questions are:

1. Early in the design process, does the company identify the target cost of products by subtracting their desired profit margin from the expected selling price?
2. Does the company specifically design new products so that they can be manufactured at the target cost?
3. Are product-level target costs achieved most of the time?
4. Does the company decompose the target costs of its products to the component level and use the resulting component-level target costs as the basis for negotiation with suppliers?
Target costing is intrinsically linked to Value Engineering. Value engineering is a series of procedures that firms use to help design products so that they can be manufactured at their target costs (Cooper and Slagmulder, 1999). There are a number of stages to the value engineering process:

1. Zero look – this is undertaken at the concept stage and is aimed at introducing some form of functionality that did not previously exist.
2. First look – this is undertaken during the last half of the concept-proposal stage and throughout the planning stage. The aim here is to increase the value of the product by increasing its functionality or reducing its cost.
3. Second look – this is undertaken at the end of the planning stage and the beginning of the development and product preparation stage. The objective is to identify further opportunities to improve functionality.
4. Teardown – this involves an analysis of competitive products in terms of materials, parts, functionality, manufacturing methods, coatings etc. There are a number of different teardown methods some of which are aimed at reducing the direct manufacturing cost and others that are intended to reduce the investment required to produce products through increased productivity.

The key concept in value engineering is to recognise that the final output is not the product per se, but the services that the product delivers for its owner. These services will be reflected in the different attributes of the product (for example, maximum cruising speed, manoeuvrability, range, payload etc.). The focus of value engineering within a target costing approach is certainly to drive down cost at the design stage in order to meet the overall target cost, but it must do so without significantly affecting the desired attributes of the product. To do this it is useful to know how costs will change as each attribute is either down-graded or enhanced. Hence, there is a need to analyse costs by attribute (or product function). In other words, there is a need to capture and make available cost data that shows the cost variation that would be incurred if maximum cruising speed, as an example of just one attribute, is increased or lowered. So what has come to be called functional costing is needed to support target costing and value engineering.

Usually there is not a need, nor time, to recalculate all such functional costs afresh at every product modification and so, where possible, standing cost tables showing variations in costs for attribute variations can be maintained to facilitate this process. How new is this? It is obvious that engineers and designers have always made cost estimates when considering
design variations. The important questions for review by a company are (1) how systematic is the process of reviewing attribute and cost variations and are attributes ranked by importance and the lowest value/cost ratios worked on first and (2) how rigorously are these costs estimated? It is likely in our view that engineers and designers will have a better grasp of materials cost and, perhaps also, direct labour costs associated with attribute variations, but, perhaps, the accountant is also needed to ensure that production overhead variations are properly assessed using appropriate cost drivers.

4.3.3 Benefits
There are significant benefits associated with target costing.

• Target costing explicitly focuses on continuous improvement, cost reduction and waste elimination at a development stage where it can still be easily removed.
• It is clearly focused on customer value, using the target market price to set target costs
• It provides clear and common goals to all employees across an organisation and, as such, can be directly linked to corporate strategy
• It reduces risk by protecting profit margins
• It enhances competitiveness and may result in competitive advantage due to the combination of cost reduction and additional product functionality and value
• It encourages product and process innovation through the rigorous Value Engineering activity that supports it
• It requires a high level of collaboration between different functions within the organisation and supports the concept of Integrated Project Teams
• It is an holistic approach, can be extended across the life-cycle and is consistent with the concept of value streams
• It demonstrates that management accounting information, if properly designed itself, can be used to achieve strategic objectives
• It outperforms cost plus approaches to pricing because it provides an achievable market price as the key goal to be met and then provides a specified cost reduction target for everyone to work towards (internal and external).

4.3.4 Limitations of target costing and compatibility with lean ideas
Target costing as currently conceived and used appears to be highly compatible with the concept of lean operations. It is explicitly concerned with providing value to the customer. Value engineering is used to reduce total costs and the target price is set based on the expected market price. The approach also emphasises a managed continuous improvement and cost reduction process. In addition, a value stream and life-cycle viewpoint is promoted.
However, currently, target costing is primarily focused on the costs incurred by the manufacturer (planning & design, development, manufacturing, sales). The extension of target costing to include the in-service costs incurred by the customer (maintenance, operation, disposal) would reflect a truer life-cycle approach, although this could prove difficult (Yoshikawa et al, 1993).

Target costing is also a collaborative process. All parties must contribute their ideas on value engineering and it will usually be preferable to organise the value engineering in nests of professionals whose activities impact upon each other rather than in conventional functional patterns. But target costing must not, because of that, be seen to be in danger of “softness” through collaboration rather than a hard recognition of market realities. The motor industry uses target costing extensively through collaboration with suppliers, but the leading car assemblers are not known for being soft on suppliers and insist on tough supplier standards including stiff cost reduction targets year on year. Target costing is based on a clear recognition of what the market will bear and so if it is applied thoroughly none of the parties involved will be allowed lose sight of that.

While target costing promotes cost reduction to meet competitive prices, it is not strictly a fully comprehensive approach to lean operations. It does not set out to reduce waste to the maximum amount possible. As Womack and Jones (1996) argue that the most important task in specifying value for the customer, once the product is defined, is to determine a target cost based on the amount of resources and effort required to make a product of given specification and capabilities if all the currently visible muda (waste) was removed from the process. They claim, quite rightly, that this approach is different from the conventional approach to setting market-based target selling prices. They suggest that lean enterprises base the target cost on the waste-free cost of a product, once unnecessary steps are removed and value is made to flow and that, as a result, the lean enterprise has the following choices:

- reduce prices (another way to increase sales volume and utilise freed-up resources);
- add features or capabilities to the product (which should also increase sales);
- add services to the physical product to create additional value (and jobs);
- expand the distribution and service network (again increasing sales, although with a time lag);
- or take profits to underwrite new products (which will increase sales in the longer term).
It is interesting to speculate on why the Japanese, the most ardent promoters of lean operations in recent years, did not endorse this notion of removing all possible waste at the new product introduction stage, when they do in the later operations stage through *kaizen* costing. It is probably because it is difficult to envisage how this approach could be implemented fully in practice. Before a product is developed there will be multiple ideas on ways for constructing it. Apart from the conceptual difficulty in defining exactly what waste-free is at the early stages of design, it would be practically impossible to identify all possible forms of waste in all methods before they have been implemented. The nature of such an optimal calculation would be immense. Hence, the Japanese developed target costing to focus on what would be best in the market, not what would be theoretically totally waste-free. It is only when that product comes into production that the search begins to make its manufacturing and operating process totally waste free. In any case, Womack and Jones offer no guidance with regard to how to identify the waste-free cost of a product that is yet to be designed or developed.

Cooper and Slagmulder (1997) also address the idea of waste-free target costs and their approach appears to be more practical. Theirs is essentially a hybrid, two-stage approach that combines Japanese target costing and the waste-free ideas like those of Womack and Jones. Cooper and Slagmulder suggest that market-oriented target costing is undertaken first and then, second, these target costs can be compared to waste-free costs, thus enabling companies to see how much waste they are currently accepting. They also distinguish between two types of waste-free costs:

1. Unavoidable waste-free cost – this is the cost of both value-added and non-value-added costs. Non-value added costs are those that cannot be avoided in the short-term.
2. Perfect waste-free cost – this is the cost of value-added activities only and excludes the costs of both waste and non-value added activities.

Cooper and Slagmulder (1997) argue that the unavoidable waste-free cost is the most aggressive short-term cost reduction goal possible but that the perfect waste-free cost is a lean enterprise’s ultimate long-term goal. Perfect waste-free costs will in almost all cases be below the allowable target cost. It is not expected that perfect waste-free costs can be achieved, but a perfection objective is created for everyone to strive towards. The unavoidable waste-free costs can be either above or below the allowable target cost, but usually it will be below the allowable target cost. This indicates that the company still has avoidable waste in its processes. If the unavoidable waste-free cost is higher than the allowable cost, the company may face a structural cost barrier that causes its costs to be
higher than its competitors. The calculation of waste-free costs can enable a long-term cost reduction path to be mapped out, see Figure 3 below.

It may also be possible to facilitate this continuing waste removal in new product development over consecutive models of the generic product by incorporating a costing element into value stream mapping activities at the manufacturing stage to enable the calculation of waste-free costs. These costs could then be used as part of the target costing process for future product improvements and modifications.⁷

**Figure 3: Cost-Reduction Path**

![Cost-Reduction Path Diagram]

*Source: Cooper and Slagmulder (1997), p 115*

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⁷ Similar arguments about product improvement for a generic class of products based on experience curves was also addressed in C. Tomkins, *Corporate Resource Allocation – financial, strategic and organizational a perspectives*, Blackwell, 1991, (p.130-1).
4.3.5 Applicability of target costing to the aerospace industry

One of the main limitations with the use of target costing in the aerospace sector appears to be the difficulty in establishing a market-driven target price.

Military programmes are heavily influenced by politics, public accountability and operational capability requirements. Traditionally, military contracts were negotiated on a cost-plus basis, where the market orientation is ignored and target costs are built up from historic cost data and knowledge related to existing technology. More recently, a hybrid approach has been followed involving negotiation between customer and supplier to establish the target price and the target cost. The UK Ministry of Defence uses Target Cost Incentive Fee contracts “where the risks are too great to enable fixed prices to be negotiated but not so great as to justify the use of cost-plus contracts” (DEFCON Guide No. 5, 1979). However, the US Department of Defence policy of Cost as an Independent Variable (CAIV) is viewed as the closest to the Japanese target costing model (Cook and Graser, 2001). CAIV requires trade-offs in defence systems in order to meet target prices.

In the commercial aircraft sector, aircraft are rarely sold at list prices but deeply discounted in the expectation that losses incurred at this stage will be recouped at a later stage through aftermarket activities. But that does not invalidate target costing. The producer must still be able to drive new product costs down in the design and development stages to below the sum of the discounted selling price and the net present value of the future expected profits on after-market sales. The calculation of the maximum target price may involve more uncertainty, but the need to use target costing is still clear unless the company wishes to sail along in the dark with little idea of what profits it can expect. Moreover, the move to “power-by-the-hour”-type contracts and total care packages should make the target costing approach incorporating a full life-cycle assessment of costs more appropriate as the producer must have knowledge of the future operating costs that it will now incur if it is to operate profitably.

Target costing may not appear to be so relevant where a customer provides quite a precise product specification or details the inputs to be used as sometimes occurs, for example, in the construction industry. The scope for value engineering is then limited and the commercial decision focuses upon whether the firm can produce that precise specification at
the desired cost. There are several points to be borne in mind before accepting such a dismissal of target costing. Certainly some firms may find themselves exactly in this position, but it is rare in project-based industries where technology is developing to find that there is no debate at all between suppliers and their customers over specification and cost variations. Certainly in the aerospace industry there is a move away from providing detailed product specifications. For example, the UK Ministry of Defence emphasises its capability requirements and it is up to suppliers to suggest appropriate solutions. It is likely that there is nearly always some scope for target costing, even if only related to parts or system components of the final product. Moreover, the growth of integrated supply chain arrangements makes this even more likely. This will be further discussed in Section 9.

In addition, it may well be that there is not time to undertake a very comprehensive target costing analysis of the whole product involving a questioning of all component parts and systems on-line during the development of one product (or a major modification thereof). However, this does not render the thinking behind target costing irrelevant. In such a situation, a component manufacturer, say, still needs to look ahead in its product planning if it is to remain competitive over the longer run (i.e. over the whole generic family of product development as described above.) It will need to consider possible and likely development paths of different technology streams and how that will affect its products. In so doing, this is no different, in general principle, from Toyota commencing its target costing analysis from a model of its business markets, considering future possible selling prices, product mix and what profit margins it could expect from different car models in that mix. This leads to a target cost for each model and the starting point for estimating the production cost with existing methods and the necessary degree of value engineering that will be needed to achieve the required reduction in that cost. It would seem that a component/systems manufacturer in the aerospace industry, for example, would be well advised to take a similar approach to guide its own research and development activities. This implies that the product attributes that new technical developments might deliver must be assessed together with their costs. This may all be undertaken off-line further back in the life-cycle at a more basic development stage, rather than on-line in specific product modifications, but the same functional accounting as defined above should underlie it. That should then lead to a continued array of well-evaluated component parts and systems coming on-stream for use in products where the evaluation is in terms of value and cost perspective and not just from a

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8 “Power-by-the-hour” contracts are now being used by aero-engine manufacturers and include not only the provision of the engine but also the spare parts and service required to guarantee power as required within agreed time limits.
technical perspective. It would be of value to ascertain how far such value and cost aspects of attribute specification currently drive basic development in the aerospace sector at present.

To conclude on target costing we strongly recommend that all parts of the aerospace industry review how they use or might use the principles of that technique. But, to plan new product introductions most efficiently in the aircraft industry, target costing must be coupled with functional costing and life-cycle costing. As stated at the outset of this report, we are continually aware that there are quite different segments of the industry, but we feel that all segments can use target cost approaches with due modification to suit different contexts.

For major new aircraft or space vehicles, the projected life cycle will be long and this is often an argument used to say that target cost approaches developed in the motor industry are not applicable in aerospace. We disagree with this argument. The initial development of a new airframe may contemplate a life of 20, or even 40, years with all the uncertainties that that entails, and it is certainly impossible to foresee what technological developments might occur in that time frame to invalidate decisions made at the outset of the project. However, in practice the time-horizon is not likely to be so far ahead. It will be more practical to look just as far ahead as the next likely phase of product enhancement in estimating costs while building the airframe in such a way to facilitate flexibility for future product enhancement. Flexibility for future development must become one of the attributes within the functional costing approach. It will be difficult to put a value on this flexibility, but if the engineers/designers can specify what the desired degree of flexibility entails it should be possible to cost it. At least then the need to make clear policy decisions on these matters will be highlighted. Furthermore, a proper focus will be placed upon managing costs down for the first model within the longer-term generic development of this vehicle. In short, even for apparent one-off large airframe type projects, there is scope for combining target costing with a limited application of life-cycle costing. If this is done, there is also scope, after arriving at a particular design and its target cost, for analysing where non-value added activities are included within these estimates and trying to push down costs further. If time and the need to set stage-gates beyond which methods are no longer reviewed limits immediate application, such learning about waste can be carried forward to the next generation of model in the generic development. We also point out that this is not so unique a situation as some would argue. While it may be exceptional, the Volkswagen car was recently dropped after 65 years of operation. Its final version was obviously different from its initial design, but it did still have some (limited maybe) aspects of the original model. Other models of cars may not have so
long a generic life, but do also exhibit a life of 20 years or so with a sequence of model developments. So, if the car industry has adopted and benefited from a target costing approach, despite initial appearances, it does not seem to be so different from the aerospace industry.

It also needs to be borne in mind that the industry also makes light planes for commercial use. While there will be the world of difference in complexity in producing such aircraft compared to major “jumbos” or spacecraft, this seems to establish that, at least for part of the aerospace industry, the automotive industry approach to target costing could probably be employed with little modification.

We also argue that major systems manufacturers should adopt the same principle. Indeed, it ought to be easier to apply at this level than for the major airframe projects. Major systems providers will be incorporated into a major asset assembler’s value engineering given the large proportion of bought in costs. Major systems providers might also chose to be proactive in developing their own systems of target costing (i.e. off-line from specific major projects) in the expectation of the technology developments. If they do not, they risk being left behind by improving technology and ceasing to become preferred suppliers.

Finally, for firms in the industry producing at the component level or even operating at the materials supplier level, the value of target costing may not appear to be as marked. But if the value engineering for the total assembled product is to be comprehensive, all parts of that assembled product should be subject to review in the target costing process. Even if this is not done, as for major systems suppliers, it may well be in the interests of the component manufacturer or materials producer itself to undertake target costing exercises relating to just its own products. This will enable them to maintain a continual technological development programme for its products, especially where these products are fairly complex and are expected to have several years life as part of the main assembled asset. It is probably only where technology has become stable over a long period and the product has become “commoditised” that target costing becomes irrelevant. It is doubted that this applies for much of the aerospace industry.
4.4 Controlling Costs of the New Product Introduction Phase Itself

Life-cycle Costing and Target Costing are aimed at reducing total product life-cycle costs by focusing on cost reduction opportunities at the earliest possible stages of New Product Introduction. However, it is also important to control the costs of the activities involved in the New Product Introduction itself and the adoption of lean ideas may make this task more difficult. Lean tools and techniques, such as target costing with its enhanced design, value engineering and functional costing activity, applied to New Product Introduction often increase the costs at the early stages of the product life-cycle in order to reduce costs at the later stages – the “pay now, save later” concept.

There are, nevertheless, a number of ways that New Product Introduction costs can be controlled:

- **Managing value engineering** – The degree of Value Engineering required to support a target costing approach will impact on New Product Introduction costs. It is probably this that led the Japanese to be satisfied with meeting a target cost that the market will bear rather than a fully optimal, totally waste free cost. So, to keep value engineering costs under control, it should be managed as a series of priorities needed to meet target cost, not universally applied to all elements of the project. This is achieved by the development of cost tables to reduce cost estimation time in each project and the use of functional costing to focus upon where, within the project, cost and customer value are out of line with each other. This doesn't invalidate the ongoing development, off-line, of specific investigations to further cost reductions in future generations of the product as Cooper and Slagmulder propose.

- **Cost analysis of the design and development process** – An activity-based or cost of quality approach (described more fully in Sections 6 and 8) may also be useful for the control of design and development costs during New Product Introduction. An analysis of the costs of the various processes required, the associated cost drivers and matters that were not right first time may highlight cost reduction opportunities within the New Product Introduction process itself. This would be quite a novel form of analysis for accounting and one suspects that there might be resistance from designers at attempts to standardise their activities. Only research could establish whether this were feasible for aerospace design.
4.5 Summary

It is widely recognised that there are significant opportunities to reduce total product costs during the New Product Introduction phase, as up to 80% of costs may be committed by the end of the detailed design stage. This section has outlined two methods – life-cycle costing and target costing – that can be applied with the aim of reducing product costs throughout the life-cycle. Although the two approaches have a different underlying philosophy, they are both compatible with each other and complementary to lean ideas. Both target costing and life-cycle costing can have a whole-life and value stream focus, can reduce total product costs and are useful management tools. Target costing explicitly focuses on providing value to the customer through a process of continuous improvement in design, innovation and cost reduction. Life-cycle costing aims to identify cost behaviours over the life-cycle of a product and this analysis may then be used to identify cost reduction opportunities.

As argued above, both approaches are useful tools for the aerospace sector. Aerospace product life-cycles are extremely long and it is important that in-service support and disposal issues are considered in the early stages. Target costing models are used to some extent within the aerospace environment, although the approach is a variation on the Japanese method as it may not be possible to identify a true market-derived target price.

The move to total care packages, prime contracting and "power-by-the-hour"-type contracts increases the need for target costing and life-cycle costing approaches. The ideal approach would be a combination of the two methods – an extension of target costing to all life-cycle phases. This would enable the aerospace industry proactively to protect and enhance profitability throughout the value stream and across the life-cycle. While it is difficult to establish target costs for all life-cycle phases, particularly in the aerospace sector where life-cycles are extremely long, the notion of a major project as a series of model developments each with its own target costing and life cycle stage reduces the weight of that argument in resisting the move to more comprehensive target costing.

The forecasting and prediction of costs, the changing nature of customer requirements over time and the impact of technological advances will remain significant issues for the use of such techniques as life-cycle costing and target costing within the aerospace industry, but, in our view these issues must be addressed and taken into account in new product development by the lean aerospace organisation. These are insufficient reasons to undertake design and development in a non-lean manner disregarding the fact that the vast
majority of costs are committed when the design is fixed. An aerospace organisation is not 
lean, or will not remain lean, if it leaves cost reduction to be obtained only at the 
manufacturing stage. The tools for achieving significant cost reduction at the design and 
development stage are now available and we feel that the ones that we have described go a 
long way to meeting those requirements, although we always like to add the caveat that 
each firm must examine its own specific context in order to match its own cost review system 
to its unique circumstances and activities.

The use of life-cycle costing and target costing raises a number of issues for the role of 
accounting personnel. These methods view engineering as being the core discipline with 
other parts of the organisation providing input and feedback. Life-cycle costing is more than 
an accounting summation of costs over the life-cycle. It has a much wider focus, examining 
cost behaviour patterns and identifying opportunities for technical improvements, as well as 
trade-offs between equipment performance and cost. While accounting data can inform the 
life-cycle costing process, it is just one of many data sources. Target costing also takes into 
account the views of a wide range of stakeholders, with value engineering being the means 
of delivering process improvements and cost reduction. Engineering & Design personnel 
may not necessarily include accountants and financial personnel in the process at all. 
However, while engineers may have a good grasp of direct costs, it is important to capitalise 
on the value that good accountants can bring to the process e.g. a broad appreciation of 
overhead cost behaviours and cost drivers, and their quantitative, financial and analytical 
skills. In addition, functional costing upon which target costing depends, will almost certainly 
need the close collaboration of engineers and accountants if the figures are to be 
meaningful. UK LAI member companies recognise that the links between engineers and 
financial personnel need to be strengthened in order to support target costing and life-cycle 
costing.
5. COSTING AND ACCOUNTING FOR LEAN MANUFACTURING

5.1 Introduction

The majority of costs in the aerospace industry are incurred in the manufacturing phase\(^9\). Although most of the cost is committed in the New Product Introduction phase and the ability to influence costs in the manufacturing phase can be limited as a result, a lot of effort is still expended controlling production costs, valuing inventory and determining product costs.

The introduction of lean manufacturing practices in the aerospace industry is expected not only to improve operational performance, but to enhance financial performance. However, despite significant operational improvements, many companies fail to experience corresponding financial improvements. As a result, those adopting a lean approach are challenging the validity of traditional costing and accounting methods. Standard cost systems are blamed for driving behaviours that conflict with lean ideas. It is claimed that:

- The building of large batches is encouraged in order to keep machines and employees fully utilised for overhead absorption purposes
- Information is not available early enough to support continuous improvement at cell/value stream level
- The benefits of lean manufacturing (higher quality, shorter lead times, increased capacity) fail to be captured (Lean Enterprise Institute, 2003).

There is, however, no clear consensus as to what constitutes appropriate costing and accounting methods for lean manufacturers. This section examines the financial implications of lean manufacturing and highlights the need for a new accounting approach to support lean manufacturing.

5.2 The Financial Implications of Lean Manufacturing

The aerospace industry, particularly in the US and the UK, has been promoting and adopting lean manufacturing methods over the past ten years. However, as just stated, there are difficulties linking the impact of lean manufacturing practices to improved financial performance. Most of the evidence supporting a positive correlation between the adoption of

\(^9\) Refer to Figure 2, Section 4
lean manufacturing techniques and improved financial performance is anecdotal or illustrated by case studies (Womack and Jones, 1996; Liker, 1998; Henderson and Larco, 1999). Quantitative data showing improved performance tends to be related to non-financial measures such as cycle times, lead times, right first time, on-time deliveries and inventory levels. In addition, the data usually relates to a small part of the organisation, e.g. a production cell, and the impact may not be of sufficient magnitude to show up in financial statements relating to the total organisation. Cook and Graser (2001) warn against the dangers of scaling up savings estimates from small improvement activities to the entire production process. They suggest that because it is much more difficult to extend lean practices across the entire production process than to apply in an individual production cell, it is impossible to assess the savings from lean manufacturing at enterprise level by looking at initial, suggestive results. However, they do believe that lean manufacturing has the potential to reduce the cost of aircraft production.

It is valuable to examine the findings of research that has investigated the links between Just-in-Time (JIT) and improved financial performance. JIT is a major element of lean thinking as it is a technique for establishing customer pull and reducing inventory levels. There is much debate regarding the financial implications of JIT (Yoshikawa et al, 1993; Pandya and Boyd, 1995; Inman and Mehra, 1993; Balakrishnan et al, 1996). A JIT approach has been shown to improve operational performance and the benefits can be demonstrated by changes in the following measures (Inman and Mehra, 1993):

- Downtime reduction
- Inventory reduction
- Workspace reduction
- Increased quality
- Increased labour utilisation
- Increased equipment utilisation
- Increased inventory turns.

It has proved more difficult, however, to establish a link between improved operational performance and improved financial performance at an enterprise level (Balakrishnan et al, 1996; Inman and Mehra, 1993). This may be due to the fact that financial performance at enterprise level is affected by other factors such as business cycles, economic trends, mergers and acquisitions and union agreements (Inman and Mehra, 1993). Nevertheless, JIT should have a financial impact by increasing Return on Investment, Return on Assets.
and profitability (Inman and Mehra, 1993; Balakrishnan et al, 1996). As Yoshikawa et al (1993) say, adopting JIT is financially attractive when a manufacturing facility can be organised so that a customer order can trigger the initial acquisition of necessary resources and they can be converted fast enough to be delivered on-time to the customer. The ability to operate successfully with minimum inventory levels is contingent upon having a reliable and stable supply chain, delivering products of high quality in short time-scales. Consequently, the following costs and risks can be avoided:

- Risk of damaging stocks
- Risk of stocks becoming obsolete
- Opportunity cost of tying funds up in stocks
- Cost of storing and moving stocks
- Risk of holding losses (where supply prices are falling).

Balakrishnan et al (1996) provide a way of resolving the paradox of improved efficiency not showing up in improved profits. They suggest that there are both benefits and costs associated with adopting JIT. They have used the change in Return on Assets (ROA) to evaluate the effect of JIT on financial performance and highlight four ways by which JIT adoption should increase ROA:

1. JIT production commonly leads to increased manufacturing flexibility, higher product quality and lower manufacturing lead times. These factors increase a firm’s competitive advantage in its product market, which favourably affects gross profit and thus ROA.
2. Lower inventory levels facilitate the identification and elimination of non-value-added activities, with corresponding reductions in Cost of Sales and increases in ROA.
3. JIT production frees up both capital and physical assets thereby decreasing the asset base and improving ROA.
4. Assuming historically increasing prices, liquidation of LIFO inventory layers increases ROA by decreasing Cost of Sales and the asset base.

They suggest, however, that these benefits can be offset by the costs associated with adopting JIT:

1. A switch to JIT production entails substantial training and implementation costs which increase overhead, reduce profit and thus lower ROA.
2. Capital expenditures associated with JIT adoption increase the asset base and the associated depreciation depresses short-term profit, both reducing ROA.
3. Reducing raw material inventory levels increases a firm's dependence on the stability of its supply chain and could result in lost sales and/or higher costs from emergency purchases.

4. In the short-term, reducing inventory levels affects profits and ROA through the mechanics of the absorption costing accounting system. Specifically, any prior-period fixed overhead included in the opening stock valuation will be expensed in the current period income statements. This may or may not reduce ROA depending on the relative decline in profits to the reduced asset base when inventory is removed.

Hence, in the short term the introduction of JIT may tend to decrease profits and the benefits will only be seen on the bottom line after inventories and costs have stabilised at the new lower level and the firm has reorganised itself to operate with lower stocks without losing sales.

In their efforts to link JIT to increased financial performance, these research investigations have relied on the validity of the financial accounting method by which profit is measured, especially in the light of point 4 above. They implicitly question the effectiveness of JIT without questioning the appropriateness of the financial accounting methods used to quantify JIT benefits. Yoshikawa et al, (1993) take this type of argument further. They say that traditional management accounting systems also do not support the JIT concept. The type of variance analysis used in Standard Costing is geared towards local optimisation, rather than optimising the whole manufacturing process. This motivates employees to build up inventories that are not required by customers in order to avoid apparently unfavourable performance as measured by local cost variances such as labour efficiency and volume variances. In addition, as JIT is based on the pull of final demand, if problems occur at an early stage in production, unfavourable efficiency and volume variances will be produced for all subsequent work areas. These work areas will not be responsible for the problems and so should not be held accountable. This last point may not cause people later in the production chain to react adversely against JIT, but it will encourage general dissatisfaction and distrust with the current management accounting system and demonstrates that management accounting controls need a rethink in a new JIT or even wider lean environment.

It seems clear that the methods used currently for measuring performance through costing variance analyses and profits by financial accounting practices represent major challenges in both identifying the financial impact of lean activities and offering performance measures in financial terms that are consistent with the drive to be lean in the aerospace industry. There
is now a drive to adopt costing and accounting methods that support lean manufacturing principles.

### 5.3 The Need for a Different Accounting Approach to Support Lean Manufacturing

Accounting is an integral part of the planning and control system of any manufacturing operation and must remain so. Nevertheless, as indicated above, both financial and management accounting systems can prove to be a major impediment to desired changes in manufacturing (Ahlstrom & Karlsson, 1996). Difficulties are likely to arise because traditional management accounting systems were designed for different environments than those faced by companies today (Turney and Anderson, 1989). Ahlstrom & Karlsson (1996), and Maskell and Baggaley (2002) are a few amongst many who have suggested that the adoption of lean principles and practices requires changes in the accounting systems. It is even claimed that efforts to transform traditional manufacturing organisations will result in failure if accounting systems do not keep pace with the manufacturing systems (deFilippo, 1996). Maskell and Baggaley (2002) argue that the financial benefits of lean manufacturing are often not visible despite significant operational improvement because financial and cost accounting systems are designed to match the costs with the revenue produced from sales. However, there is no provision for showing the financial effects of reduced production lead time, improved quality, on-time delivery and other operational improvements.

Womack and Jones (1996) ask the question “what kind of management accounting system would cause our product team leaders to always do the right (lean) thing?” They seem to assume that financial personnel within individual organisations will be capable, and willing, to come up with the answer to this question. Moore and Scheinkopf (1998) believe that Womack and Jones have understated the difficulties involved in changing traditional financial and costing ideas. While there is recognition of the need for change both in industry and academia, there is no real consensus as to how accounting practices should be adapted or developed to support and drive lean manufacturing. Contextual factors also need to be taken into account as different industries and different levels of the supply chain may require a different approach.

Kaplan (1988) states that management accounting serves three purposes:

1. Inventory valuation for financial reporting
2. Product costing
3. Operational control.

He claims that although the use of standard costing is suitable for inventory valuation purposes, it is not appropriate for performance measurement and product costing. For financial accounting purposes, periodic production costs must be allocated to all items produced. Inventory valuation systems under a full absorption approach divide all costs—labour, materials and manufacturing overhead—between items sold and those still in stock. Financial accounting principles do not require that assigned overhead costs be causally related to the demands of individual products, so many companies continue to use direct labour to allocate overhead, even though direct labour may account for a small proportion of total manufacturing costs. In addition, businesses can use a plant-wide overhead rate for allocating overhead to products, regardless of the diversity of their production processes. Therefore, a company’s overhead allocation scheme may not correspond to the underlying production process or to the demands individual products make on the enterprise’s resources. As long as the split of costs between products sold and products in stock is fairly accurate, the needs of financial reports will have been met.

For purposes of this report, we differ a little from Kaplan’s three-way classification of the purposes of accounting. In this report we feel that it is essential to split his first category into two parts by recognising that financial accounting reports themselves serve two purposes: external reporting to the stock-market, shareholders and other external interested parties and internal financial reporting to measure profit performance of the whole enterprise and its main parts. Following arguments already given, it is not, in our view, necessarily sufficient to argue that traditional absorption methods of valuing inventory are satisfactory for internal profit reporting. At least alternatives need to be considered. We will deal with this by focusing on Kaplan’s other two purposes of accounting: product costing and operational control methods, but, when we deal with operational control, we must also address possible changes in internal financial accounting practices in so far as profit and loss accounts are used to measure performance within the company. We have already seen how the allocation of some of this period’s costs to closing inventory in financial accounting may indicate that JIT reduces rather than increases profits in the short run. That may dissuade those that do not fully understand the financial accounting system from implementing JIT.

10 In the longer run they may not be seen as appropriate for external reporting either, but the financial accounting requirements for inventory valuation are well prescribed for external reporting and will not be examined here.
The following three sections (Sections 6 – 8) examine the requirements for product costing and operational monitoring and control in a lean aerospace environment. In addition, costing methods to support continuous improvement efforts are discussed.
6. PRODUCT COSTING & OVERHEAD COST ALLOCATION FOR LEAN MANUFACTURING

6.1 Introduction

We have already stated in this report that a major criticism of traditional standard cost systems in manufacturing companies is that they are designed primarily to value inventory rather than to measure product costs accurately. Kaplan (1988) states that a good product cost system should produce product cost estimates that incorporate expenses incurred in relation to that product across the organisation’s entire value chain. Consequently, a product’s cost includes not only the cost of factory resources to convert raw materials and purchased components to a finished item but also the cost of resources to establish the distribution channel, make the sale, service the product and supply support services. However, he claims that standard product costs usually bear no relation to the total resources consumed by a product. This is due to the fact that overheads are allocated, often on the basis of direct labour hours, and as a result can cause distortions to product costs. As overheads do not need to be causally related to the demands of individual products to satisfy financial accounting requirements, many companies continue to use direct labour as the basis for allocating overheads even though it may account for less than 10% of total manufacturing costs.

The allocation of overhead on the basis of direct labour sends the following messages (Turney and Anderson, 1989):

- Direct labour is expensive and should be removed from the product
- Product design is costless
- Unique components cost the same as common components
- Low-volume speciality products cost the same as high-volume products
- Options and accessories may be offered with little impact on cost.

A study of the US military aircraft industry estimates that overhead rates at the prime level can represent up to 35% of the recurring flyaway cost of the total value stream of costs of the aircraft (Cook and Graser, 2001). This study also claims that overhead costs are 150-250% of the cost of a direct labour hour. Kaplan (1988) and Maskell (1996) also argue that the distortion of product costs, as a result of the inappropriate allocation of overheads, can lead managers to choose a losing competitive strategy by de-emphasising and over-pricing
products that are highly profitable and by expanding commitments to complex, unprofitable lines. In fact, Kaplan has demonstrated that this does occur in several well-known case studies and that this accounting flaw is not just a matter of technical accounting detail, but can have major strategic importance in terms of planning product mix (Kaplan and Atkinson, 1998).

If it is accepted that conventional product costing often does not provide a true understanding of product costs and that the allocation of overhead on the basis of direct labour results in dysfunctional behaviours, then what form of product costing is needed to support lean manufacturing? The concepts of Activity-based Costing, Time-based Costing and Value Stream Costing will now be examined. First, we shall briefly describe each and consider their applicability in a lean environment and, second, consider their applicability to the aerospace industry.

6.2 Activity-based Costing (ABC)

Activity-based Costing developed as a direct response to the problems that could arise as a result of the allocation of overhead on the basis of direct labour. It’s main objective is to provide improved product cost information, using appropriate cost drivers as the basis for overhead allocation (Cooper and Kaplan, 1988, 1991, 1992).

Activity-based costing is based on two premises (Yoshikawa et al, 1993):
1. Activities consume resources
2. Products consume activities.

The activities conducted by an organisation cause that organisation to have a certain mix of financial, physical and human resources in place. Wherever possible, costs are traced to their sources, i.e. the activities that generate the need for the resources. For each activity there is a cost driver that generates the volume of activity and hence cost. For example, procurement costs for a product within current manufacture may be driven by the number of procurement orders placed and so the procurement costs per order placed will be estimated and the product allocated procurement costs equal to that times the number of procurement orders it generates. Another example, might relate to production set-up costs and the product will be allocated a share of set-up costs based upon the number of set-ups it generates. The point to note is that ABC attempts to identify how the product in question actually causes different types of costs to be incurred, rather than it being assumed that all
these overheads can be lumped together and allocated on a labour hour or other simplistic volume basis. ABC advocates a much more refined analysis of overhead costs and recognition of what causes each type. If one wants to have a true understanding of a product’s cost, ABC is a more theoretically valid than traditional volume based allocation methods. The key question in practice is how far one needs to go towards theoretical validity and how far one can be adopt a more pragmatic, but less costly, accounting approach.

Cooper and Kaplan (1992) outline the implementation steps required for Activity-based Costing:
1. Identify activities needed to support the product
2. Determine the cost of activities
3. Identify cost drivers for each activity
   - Stage 1: first assign overheads to a cost centre
   - Stage 2: then assign the costs to products based on a causal driver
4. Determine the annual capacity for each activity
5. Calculate each activity’s overhead rate.

Table 2 below shows Cooper’s hierarchy: the recommended method for assigning activity-based costs (Cooper, 1990). He says that ABC cost assignments can be organised by recognising that there are four categories of overheads – (1) those incurred as more units are produced, (2) those incurred a more batches are produced, (3) those incurred because more products are produced and (4) those associated with general facilities. Only the last category should be allocated on a broad basis. Costs for the first three categories should all be assigned by reference to appropriate cost drivers.

**Table 2: Cooper’s Activity-based Costing Hierarchy**

<table>
<thead>
<tr>
<th>Activity levels</th>
<th>Cost assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit-level activities</td>
<td>Assign using appropriate drivers</td>
</tr>
<tr>
<td>Batch-level activities</td>
<td>Assign using appropriate drivers</td>
</tr>
<tr>
<td>Product-level activities</td>
<td>Assign using appropriate drivers</td>
</tr>
<tr>
<td>Facility-level activities</td>
<td>Period expense/ allocation</td>
</tr>
</tbody>
</table>
The use of Activity-based Costing provides a number of benefits (Sakurai and Scarborough, 1997; Yoshikawa et al, 1993; Thrun, 2003):

- It is a sophisticated method of allocation using cost drivers. It indicates why the costs were incurred and, therefore, links costs to their causes.
- Overhead allocations are improved and direct charge overhead to product lines is possible. This makes it an effective tool for cost reduction activities.
- As costs can be linked to their causes, individual accountability is promoted.
- It enables value-added analysis.
- It enables improved product mix decisions to be made.
- It is a useful analysis tool where products have to share resources.
- It provides a means of examining overhead expenses in detail. They can subsequently be monitored and controlled.

Although activity-based costing is viewed as an improvement on the conventional overhead allocation basis, there are still limitations associated with this approach (Dhavale, 1996; Thrun, 2003):

- Activity-based costing models are only a representation of reality and do not reflect true causality. Therefore, true product costs can never be known.
- It is too complex for day-to-day use and not easy to understand
- The implementation of an activity-based costing system can result in increased data collection and additional paperwork. A bureaucratic system could work against waste elimination efforts.
- It may encourage management of the numbers rather than the business e.g. a cost driver activity may be reduced without any streamlining of the operation.
- While ABC may produce the most accurate product standard costs, there is no direct relationship between standard cost accuracy and operating profit improvement.

Activity-based costing may, however, be compatible with lean manufacturing in certain respects. It provides a greater understanding of what drives product costs and is, therefore, valuable in showing which products are really most profitable and gives more insight into the most desirable product mix. One of Cooper’s case studies shows how, before changing its costing system, a company was putting much more emphasis on selling product lines that were not so profitable than others that were very profitable (Cooper, 1986). This is clearly a waste of effort and not a lean way of operating the marketing and sales department. In
Addition to product costing, Activity-based Costing logic can be applied in many other ways, including:

- The assessment of customer profitability
- The comparison of distribution channel profitability
- The measurement of product attribute costs (which is of value in functional costing)
- The re-design of business processes through the identification of value-added and non-value-added activities
- The identification and prioritisation of cost reduction opportunities.

The extension of Activity-based Costing ideas to areas other than product costing is often referred to as Activity-based Management and research evidence exists that those companies that have adopted ABC tend to use it on an ad hoc basis for these wider management purposes and do not change their detailed everyday costing systems to an ABC basis. Even for product mix decisions there is no need to do so as such decisions are not made so frequently in most businesses.

However, Activity-based Costing is not necessarily compatible with lean. Activity-based Costing can be applied in any organisation, regardless of whether or not lean manufacturing principles are applied. Costs are assigned based on activities and the consumption of resources by products. However, there is no pre-requisite that activities and resources are structured by product value stream. Some advocates of lean manufacturing do not accept that Activity-based Costing provides the solution to the problems caused by standard costing, believing that "in reality it's just another method of allocating overhead" (Womack and Jones, 1996, p136). A key element of lean thinking is the drive to eliminate waste. Activity-based costing may actually introduce waste, or non-value activity, into an organisation. There are significant implementation difficulties and an increased requirement for data collection and paperwork (Dhavale, 1996; Plenert, 1999). In addition, existing research has found that companies involved in world-class improvement programmes did not tend to implement Activity-based Costing in a serious and systematic way and were unlikely to do so in the future (Jazayeri and Hopper, 1999). However, although a full-blown Activity-based Costing system may not be appropriate in a lean environment, there is evidence that aerospace companies and other industries are using Activity-based Costing/Activity-based Management logic to inform decision-making and to prioritise cost reduction opportunities (Crute et al, 2003; Ward, 2001; Jenson et al, 1996).
6.3 Product Costing in a Cellular Environment

Lean manufacturing facilities usually reject the traditional functional organisation structure, choosing instead to adopt a cellular structure that supports the value stream concept. Cellular manufacturing (or continuous flow layout) is where a manufacturing facility is organised into production cells. Each cell incorporates all the resources required to produce a specific product type/product family or a number of cells are organised in sequence to produce a specific product type/product family. Where possible, support services are also located within the cell, e.g. engineers are co-located within production cells to support the operators within that cell. In practice, cells may need to share resources and often support functions need to work across cells and value streams, especially in smaller companies.

A cellular manufacturing structure provides a clear factory layout, creates visibility of Work-in-Progress inventories and makes the sources of waste more obvious. In addition, the adoption of a cellular approach can free up floor space that can be used to generate value-creating activities.

The adoption of a cellular manufacturing structure has implications for cost and management accounting. Dhavale (1996) examines product costing in a cellular environment and concludes that, due to its operating characteristics, product costing is simpler and more accurate for the following reasons:

- Many costs become direct cell costs. For example, support personnel are often co-located within cells and so costs can be traced directly to the cell. Also, many manufacturing overheads become direct costs to cells, e.g. materials handling.
- As cells make homogeneous products, it is easier to develop cost drivers that have a correlation with the consumption of manufacturing overhead resources.
- Costs are current in the cell environment. The use of JIT reduces inventory levels, especially Work-in-Progress. Higher stock turns means that product costs are closer to replacement costs.
- Direct labour can be included in manufacturing overhead. In a cellular manufacturing environment, some companies do not treat direct labour as a separate component in product costing; therefore, manufacturing overhead (including direct labour) can be referred to as conversion cost.

Dhavale (1996) has described how Activity-based Costing can be simplified in a cellular manufacturing environment. The accounts will indicate the cells to which resources are
attached, therefore eliminating the need for resource drivers to allocate resources to cells. Each cell is treated as an activity centre and each resource traced to a cell forms a cost pool.

Unit/batch/product level costs can be directly traced to a cell. Cell-level costs (costs of operating a cell) are all the costs incurred in keeping a cell operational and administered. These costs are unaffected by short-term fluctuations but will be affected by permanent increases or decreases in volumes. Facility-level costs may be allocated using allocation bases such as value-added per cell or manufacturing cost of products at the point of exit from a cell. Some facility-level costs may be considered cell-level costs. If the magnitude of facility-level costs is small compared to cell-level costs, then the efficacy of including all facility-level costs in cell-level costs should be considered.

The movement to lean manufacturing in the form of cellular production therefore enables a simplification of product costing which is the concern of this section because it is easier to trace more costs directly to cells that are involved with only one product or product group. Nevertheless, when one considers continuous improvement, each cell will need a good understanding of what drives the costs that it incurs within its cell and so ABC and its underlying concepts of cost driver analysis should not be discarded in a cellular regime. Those notions may well be useful to enabling cost reduction.

6.4 Time-based Costing Methods

Dhavale (1996) describes three distinct costing methods using “Time spent in a cell” as the overall cost driver.

(a) Cell time method

Cell time is taken to mean the time from the arrival of a product in the cell until the time the product leaves the cell. The cost driver is the throughput or cycle time for a product. This costing method assumes there are no interruptions or downtime. It is similar to renting a cell for a period of time. When cell time is used, products are charged for both used and unused resources. This influences managers to develop optimum cells and standardised designs and brings into consideration the opportunity costs of idle resources. However, this method does not adhere to the major requirement of Activity-based Costing as it does not attempt to explain what causes costs to occur and doesn’t provide adequate product costing details. It is based on the simple premise that cost will be reduced as a result of cycle time reduction.
However, there is no guidance on where to focus improvement efforts. This method works best where products use all the machines in the cell for a similar amount of time, have similar set-up times and are homogeneous with regard to the consumption of manufacturing overhead resources.

(b) Bottleneck machine time method

This method can be used where a bottleneck machine results in inadequate capacity and there is no practical way to increase capacity in near future or where outsourcing is not an acceptable option. The longest flow time controls overall flow time of cell. Costs are allocated to products on the basis of the length of time required on the bottleneck machine. This does not necessarily indicate the appropriate product cost for product mix purposes. The correct way to approach the product mix problem in such a situation is to specify exactly what the costs and revenues attached to each product are together with their call upon the limited resources and to solve for the optimal mix using a constrained maximisation algorithm. Even so, this method of cost allocation will highlight which products are taking up most time on the bottleneck resource.

(c) Process time method

The process time is the total amount of time spent by a unit or batch at the machines. This can be used where not all units/ batches use all the machines in a cell. The products are only charged, therefore, for the machines that they actually use. Opportunity costs or set-up times are not included and, as a result, the cost distortions associated with the cell time method can be avoided. This method works best where products are homogeneous with regard to the consumption of manufacturing overhead resources.

Dhavale (1996) also highlights the benefits of using time-based costing methods:

- They are simple and straightforward to use
- Amounts from ledger accounts can be used without the dis-aggregation and aggregation steps required in Activity-based Costing
- No adjustment is necessary for external reporting
- They are inexpensive to implement, maintain and operate and do not require any non-value-added activity to be performed
• They provide accurate product costs if cells are designed to have homogeneous consumption patterns for manufacturing overhead across products
• They encourage efficient use of cells and reduction of cycle time and emphasise the opportunity cost of cells.

The main advantage of these methods is that they are easy to use and encourage reduced cycle times. The latter characteristic relates, however, to cost reduction and continuing improvement that is to be addressed in Section 8. As Kaplan has emphasised, it is very important to separate out the different purposes of costing. In this section we are focusing upon product costing for the purposes of informing product mix decisions and estimating product profitability. Time based allocations have their attractive features, but, unless costs are incurred in relation to time spent, they will not yield reliable product cost estimates. They may well, however, be a good enough basis for allocating costs of service departments, such as chemical treatments, coatings or paint, to production cells and thence to products where cells share industrial services which may be situated outside the cells for practicality or safety reasons.

6.5 Value Stream Costing

In keeping with the value stream logic of lean manufacturing, Womack and Jones (1996) advocate “value stream/ product-based costing...so that all participants in a value stream can see clearly whether their collective efforts are adding more costs than value or the reverse” (p.262). However, there is little detail provided regarding the characteristics of such a system or methods for implementation apart from some case study examples. The approach promoted by some of the companies showcased in Womack and Jones (1996) is as follows:

1. Organise production by product families (by value stream)
2. Allow each product team do its own purchasing and buy its own tools
3. Design a simple system to assign real costs to each product line (value stream).

The essence of this approach is that, once an organisation is structured by value streams or production cells, it is easier to trace costs directly to the product, rather than allocate costs to products. Where cellular structures are widespread throughout the factory, value stream

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11 Wiremold (p136) and Showa (p226) case studies, Lean Thinking, Womack and Jones, 1996
costing is very similar to that already discussed with reference to cellular production. As a result, Womack and Jones (1996) argue that up to 90% of costs can be directly assigned to individual products/or product groups and only a small fraction requires allocation from general overhead. They believe Value Stream Costing is an advance on other management accounting techniques, such as Activity-based Costing.

Maskell and Baggaley (2002) also support the idea of Value Stream Costing and Value Stream Cost Analysis. They recognise that although non-financial performance measures provide excellent motivation towards lean goals, a clear understanding of costs is required in order to achieve customer-focused price targets through continuous improvement. The tracking of the actual costs of a value stream aligns cost reporting with lean goals. **Value Stream Direct Costing** is promoted as a method of product costing that supports lean manufacturing. All costs incurred by the value stream are charged into a cost pool for that value stream, including labour, materials, support services and facilities. As a result, there is little or no allocation. The product cost is then the average cost of the items manufactured by the value stream during the period. This is illustrated in Figure 4 below:

**Figure 4: Value Stream Costing**

![Value Stream Costing Diagram](image-url)

Value Stream Costing is similar to process costing and is believed to be more appropriate as companies significantly reduce lead times, reduce inventories and adopt cellular manufacturing and single-piece flow methods. Where it can be applied, Maskell and Baggaley (2002) state that Value Stream Costing has distinct advantages:

- It is simple and easy to use
- It is useful for measuring the performance of the value stream
- It eliminates the need for transaction and overhead allocation.
However, they also acknowledge that Value Stream Costing can only be adopted when a company has achieved short lead times, has low and stable inventory levels and has organised itself along value stream lines.

Moreover, there is the question of whether the factory can be feasibly organised on a “100% cellular” or “value stream” basis. Value stream accounting can only be conducted if the factory can be organised in that way. And if it is, the consequent remarks about the possible simplification of product costing is simply tantamount to saying that a firm producing just one product will not have a cost allocation problem! If multi-product firms can keep all their different products or product groups entirely separate throughout production with no shared resources between them, one wonders why such a growth of multi-product firms has come about. There must be some synergies between products to sustain such multi-product firms long term. Moreover, even if each product needs to draw on no shared resources, we doubt if this is the case for non-manufacturing costs such as sales and administration. We certainly do not wish to belittle value stream organisation and the associated simplification of management accounting. Indeed, we find the ideas of simultaneous simplification of the production and accounting process very attractive and this should be the ideal sought, but care must be taken not to address this in too simplistic a manner. Some movement towards value stream organisation and costing may be desirable, but full separation of products and product groups may be difficult in some firms. This is especially true for companies that produce a high variety of components; many aerospace companies manufacture thousands of different components, although not necessarily in large volumes. However, at the component manufacturer level, where a company manufactures a restricted range of products, there is evidence that cell/ value stream costing is beginning to be adopted in the aerospace sector, supplemented by time-based costing methods for shared resources.

Maskell and Baggaley (2002) move beyond a simplistic view of value stream costing to recognise that products within a broad value stream structure may not be homogeneous, and in that case a simple average cost would distort product costs. They advocate the use of Features and Characteristics Costing to make product costs more accurate. At first sight this seems the same as Functional Costing as addressed under Target Costing (see Section 4), but it has a different emphasis. Features and Characteristics Costing is a technique that identifies the features and characteristics of a product that make it more difficult to manufacture. A cost factor can then be added to or subtracted from the average cost to take account of the additional or reduced effort required. This may well help to relate costing to a practical degree to which value streams can be made to focus on only one homogeneous
product, but it is only a halfway house towards resolving the problem of cost allocation by volume factors that ABC was developed to solve.

In summary, our view is that in general throughout all industry, ABC is the standard against which product costing approaches should be compared as it tries, more explicitly than other methods to identify the precise causes of overhead cost variation. It has its limitations, but it is the most complete description of the ideal way to measure actual product costs that we have. (We feel it necessary to continue to stress that we are talking here about identifying the actual historic cost of a product, not saying that ABC is the best costing approach for all purposes). But whether a company needs to adopt ABC, (even for ad hoc product costing calculations as distinct from changing the routine costing system to an ABC basis), or use simpler versions we have described, will depend upon (1) how far the factory can be organised on a value-stream basis and (2) on what commercial difference the application of ABC to product costing makes. If ABC, while theoretically more sound as a basis for product costing, only moderates perceived product costs to a small degree, that may not be significant in terms of changing product strategies and simpler, less expensive approaches may be good enough. The design of the product costing system needs to be based upon such pragmatism and not theoretical nicety.

6.6 Product Costing Requirements for Lean Aerospace

We must first remember that we are still focusing solely upon the need for product costs. It is, therefore, relevant first to ask why firms in aerospace need product costs and, in doing so, bear in mind that what is perceived to be “a product” will be quite different at different levels in the industry.

6.6.1 Product costing for prime contractors and final assemblers

At the level of the prime contractor, where most parts are bought in for the assembly of a large aircraft or spacecraft, the product is that major vehicle. Such a prime contractor does not really have a shorter-term product mix problem in the same sense that, say, a household appliance manufacturer has. In so far as the prime contractor (assembler) has clear purchase prices for components, whether bought in or produced in the same firm, it does not have a severe product-costing problem in terms of allocating costs that are indirect to that major project. Almost certainly an account will established for the major project (which may, of course, relate to a number of the same or very similar aircraft) and virtually all costs can be assigned to that account without the need for allocation. There will be, in most aerospace
applications, the need to use some central facilities (painting, coatings, etc as mentioned earlier), but the use of such services can usually be charged out on a basis that fairly reflects usage without too much complexity. However, some assemblers themselves also produce thousands of components. It is likely, therefore, that at the component production level such firms will have an overhead allocation problem, as discussed in Section 6.6.3 below.

So we can conclude that, in this part of the aerospace industry, things are rather different from most of industry with regard to project costing. It is relatively straightforward to estimate product (i.e. project) cost and ongoing checks upon product mix are not required. As Kaplan (1988) points out, this position is also likely to be met in a number of project-based industries, such as major construction, ship-building or the design and manufacture of very large machines.

That does not mean, however, that the prime contractor does not need knowledge of product (i.e. major project) cost. He needs it at the stage where the sales contract and price are being negotiated. The first estimate will, however, come at the design stage employing a target costing/limited life cycle approach if our recommendations in this report are adopted. This might well use ABC cost driver concepts to arrive at ex ante estimates for overheads, but even here care must be taken. We referred to the need for functional costing within target costing and gave examples of the way in which various product attributes should be costed. It is probable that some costs, for instance those associated with the speed of an aircraft, do not increase linearly with speed potential. While increased costs associated with increased speed may affect mainly direct labour and materials, it may also affect the way overheads are incurred. ABC identifies cost drivers for overhead estimation, but still assumes linear cost-to-cost-driver relationships. Functional cost estimates need to be more sophisticated and based on more detailed engineering knowledge and feasibilities. So, as advocated earlier, functional costing must be the dominant concept for estimating the product’s cost at the design stage. In aerospace projects, this may or may not gain from using ABC cost driver concepts to estimate the impact of product attributes upon overheads. Further delving into the detail of required processes for cost-estimation for major aerospace projects is required before one can be definite on this.

Remember, however, that it was recommended that target costing be extended beyond the assembly of the main aircraft to include at least the life-cycle costs and after-market sales of the current model being produced. Hence, “product cost” will include these later costs and revenues. As stated earlier, if replacement parts for a given aircraft model are not produced
in separate cells, but manufactured along with parts for other aircraft such that both call for a share of common resource use, there will be a cost allocation problem in producing an estimate of the full life-cycle project cost. It may then be necessary to resort to ABC to allocate production overheads to the direct costs of spare parts for the model concerned. Whether this is necessary in practice will depend upon the way the factory is organised and the degree of pragmatism desired as mentioned in Section 6.5.

Once the product has moved into production, functional costing can be left aside as a means of monitoring cost progress. The question now arises as to whether the prime contractor needs a figure of actual product cost as part of the system of financial control. (This section and that on operational control overlaps here to a small degree). Possibly it is at this stage that the prime contractor needs an estimate now of actual, not estimated, product cost to check that costs are being kept within the limits planned to ensure that a profit is earned, but this may not necessarily be so. The final cost estimate incorporated into contracts, though developed originally in functional cost form, needs for control purposes to be “cross-walked” into a more conventional cost format in terms of components and processes needed for production. Actual costs can then be more easily tracked and compared against these initial estimates. In fact, following Japanese practice, with adequate staff training and trust, these component and process costs may need not even need be combined into a report on actual total product cost. Each section or cell can be given an estimate of its own expected costs and told to report to the centre if costs are in excess of those initially estimated. Overall profit control for each major project can then be on the basis of exception-reporting. If control can be exercised in this way, it is not clear that a comprehensive measure of the project’s actual cost is needed. If expected component and process costs are not exceeded, the project should be profitable.

The ability to present a reliable figure for actual project cost may, however, arise in another way. It has been stated a number of times that the industry will negotiate with respect to the development and pricing of major projects and should ideally use functional costing to provide cost estimates. But, given, that much negotiation takes place on such major projects and customers cannot simply rely upon a widely competitive market to provide downward pressure on prices, it seems that customers will need to see details of actual costs of their project in order to convince themselves that the original estimates were not unfairly inflated. This seems to us that this may be the case, even where contracts are not written on a cost-plus basis where there must obviously be a calculation of actual product cost. So, whether
prime contractors would otherwise calculate actual product cost or not for control purposes, it is probable that they will need it to satisfy customer relations.

It is clear, then, that much of the general discussion about how to undertake product costing in recent decades and how it needs to be made more sophisticated in terms of overhead allocation using ABC cost driver ideas, probably does not apply to a great extent in this section of the industry in determining a major aerospace project’s estimated or actual cost. Obviously an estimated total project cost is needed at the outset of the project, but functional costing should dominate ABC as the prime approach in determining that cost, even though ABC may or may not be used to inform the estimation of some types of cost within functional costing. If the prime contractor needs a calculation of actual project cost, once more it is likely that there will not be a severe overhead cost allocation problem if each project is kept distinct with its own value stream. However, the industry consists of somewhat more than the prime contractors. For convenience, we divide the rest into the main systems providers and the small component and materials suppliers.

6.6.2 Product costing for major systems providers
The previous paragraphs addressed the need of product costing from the viewpoint of the prime assembler of a major aircraft or spacecraft, but many firms or business units in the industry produce systems for such aircraft, rather than the aircraft itself. So do the conclusions derived for prime contractors hold at that level? Given the arguments already outlined above, the answer can be specified quite briefly. If the firm produces systems in a factory organisation that keeps each type of major system separate from others, i.e. it has its own distinct value stream, the same conclusions hold as for prime contractors. Systems should initially be target costed including life-cycle implications and the need for actual product costs, and the possible need for ABC concepts in arriving at those product costs, will be determined by exactly the same arguments as given for prime contractors. If, in contrast, the production of some systems is interlinked with others with the use of common production resources or common overhead services, there will be a product costing problem. But, while the factors that should determine the costing basis used are the same, we suspect that more firms involved in the production of systems for aircraft will have related processes for different systems and will, therefore, need to give greater thought to product costing and overhead cost allocation. Moreover, we observe that some firms in this category still depend heavily, in their product costing systems, on direct labour hours as the basis for overhead allocation. Such firms should consider whether a move to a more sophisticated system of cost drivers should be used.
We would, hence, expect to see a difference in this regard between firms that are mainly prime contractors or assemblers and those that produce sub-systems. Possibly the same difference would be observed as one moves from producers of major aircraft systems (e.g. engines) to smaller sub-systems. We cannot go further that this in making recommendations in this report as it is now clear that the specific manufacturing context of each firm must be considered in designing the appropriate costing product costing system.

6.6.3 Product costing for component and materials suppliers
As one moves down the supply chain, we can again use the same factors to assess what product costing system is needed. We have already discussed that, even at component and materials level, target costing, albeit of less extensive type and perhaps off-line associated with continuing research rather than ongoing production, is desirable if continuing improvement is needed to cope with ever changing technology. The same arguments, therefore, apply about the need or lack of need for sophistication in overhead cost allocation at the original product cost estimating stage. At the production stage, once more the value stream argument comes to the fore. If the factory is not organised that way, overhead cost allocations will be needed. At the component and materials supply level, we would, however, expect production processes to be related and share common resources for those firms that produce many (perhaps thousands) of different components. And so they will have an overhead allocation problem. For component manufacturers with a restricted product range, value stream organisation and avoidance of complex overhead allocation systems should be achievable.

6.7 Summary
To conclude this section, the higher one is in the supply chain hierarchy, one is likely to find separate value streams and there will not be a severe overhead cost allocation problem in arriving at product cost. As one moves down that hierarchy to major systems providers, that also produce many different types of components themselves, the overhead allocation problem continues to exist. Moving even lower down the supply chain to smaller firms with restricted product ranges, it should be possible to avoid most of the overhead allocation problem by adopting value stream organisation. However, the rationale for value stream organisation must be whether it will make the industry leaner, not whether it will make product costing easier. Product costing will be more complex where a high degree of shared resources are required, but then that complexity should be addressed and resolved in the way that we have suggested.
7. OPERATIONAL MONITORING & CONTROL FOR LEAN MANUFACTURING

7.1 Introduction

Within a lean factory, it is important that the operational control system encourages low inventories, focuses on on-time delivery to customer and supports the concepts of flow and pull production. It has been shown that traditional control mechanisms often work against these objectives.

Following Kaplan, it was argued earlier that the accounting needed for inventory valuation for production of the external financial accounts (Profit and Loss Accounts and Balance Sheets) should be separated from the accounting concepts required to support both product costing and operational control. We also said earlier, however, that, as Profit and Loss accounts are used extensively in practice to monitor overall progress internally and so we do need to consider financial accounting processes within this heading of Operational Control.

In addition, standard costing has also traditionally been used for operational control purposes. However, measures such as labour productivity, the difference between standard and labour hours, and machine utilisation, in conjunction with variance analysis, can encourage behaviours that conflict with lean manufacturing principles because they encourage local optimisation rather than optimisation of the value stream. These non-lean behaviours include the manufacture of large batch sizes, high inventory levels, the acceptance of poor quality and a lack of motivation for continuous improvement. Plenert (1999) argues that operating cost controls, especially labour cost controls, often defeat the overall organisational goals of profitability. Kaplan (1988) supports this view and also suggests that cost accounting calculations such as the allocation of overheads or variance analysis should not be part of the company's operational control system because they obscure the information that cost centre managers need to operate effectively.

Standard costing might be dysfunctional in yet another sense. It might instil a sense of the standard cost being the correct target cost and inhibit thinking about continuing improvement.

It is important, therefore, that this report addresses these issues leading to recommendations about how aerospace companies can exercise operational control to
achieve their lean goals. This section will be structured as follows. First we shall examine the use of non-financial measures as alternatives to control by standard accounting variance analysis. Second, we shall address how increased use of a cellular or value stream structure might facilitate more meaningful financial operational measures. Third, we will consider alternative bases for constructing periodic financial accounts for internal monitoring purposes.

7.2 Non-financial Performance Measurement

Traditionally, financial measures were viewed as the only measures of success. However, although profitability is the ultimate goal of a business, it cannot be the only focus for operations (Plenert, 1999). Plenert (1999) explains that focusing too heavily on financial statements and financial ratios causes inefficient and rapid cost-cutting measures. Labour costs are often cut because of their visibility, not because it makes sense operationally. Because of the lack of visibility of in-transit inventory carrying cost, operating costs appear to have been reduced as a result.

In Japan, extensive use is made of non-financial measures to evaluate factory performance (Hiromoto, 1988) and, over the past ten years or so, there has been a significant move towards the use of a more balanced set of measures across all industries in the West, including aerospace. The use of both financial and non-financial measures is widely promoted (Kaplan and Norton, 1998; Maskell, 1996; Brown, 1996; Bicheno, 1998). It is also widely accepted that measuring an organisation’s performance based on operational measures has a more positive effect on long-term profitability than measuring the plant’s profitability (Plenert, 1999). Kaplan (1988) argues that cost information may, in fact, only play a minor role in operational control. He recommends that shop-floor control be achieved through the use of measures like yield, defects, output, set-up times, throughput times and physical inventory levels.

Advocates of lean manufacturing also promote the use of non-financial, customer-focused measures to measure operational performance believing that these type of measures are available when required for good decision-making, are within the control of operations personnel and are more appropriate than financial performance measures derived from a standard costing system. It is also believed that focusing on measures such as Right First Time Quality, On-time Delivery, Customer Acceptance Rates, Scrap and Rework Rates and Inventory Turns will result in reduced costs. Variance analysis can be performed with regard
to deviations from these non-financial measures and be combined with Root Cause Analysis in order to determine the origin of the variance.

The UK Lean Aerospace Initiative has been instrumental in promoting a lean approach to performance measurement and developing a balanced set of measures for use in the aerospace industry, known as Aerospace Metrics (Jones et al, 2001; Ward and Graves, 2001; SBAC, 2000). The Aerospace Metrics are:

- Customer acceptance/ reject rate
- Delivery schedule achievement
- Value added (per person/ per £ payroll)
- Employee training and development days
- Stock turns
- Floor space utilisation.

These measures can be used as part of a more comprehensive performance measurement system and also used to promote continuous improvement, both within companies and throughout the aerospace supply chain. They also have the potential to be used at cell level, value stream level and enterprise level. It is important that one measure is not focused on to the detriment of other. The experience of some UK LAI member companies illustrates that focusing too heavily on Delivery Schedule Achievement has resulted in increased levels of inventory.

The Aerospace Metrics are currently being widely adopted throughout the UK aerospace sector, both by individual companies and through specific supply chains. There is a need, nonetheless, to provide a link between success using such measures and financial performance and the next two subsections examine proposals made to date to do this.

### 7.3 Value Stream Box Scores

Value Stream Mapping is a tool used to visually represent the flow of a product from raw material to delivery to the customer (Rother and Shook, 1998). Value Stream Box Scores can be used to link performance measures with Value Stream Mapping (Womack and Jones, 2003). The Value Stream Box Score, as illustrated in Table 3 below, shows the
current status and future targets. These lean measures are seen as appropriate for running the business on a day-to-day basis.

**Table 3: Value Stream Box Score**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Current State</th>
<th>Future State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total lead time</td>
<td>23.5 days</td>
<td>4.5 days</td>
</tr>
<tr>
<td>Value creating time</td>
<td>184 seconds</td>
<td>169 seconds</td>
</tr>
<tr>
<td>Changeover time</td>
<td>10 minutes in assembly</td>
<td>0 minutes in assembly</td>
</tr>
<tr>
<td></td>
<td>1 hour in stamping</td>
<td>10 minutes in stamping</td>
</tr>
<tr>
<td>Up-time</td>
<td>80% in weld/ assembly</td>
<td>100% in weld/ assembly</td>
</tr>
<tr>
<td></td>
<td>85% in stamping</td>
<td>99% in stamping</td>
</tr>
<tr>
<td>Scrap/ rework</td>
<td>5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Inventory</td>
<td>17,130 pieces</td>
<td>3,250 pieces</td>
</tr>
<tr>
<td>Every part made every</td>
<td>2 weeks</td>
<td>8 hours</td>
</tr>
</tbody>
</table>

The usefulness of Value Stream Box Scores has been extended by Maskell to include financial information as well as non-financial performance measures. This is demonstrated by the experience of Parker Hannifin Corp., a company that has implemented Maskell’s Value Stream Box Score (Lean Enterprise Institute, 2003). Parker Hannifin Corp. is the world’s leading diversified manufacturer of motion and control technologies, providing systematic, precision-engineered solutions for a wide variety of commercial, mobile, industrial and aerospace markets.

Parker Hannifin adopted a step-by-step process to introducing a lean operational control system:
1. Development of cell performance measures
2. Development of value stream performance measures
3. Development of a value stream P&L account
4. Calculation of improvements in capacity to provide valuable decision-making data
5. Development of a value stream box score that integrates operational, capacity and financial data
6. Rejection of the standard cost system.

Maskell introduces some financial measures into this system and his Value Stream Box Score, including values for additional capacity, is shown below in Table 4:
### Table 4: Maskell’s Value Stream Box Score

<table>
<thead>
<tr>
<th></th>
<th>Current State</th>
<th>Future State Short-term</th>
<th>Future State Long-term</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operational Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales per person</td>
<td>$221,833</td>
<td>$224,833</td>
<td>$277,031</td>
</tr>
<tr>
<td>Inventory turns</td>
<td>6.5</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Average cost per unit</td>
<td>$31.32</td>
<td>$31.32</td>
<td>$24.25</td>
</tr>
<tr>
<td>First time through</td>
<td>81%</td>
<td>95%</td>
<td>95%</td>
</tr>
<tr>
<td>Lead time in days</td>
<td>25</td>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Capacity Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productive</td>
<td>55%</td>
<td>52%</td>
<td>79%</td>
</tr>
<tr>
<td>Non-productive</td>
<td>42%</td>
<td>40%</td>
<td>12%</td>
</tr>
<tr>
<td>Available capacity</td>
<td>3%</td>
<td>8%</td>
<td>9%</td>
</tr>
<tr>
<td><strong>Financial Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revenue</td>
<td>$4,062,000</td>
<td>$4,062,000</td>
<td>$5,686,000</td>
</tr>
<tr>
<td>Material costs</td>
<td>$1,164,184</td>
<td>$1,164,184</td>
<td>$1,552,840</td>
</tr>
<tr>
<td>Conversion costs*</td>
<td>$1,483,416</td>
<td>$1,483,416</td>
<td>$1,657,500</td>
</tr>
<tr>
<td>Value stream profit</td>
<td>$1,414,400</td>
<td>$1,414,400</td>
<td>$2,475,660</td>
</tr>
<tr>
<td>Value stream ROS</td>
<td>34.82%</td>
<td>34.82%</td>
<td>43.54%</td>
</tr>
</tbody>
</table>

*Conversion costs are made up of employee costs and machine costs
Source: BMA Inc.

Where it is feasible to organise by value streams, it seems eminently sensible to develop value stream scores in financial as well as non-financial terms for both short-term and long-term goals as Maskell proposes in order to keep all concerned aware that it is performance in financial terms that ultimately matters. Valuable as such a proposal is, it is of limited value unless the value stream has the requisite tools systematically to analyse its possible improvement path. Otherwise, the financial targets will have little credible foundation. Some of the appropriate tools are addressed in the subsequent section on continuing improvement. Suffice it to say here that Value Stream financial targets need to be seen as merely the summary of underlying detailed activities to improve. As such they can provide fairly simple, but relevant, management control tools.

#### 7.4 Changing the basis of internal financial accounting: Accounting for Flow and Throughput Accounting

Once the manufacturing value streams have been identified, it is important that the value-creating steps flow. In a functionally structured organisation, the flow of specific products is difficult to visualise as products travel between various departments for each of their required processes. In this situation, measures such as machine utilisation and labour productivity are often used to demonstrate the effectiveness of each department. However, as we have seen earlier, these measures create behaviours that are counter to lean
manufacturing principles. Traditionally, departments seek to optimise their own processes without regard to the consequences both upstream and downstream. The reliance on theories such as Economies of Scale and Economic Order Quantities maintains the drive for local optimisation and results in increased batch sizes and high work-in-progress and finished goods inventories. Production is not matched to customer demand. In contrast, where clearly beneficial, the lean manufacturing approach is to organise along value stream lines in production cells (as discussed earlier). Within the production cells, single-piece flow is promoted, whereby batch sizes are reduced as much as possible (ideally to a batch size of one) and the cycle for a specific product can be completed within the cell (Rother and Harris, 2001). Within the cell, people, machines and materials are located within close proximity so that excess movement is avoided, the need for high inventory levels is eliminated and the product can flow through the cell to match customer demand. This approach emphasises time compression – the reduction of order to delivery time, manufacturing lead times and cycle times. Within the aerospace industry, cycle time reduction is viewed as an important area of cost saving and improved customer service (Cook and Graser, 2001). Creating continuous flow and reducing lead times has financial implications. Once raw materials and other components and assemblies have been acquired, the faster the conversion and selling processes occur, the greater the financial benefits that can be derived from the whole operation (Yoshikawa et al, 1993). The longer the time taken to build an aircraft, the higher the costs and the risk of quality problems becomes due to the fact that an aircraft accumulates costs based on its status as part of WIP inventory, without operational availability to the customer/operator (Cook and Graser, 2001).

The emphasis, therefore, is on the rate of throughput, although, in lean manufacturing terms, the idea is not to speed up throughput time for its own sake, but to use this time compression to increase customer satisfaction – through faster delivery, better quality, providing the right products at the right time – while simultaneously reducing internal costs. An approach to financial accounting that focuses on increasing the rate of throughput is Throughput Accounting. Throughput Accounting is derived from the Theory of Constraints (Goldratt, 1993).

Apart from the traditional use of standard costing variances which tend to induce local optimisation, the motivation to produce excessive inventories in large batch sizes is also said to be caused by the traditional full absorption costing practice of assigning some current period costs (in particular fixed overhead) to partly finished and, indeed, finished but unsold
products and showing them as a credit along side sales in the P&L account. Costs incurred are deducted from the sum of these credits to arrive at gross profit. Hence, by building up stocks, irrespective of whether they can be sold in the near future, a manager, in effect, reduces current costs by the amount of fixed costs for this period that he can “transfer” on to the next period within the stock valuation. This then increases this period’s gross profits.

It is this valuation of unfinished and unsold stocks that causes the problem. If stocks were at significant levels, why not charge all costs incurred in this period to the units finished in this period? Well, it would then be argued that the financial accounts would not show a true view of the financial progress that the firm made during the period. For example, a unit could just be packed in this period but be manufactured in a previous period when costs were different. Most of its value had been created in the previous period. Also, the firm must show its correct position in relation to on-hand partly finished or finished but unsold products. To take the extreme, suppose a firm fully produced and sold no units during the year, but worked solely on one unit that was almost finished and would sell shortly after the year-end for millions of pounds (this might be the case in aerospace). Financial accounting says that the accounts must reflect the value that the firm created in that year. So a stock figure is needed. Nevertheless, proposals have been made to change the basis of stock valuation in financial accounting to lessen this problem. In fact, it may well be that, in many firms this is not a problem as stock levels are strictly controlled directly by inventory measures that override in importance more global measures of profit in assessing the performance by operational managers. This is an empirical matter on which we know of no research. Given the considerable attention paid to the issue in developing alternative bases of financial accounting as discussed in this section, we assume that it is a problem we need to address here. Practitioners will have to decide on the basis of empiricism for themselves.

Goldratt (1993) developed Throughput Accounting as an approach to this problem. He also saw it as far more in line with the notion of increasing throughput through the factory in order to increase efficiency. In Throughput Accounting, throughput is defined as sales less direct materials costs. That is, all costs are considered fixed (i.e. charged to the current accounting period) except direct materials costs. Direct labour is included as part of fixed operating expenses and is not capitalised in inventories. This is the only difference between Throughput Accounting and traditional absorption accounting. This means that, if a manager were tempted to increase production in order to increase profits without increasing sales, as he might under absorption costing, he would not succeed. The extra amount added to closing stock would be just the extra direct materials cost of that inventory which would be
counterbalanced by the extra cost of acquiring those materials; hence, profits would be unchanged by his action. Throughput Accounting is closer to a cash flow concept of income. It would also give exactly the same measure of profit and inventory as variable costing if, under the latter, direct labour costs were assumed to be wholly fixed (Noreen et al, 1995). One can demonstrate, in fact, that Throughput Accounting is just one possible way of measuring profit and valuing inventory amongst a continuum of methods where absorption costing represents one extreme and reports profits as early as possible and pure cash flow accounting the other which does not report a surplus until the proceeds of sales are received. However, Throughput Accounting does not encourage stock building in order to increase profits irrespective of sales levels.

Galloway and Waldron (1998) say that this approach “is more useful and infinitely simpler to consider the entire cost, excluding material, as fixed and to call the cost the Total Factory Cost”. Throughput Accounting can encourage behaviours that are aligned with lean thinking. Using this approach, there are three ways to increase profit (Noreen et al, 1995):

1. Increase throughput/sales
2. Decrease operating expenses (fixed costs)
3. Decrease investment, especially stock.

Throughput Accounting emphasises sales growth and inventory reduction rather than cutting operating expenses. Cutting operating expenses could heighten redundancy fears as labour is treated as a fixed cost. Lean manufacturing also advocates business growth rather than employee redundancies to utilise the capacity released by waste elimination and cost reduction activities.

But care must be taken as Throughput Accounting may not necessarily be consistent with lean manufacturing principles. Despite the fact that Throughput Accounting measures of profit will not encourage stock-building irrespective of sales, any stress placed upon maximisation of throughput may itself lead to stock-building. Lean manufacturing stresses the idea that goods should be manufactured just-in-time to meet customer demand for each value stream. If Throughput Accounting discourages any deviation from this, it does not fully support lean manufacturing.

In summary, the benefits and limitations of using Throughput Accounting in a lean environment are highlighted in Table 5:
Table 5: Benefits and Limitations of Throughput Accounting in a Lean Environment

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focuses on optimising the whole system/systems theory</td>
<td>Does not take a value stream approach – no pre-requisite for a cellular/ product-oriented structure</td>
</tr>
<tr>
<td>Encourages inventory reduction, compatible with JIT, suggests WIP be valued at just the direct material cost content of inventory.</td>
<td>Focuses on maximising throughput in shorter timescales – does not appear to be linked to customer demand/ requirements/ takt time</td>
</tr>
<tr>
<td>Focuses on time compression and schedule adherence</td>
<td>Takes a short-term focus</td>
</tr>
<tr>
<td>Requires a change of mindset – takes the focus away from local machine utilisation and labour productivity and instead emphasises the rate of throughput/schedule adherence</td>
<td>There is little evidence that it has been widely implemented</td>
</tr>
<tr>
<td>Improves internal operations so that existing resources can handle greater diversity and volume</td>
<td>Viewed as not useful for making decisions on product mix where fixed costs associated with products must be considered.</td>
</tr>
</tbody>
</table>

7.5 Accounting for Pull and Backflush Accounting *(Cost recovery delayed until the point of sale)*

As emphasised many times now, the object of lean operations is, where appropriate, to create value streams and value steps within them to support continuous flow. It is important that the flow is only initiated when pulled by the next step in the process. Goods or services should not be produced upstream unless required by the customer downstream (Womack and Jones, 1996). In this way, value is pulled through the value stream. Backflushing (or cost recovery delayed until the point of sale) is an accounting technique used to support a pull production system (Maskell, 1996). Backflushing refers to the rejection of the traditional costing practice of keeping track of every unit or batch of production as it moves through different stages of production and building up its cost according to that specific unit’s or batch’s consumption of resources (materials, labour and overhead) at each stage.

With lean manufacturing, the objective of reducing production cycle times means that, at a certain point, it no longer serves any useful purpose to maintain detailed transaction records on the movement of Work–in-Progress (Jenson et al, 1996). As a practical matter, the product would be finished and dispatched before Work-in-Progress reports reflected its movement or status. Therefore, the extra effort required to record and process these additional transactions is no longer justified.
Backflushing is the term used in financial accounting to refer to the practice of not giving credit for any expenditure in the accounts until the sale is agreed. Outlays on materials, labour and overheads are recorded as they are incurred and the number of units/batches produced is counted, but none of that expenditure is shown as a credit for inventory until the sale of those units have been agreed and there is a contractual commitment of the customer to pay. Once this has happened, accounting entries showing transfers from stocks of materials, the use of direct labour and overhead services is calculated by reference to standard costs based on the Bill of Materials and standard cost statements and set against the sales value to show the profit on those items. Only then is the inventory of those units given a (finished goods) value. As a result, detailed transactions are not recorded every time a piece of raw material is introduced into the manufacturing process or moves from process to process. Backflushing radically reduces the number of accounting transactions, reduces the opportunity for error and discourages inventory build-up unless the products can be sold.

Backflushing can eventually be extended through to accounts payable where component supply can be called off from blanket orders with certified suppliers (Maskell, 1991). The assumptions underlying this process are:

- If a product has been completed, certain components must have been used
- If the components have been used, they must have been received
- If the components have been received, they must have been called off from the supplier
- If the components have been called off from the supplier, the supplier needs to be paid.

7.6 Operational Monitoring and Control Requirements for Lean Aerospace

The question we need to address is whether or not the basis of profit calculations should be changed in the aerospace industry for internal control purposes in a lean environment?

Once again we need to consider the needs of the prime contracting/major systems providers separately from component manufacture. With major projects involving the assembly of aircraft/aero-engines etc., aerospace prime contractors do not feel there is a major advantage in adopting backflush accounting. While there might, in theory, be something to be gained in doing so by increasing pressure for project completion, other project management routines already deal with this.

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12 This is the most extreme version of backflushing. Credit could be given to finished goods at the time of
Component and materials manufacturers should, in contrast, apply backflushing to all of their normal production output. Granting no credit for inventory until production is in a saleable form, or even sold, can even play a significant part in inventory control and incentivise inventory reduction.

If these recommendations were adopted, we do not see that great advantage would be gained from adopting Throughput Accounting. In some sense Throughput Accounting and Backflushing are aimed at similar problems. We think that a fully backflushed system analysed by value stream would provide all the advantages of Throughput Accounting and more.

The aerospace industry is in an excellent position to exploit pull production as this concept is to a large extent built into the aircraft manufacturing mindset (Cook and Graser, 2001). In both the commercial and military arenas, aircraft are built-to-order. Prime contractors build aircraft that have been committed to by the customer, to an agreed schedule. Therefore, it is possible to work backwards from known delivery dates to schedule production. However, traditionally the demand signals have been amplified down through the supply chain resulting in high levels of inventory along individual product value streams. Therefore, the aerospace industry, in a similar manner to the automotive industry, has widely adopted a Just-in-Time (JIT) approach over the past ten years or so. As is well known, JIT involves having the appropriate inventory available when required. The customer delivery date is used as a starting point and all activities are scheduled back from that date through the production process. Kanban systems are often used to trigger inventory movements and ordering of materials and components. Direct supply to the production line or cell is also promoted in order to minimise the amount of stock required on-hand, to increase inventory turns and to reduce lead times. A backflush accounting system would act in way that is consistent with this production approach and get rid of the signals that are derived from traditional absorption costing that run counter to lean operation.

In fact, one of the UK LAI member companies has already adopted a Throughput Accounting approach subsequently backflushed to draw up the financial accounts in order to encourage lean behaviours. This was developed from a clear statement of lean principles and the behaviours that it wanted to motivate in management by producing the regular internal completion if sales were highly likely, but still no credit given for materials or work in progress held.
financial accounts. Table 6 below shows how the company set out these principles and desired behaviours.

**Table 6: Behavioural matrix which Throughput Accounting / Backflushing supports**

<table>
<thead>
<tr>
<th>Principle</th>
<th>Behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reward will be given for delivery of inventory to the customer which meets the agreed schedule</td>
<td>The management of the cell will focus the efforts of the cell on satisfying the customer</td>
</tr>
<tr>
<td>No reward will be given for WIP</td>
<td>The practice of making-for-stock will cease. Lead-times will reduce to allow full reward to be claimed for production in the period</td>
</tr>
<tr>
<td>No reward will be given for work completed or delivered for which no customer requirement exists</td>
<td>The practice of pushing unwanted inventory at the customer will cease</td>
</tr>
<tr>
<td>Failure to deliver the right mix to the customer cannot be mitigated by delivery of volume</td>
<td>The management of the cell will understand the customer requirement at micro level and manage the cell in a manner which delivers the right mix</td>
</tr>
<tr>
<td>No reward will be given for work performed on parts which fail to reach the customer</td>
<td>Increased attention will be paid to prevention of quality failures. Effort will be expended in avoidance rather than rectification</td>
</tr>
<tr>
<td>Control of controllable costs will have a direct impact on the level of reward obtained</td>
<td>Cell management will know what their controllable costs are, understand what they can do to influence them, and only incur costs where there is an equal or greatly increased reward</td>
</tr>
<tr>
<td>WIP will incur a holding cost which will be charged to the controllable costs of the cell</td>
<td>Cell management will avoid WIP build-up by applying JIT techniques</td>
</tr>
<tr>
<td>Short-run sourcing and capacity decisions will have a direct impact on the controllable costs of the cell</td>
<td>Cell management will judge all such decisions, rather than just domestic activities, on a value-for-money basis</td>
</tr>
</tbody>
</table>

This represents a serious move in the right direction to attempt to link internal financial reporting with the requirements for lean operations.

**7.7 Summary**

Moving to summarise our findings for control over lean manufacturing activities, there does seem to be the need for a clear, but not overlarge, set of physical measures to complement accounting controls. Most of the industry has adopted a more balanced approach to performance measurement, but only recently has the industry attempted to develop a unified set of measures to enable cross-company comparison.
It also seems clear that variance analysis conducted under standard costing encourages local optimisation and this hinders the development of lean manufacturing. Companies still using such variance analysis should rigorously question whether to drop or significantly modify such practices.

In addition, it was shown how financial accounts used to monitor profitability internally may motivate different behaviours from lean manufacturing if the accounts are constructed along traditional absorption costing lines. Even variable (direct) costing may also encourage over-stocking, if direct labour is truly fixed in the short-run. Once more, this would not tend to apply for the production of large products – aircraft, spacecraft or major systems where it will still be necessary to show credit for work done on contracts by the end of the accounting period even though the final product has not been delivered. The problem arises more in routine volume component production and the solution lies in adopting throughput accounting or backflushing (or a combination of both). We feel that the adoption of backflushing will normally be sufficient. That will also reduce the amount of accounting entries that need to be made and make the accounting process itself leaner.
8. COSTING FOR CONTINUOUS IMPROVEMENT

8.1 Introduction

Instilling a continuous improvement ethos requires focusing on all aspects of manufacturing including cost, quality and delivery (Turney and Anderson, 1989). Management accounting systems can be simplified and adapted to support and drive continuous improvement efforts.

Although the operational control methods explored above can provide significant incentives for continuous improvement, supplementary techniques may be required to manage cost reduction and support waste elimination activities. Womack and Jones (2003) have expressed concern about the way Value Stream Mapping is used by many companies. They claim that although many companies map their value streams and develop Value Stream Box Scores for both current and future states, the achievement of the future state is often not realised because an implementation plan to move from the current to the future state is not put in place. This section outlines methods that can supplement lean operational control methods in the achievement of the future state by explicitly focusing on waste elimination and cost reduction.

8.2 Benchmarking

Benchmarking is the continuous process of measuring performance against other parts of the organisation, the toughest competitors or those companies recognised as global industry leaders. Benchmarking can provide a “wake-up call” – “sometimes the only spur to improvement may be the knowledge that ‘someone else is doing it better’” (Mayle et al, 1998). For benchmarking to be effective and worthwhile, it is important to move beyond simply measuring quantitatively and understand the processes which lead to dramatically different performance levels between organisations (Mayle et al, 1998; Francis et al, 1999). Benchmarking, however, must not introduce additional waste or be used to avoid action (Womack and Jones, 1996). Rather, benchmarking should form an integral part of an organisation’s continuous improvement activity, used to make comparisons and implement change (Holloway et al, 1998). There are limitations associated with benchmarking – it is often difficult to obtain information, it is best suited to environments of high certainty, stability and repetition, and there is frequent misuse (Adler, 1999). Womack and Jones (1996) dismiss benchmarking, advocating instead to “compete against perfection by identifying all waste and eliminating it”. However, it is dangerous to rely solely on internal benchmarks.
This insular approach may prevent a company realising its full potential through an understanding of how global industry leaders have achieved their success.

The Aerospace Metrics, as described in Section 7, form the basis for an annual benchmarking activity conducted by the UK Lean Aerospace Initiative (Stone et al, 2002). The wide adoption of the Aerospace Metrics is evidence that this approach can be valuable in aerospace.

8.3 Kaizen Costing for Cost Reduction

Kaizen (continuous improvement) activities are also widely used in the aerospace industry. They are used for a variety of purposes – to increase quality, increase throughput, reduce work-in-progress, implement pull/kanban systems and to reduce set-up times, cycle times and lead times, among others. Companies often find it difficult, however, to measure the financial impact of these activities. It may be possible to measure improvements at cell level and to estimate the potential savings of kaizen events. However, scaling up these improvements is a challenge and the financial impact is not usually obvious at an enterprise level.

The Japanese believe that standard costing is an unsuitable tool for cost reduction in the manufacturing phase due to its financial accounting purpose (Monden and Hamada, 1991). Instead, kaizen costing is used outside the standard costing system as part of the overall budget control system. Kaizen costing forms part of the target costing approach to the reduction of total product cost (as outlined in Section 4) but is applied during the manufacturing phase rather than during the New Product Introduction phase. Kaizen costing includes cost reduction activities that require changes to the manufacturing methods of existing products. It involves both cost reduction activities for each product and for each cost (Sakurai and Scarborough, 1997). Monden and Hamada (1991) describe how kaizen costing has been employed in the automotive industry. Japanese automotive companies do not implement the traditional cost variance analysis based upon the gap between the standard cost and the actual cost for each period. Instead, the actual cost per car for the latest period is the kaizen cost budget and that must be reduced in each successive period in order to meet target profit. Kaizen costing activities are undertaken to improve the performance of new product production where actual performance is significantly greater than target after three months and also to continually reduce the cost of existing products. Sakurai and Scarborough (1997) explain that, generally, Japanese companies control direct material and
labour costs through value analysis whereas they manage overhead mainly through budgeting, the empowerment of all employees and the use of approaches such as Total Quality, Total Productive Maintenance and others.

All this says little more than that all staff are urged to look continually for improved ways to operate and reduce costs and that this is enforced through tighter and tighter budgets. This will require a marked cultural shift in most Western companies if such attitudes are to be adopted throughout the enterprise. Also, the general exhortations to adopt kaizen in Western literature gives little insight as to how staff should organise the search for cost cutting and what techniques might prove useful. Aerospace companies adopting this approach need to be aware of the human resource cultural shifts that will be needed and organise kaizen by value streams with clear objectives set for each part of the stream. If that is not done, one might have considerable wasted effort with some groups locally optimising and, perhaps, developing new approaches that they see as relevant from their perspective that were considered and left aside when a broader perspective was taken at the target costing stage of New Product Introduction. Similarly, efforts at local improvement need to be aware of the on-going research being conducted off-line. In aerospace, it would seem that before moving into a general adoption of kaizen, there will be a need to classify different levels of improvement activity and ensure that each group involved is aware of the constraints within which it must search for improvements. Otherwise, overall co-ordination could suffer. Having stated that, when kaizen is adopted, it may well make use of all or any of the tools or approaches described in the rest of this section.

8.4 ABC and Cost Reduction

We have been careful throughout this report to explain where ABC might be useful and where it probably has little use, the latter being to provide product costs where there is a widespread application of cellular operations (i.e. value stream organisation). ABC logic may, however, have a central part to play in cost reduction, even where production and non-manufacturing activities are organised into value streams. For product costing one may not need to allocate many indirect costs to a manufacturing cell because all the resource inputs and associated costs for the product may be directly assigned to that cell, but, if each cell has continuing cost reduction responsibility, it will itself need to understand what drives the different types of costs that it incurs in its own cell. Cell members will need to be trained in the logic of cost drivers that underlies ABC.
8.5 The Cost of Waste

Value Stream Mapping can be used to expose non-value-added and wasteful activities (see Table 7 below) and, as a result, can be further developed in order to support waste elimination and cost reduction.

Table 7: Value Added, Non-Value Added and Wasteful Activities

<table>
<thead>
<tr>
<th>Type of activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value Added Activities</td>
<td>Those which actually create value as perceived by the customer</td>
</tr>
<tr>
<td>Non-Value Added Activities</td>
<td>Those which create no value but are currently required by the product</td>
</tr>
<tr>
<td></td>
<td>development, order filling, or production systems and cannot be eliminated at</td>
</tr>
<tr>
<td></td>
<td>present</td>
</tr>
<tr>
<td>Waste</td>
<td>Those actions which do not create value as perceived by the customer and can</td>
</tr>
<tr>
<td></td>
<td>be eliminated immediately</td>
</tr>
</tbody>
</table>

An analysis of the value stream by value added, non-value added and waste categories can be used to prioritise kaizen (continuous improvement) activities aimed at reducing costs, lead times, inventory and waste. Costing, accounting and financial data can be a valuable element of the value stream mapping process. This data can be used to illustrate the cost of delays, the costs associated with holding excess inventories and the costs of overproduction, for example. However, where companies have been structured along traditional functional lines, or traditional costing and accounting methods are still being used as the main control method within a lean operational environment, it is often difficult to obtain relevant data in the relevant format to support improvement activities.

A more detailed approach to waste classification to complement Value Stream Mapping can also be undertaken. Ohno (1988) has classified waste into seven categories, as shown in Table 8.

Table 8: The Seven Wastes

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Over-production</td>
</tr>
<tr>
<td>2</td>
<td>Waiting time</td>
</tr>
<tr>
<td>3</td>
<td>Transport</td>
</tr>
<tr>
<td>4</td>
<td>Poor process design</td>
</tr>
<tr>
<td>5</td>
<td>Excess inventories</td>
</tr>
<tr>
<td>6</td>
<td>Unnecessary motion</td>
</tr>
<tr>
<td>7</td>
<td>Defective parts</td>
</tr>
</tbody>
</table>
As already stressed, traditional costing systems may drive behaviours that actually cause some of these wastes, e.g. over-production and excess inventories, by focusing on labour productivity, machine utilisation and local optimisation. This in turn can lead to increased waiting times and can impact on quality standards. A value stream costing system should be able to identify these costs in order to support and drive continuous improvement efforts. A **Cost of Waste Index** could possibly be constructed to highlight the costs associated with the Seven Wastes.

### 8.5.1 Cost of Quality (or the cost of non-conformance)

The Cost of Quality is an approach to the measurement, management and control of quality defects in the production process (Kumar and Brittain, 1995). This approach assumes that quality is free and that it is a lack of quality that increases costs (Crosby, 1979). It is also assumed that these costs would disappear if products and processes were perfect (Juran, 1988). A Cost of Quality exercise could potentially capture a number of the Seven Wastes – defective parts, poor process design that results in defective parts and damage of parts as a result of transportation or excessive waiting times.

The Cost of Quality approach is broadly compatible with lean manufacturing practices. In lean manufacturing, high levels of quality are seen as a major enabler of cost reduction, both directly through reductions in scrap, rework and inspection, and indirectly by facilitating the reduction of inventory buffers and reduction in cycle time. The focus is also on the customer (internal and external) as right-first time quality is emphasised.

Womack and Jones (1996) illustrate the effectiveness of using a Cost of Quality approach in their case study of Porsche. The true costs of eliminating a defect at various points along the value stream were calculated. The findings are shown in Table 9:

**Table 9: Cost of Quality at Porsche**

<table>
<thead>
<tr>
<th>Cost of eliminating defect.....</th>
<th>Cost (German marks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>... at the point when defect occurs</td>
<td>1 mark</td>
</tr>
<tr>
<td>... at the end of the line</td>
<td>10 marks</td>
</tr>
<tr>
<td>... in the rectification area at the end of the plant</td>
<td>100 marks</td>
</tr>
<tr>
<td>... under warranty</td>
<td>1000 marks</td>
</tr>
</tbody>
</table>

Source: Womack and Jones, Lean Thinking, 1996, p199

It obviously pays to rectify defects as early in the value stream as possible.
Cook and Graser (2001) describe the attempts being made to cut the costs of quality in the US military aircraft industry. They draw attention to the fact that the costs of the Quality Assurance function are often estimated and reported as a percentage of factory labour or manufacturing costs, rather than collected in their own right. They suggest this is probably due to difficulties associated with collecting dispersed information and applying it to specific work areas within a production area. In our view this reflects the lack of a serious and determined effort to apply the basic principles of estimating the Cost of Quality which are now well established in standard form.

Most Cost of Quality exercises are ad hoc investigations and attempt to estimate costs in four categories:

• Costs incurred through defects that are not discovered until the products reach outside the firm
• Costs incurred because of defects identified within the firm
• Costs of defect prevention
• Costs of product appraisal for defects.

The underlying assumption is that manufacturing and operating processes can be changed such that they can be relied upon to be defect free, the costs of prevention and avoidance can also be removed. Often firms undertaking this form of analysis for the first time find anything between 10% and 20% of sales turnover is equal to the identified costs of non-conformance. Getting rid of such costs can have a dramatic effect on the bottom line (Atkinson et al, 1991).

For application in the aerospace industry, the approach has obvious validity in production and non-production operations at all levels. It may be less straightforward to apply in the research and design processes, but, where, these activities consist of fairly routine aspects, there may well be something to gain from applying Cost of Quality analyses there as well.

8.5.2 Cost of Waste Index

The concept of Cost of Quality would need to be expanded to capture the other elements of waste in order to construct a Cost of Waste Index. Table 10 illustrates the types of information required for the design of such an Index. A Cost of Quality exercise could capture information relating to a number of the Seven Wastes – defective parts, poor process design that results in defective parts and damage of parts as a result of transportation or excessive waiting times.
### Table 10: Constructing a Cost of Waste Index

<table>
<thead>
<tr>
<th>Waste</th>
<th>Types of Information Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Over-production</td>
<td>• Value of products made and not sold</td>
</tr>
<tr>
<td></td>
<td>• WIP inventories</td>
</tr>
<tr>
<td>2. Waiting time</td>
<td>• Value Stream Mapping – proportion of Value Added to Non-Value Added Activity</td>
</tr>
<tr>
<td></td>
<td>• Time compression - Reduction of cycle times, manufacturing lead times, order to delivery lead times etc</td>
</tr>
<tr>
<td>3. Transport</td>
<td>• Parts distance travelled</td>
</tr>
<tr>
<td></td>
<td>• Travel between different plants (parts/people)</td>
</tr>
<tr>
<td></td>
<td>• Logistics costs</td>
</tr>
<tr>
<td>4. Poor process design</td>
<td>• Six Sigma figures</td>
</tr>
<tr>
<td></td>
<td>• Floor space utilisation</td>
</tr>
<tr>
<td>5. Excess inventories</td>
<td>• Parts made for stock</td>
</tr>
<tr>
<td></td>
<td>• Parts made without customer order/kanban signal</td>
</tr>
<tr>
<td></td>
<td>• Over-ordering of parts from suppliers</td>
</tr>
<tr>
<td></td>
<td>• Inventory buffers</td>
</tr>
<tr>
<td></td>
<td>• Inventory levels – RM, WIP, FG</td>
</tr>
<tr>
<td></td>
<td>• Value of inventories</td>
</tr>
<tr>
<td></td>
<td>• Inventory carrying costs</td>
</tr>
<tr>
<td></td>
<td>• Materials handling costs</td>
</tr>
<tr>
<td>6. Unnecessary motion</td>
<td>• Time spent looking for tooling etc</td>
</tr>
<tr>
<td></td>
<td>• Ergonomics</td>
</tr>
<tr>
<td></td>
<td>• People distance travelled</td>
</tr>
<tr>
<td>7. Defective parts</td>
<td>• Scrap</td>
</tr>
<tr>
<td></td>
<td>• Rework</td>
</tr>
<tr>
<td></td>
<td>• Customer returns</td>
</tr>
<tr>
<td></td>
<td>• Supplier defects</td>
</tr>
<tr>
<td></td>
<td>• Inspection</td>
</tr>
<tr>
<td></td>
<td>• Warranties</td>
</tr>
</tbody>
</table>

In practice, companies may identify additional wastes, e.g. overtime, over-capacity, that they may wish to quantify as part of a Cost of Waste exercise.

At present, there may be a number of difficulties with the construction of a Cost of Waste Index. Much of the data required will not be readily available from current management accounts or information systems. Hence, ad hoc studies will be needed to establish such measures and it may be difficult to capture the relevant data. Also, employees may not be willing to gather the data that will put increasing pressure upon them. In addition, many organisations do not have Value Stream Managers and there may be issues as to who is responsible for data collection, analysis and any actions required as a result of such an analysis. Nevertheless, most large companies now have some measures of waste and it
would be valuable to use Table 10 to check whether their waste measurement systems are comprehensive enough and closely aligned to a continuous improvement process. Certainly companies that measure only rework, customer returns and excess inventory are overlooking possibly large areas where waste could be removed and profits improved.

### 8.6 Inventory Reduction

In many places in this report it has been clear that being lean implies, amongst other things, keeping low inventories. There is, therefore, some repetition in this section of earlier points. It was thought valuable, nevertheless, to include this section here in order to provide completeness in listing approaches to cost reduction for anyone just consulting this section.

One major element of waste within the value stream is excess inventory and, as a result, a key goal of lean manufacturing is inventory reduction. Womack and Jones (1996, p146) cite the example of Wiremold to illustrate the benefits of inventory reduction. The Wiremold company's inventory reduction strategy resulted in:

- freed up money to acquire other companies
- the avoidance of carrying costs (assumed 10%)
- the generation of extra sales volume
- freed up space to enable growth.

Value is added to products as they move through the manufacturing process and, therefore, the extent of the financial benefit from inventory reduction is dependent on the type of inventories that are reduced. Greater financial benefit is gained by reducing finished goods and work-in-progress inventories than reducing raw material stocks. Additional benefits arising from inventory reduction include reduced warehousing/ storage requirements, decreased floor space utilisation due to lower WIP and re-organised cell layouts, improved lead times and increased responsiveness to the customer.

Yoshikawa et al (1993) heavily emphasise inventory reduction to support JIT and make suggestions regarding the management of this process:

1. Inventory analysed by Raw Material, WIP and Finished Goods.
2. Inventory analysed by product type to identify where JIT is proving difficult to implement
3. Inventory analysed by physical location to show where buffers appear to be needed
4. Inventory aged by date of acquisition to help judge how near to usage stocks have been acquired
5. Stockholding can be projected forwards – can investigate exceptional lead times
6. Possibly impute a charge to all stock representing the real cost of funds which are invested in it - penalise the holding and growth of inventory
7. Attach costs to finished output and eliminate the tracking of WIP (Backflushing).

However, it can be difficult to isolate the financial benefits of inventory reduction and to convince all stakeholders that reducing inventories is the right thing to do. There are a number of reasons for this:

1. **Inventories are viewed as assets in terms of the financial accounts**
   Inventories are carried on the balance sheet as assets and that is said to encourage the holding of high stock levels. Womack and Jones (1996) acknowledge that inventories will still need to be valued as assets for the purpose of the financial accounts. However, they recommend that this information is not used for the purposes of shop floor control. This seems a strange argument. Is it really necessary to explain to managers that stocks need to be reduced where possible and not increased? In addition, different types of inventory will have different values and, while it will be beneficial to get rid of all types of excess stock it will be financially more advantageous to ensure first that the most valuable inventories are not over-stocked. That cannot be assessed without information on the value of stocks.

1. **Inventory carrying costs and materials handling costs are often hidden in overhead figures**
   Inventory carrying costs and materials handling costs are often hidden in overheads (Plenert, 1999). Plenert (1999) argues that these costs are actually a part of material costs and should be treated as such. By reducing inventory, the operating cost-saving effects of reducing carrying costs become apparent (Plenert, 1999). The Value Stream Mapping

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13 While sometimes heard as an argument, this is very misleading. Accountants, as a matter of course when interpreting the balance sheet for managers, would check that the stock-turn was not too low (i.e. inventories of stocks too high). That would be one of their routine ratio checks. If the fact that inventories are shown as assets in the balance sheet induces over-production, it will be because producers do not understand the balance sheet. We are very sceptical that this argument has much weight. The earlier arguments relating to the effects of absorption costing are probably a far more influential force for over-stocking.
exercise or the construction of a Cost of Waste Index may be a means of making these costs more visible.

2. *Rapid inventory reduction wipes out short-term profit (as shown in financial statements)*

Womack and Jones (1996) draw attention to the problems faced by publicly traded companies when inventories are run down over a short time period. As companies adopt cellular manufacturing and single-piece flow systems, huge amounts of cash are suddenly made available as a result of reducing inventory levels to support these systems. However, as explained earlier in this report, the removal of these inventories appears to increase production costs, as shown in the financial statement, and can easily wipe out profits. Womack and Jones (1996) suggest that, as a result of this phenomenon, companies often revert to “a slash and burn campaign of headcount and cost reduction to restore short-term profit”, damaging their efforts to introduce lean thinking in the process.

Inventory reduction is seen as vital in the aerospace industry, especially when the impact of design changes, customer re-scheduling and stock obsolescence are considered. However, UK LAI member companies believe that process stability must be addressed prior to inventory reduction efforts.

**8.7 Summary**

As regards accounting to support continuing improvement, there is much more that accountants can do other than just measuring improvement as shown in the accounts. We have outlined a range a variety of different ways in which accountants can help in identifying where improvement activities can best be focused and methods that can be used. We have no strong preference for any of these methods. Each company should examine the methods available and decide for itself which approaches to try. None of the approaches described are part of conventional accounting and so ad hoc studies will be needed and new ways developed to capture the relevant information. Studies in other industries have shown significant waste reductions from using some of these methods and there is no reason why aerospace should not benefit equally.
9. COST MANAGEMENT IN THE EXTENDED VALUE STREAM

9.1 Introduction

Many companies that adopt lean ideas initially focus on making changes within their own organisations. The predominant emphasis to date within the aerospace industry has been in the manufacturing area. More recently, aerospace companies have begun to extend lean ideas to the other areas of their businesses such as engineering and design, procurement and administrative functions. However, as lean ideas are adopted by individual companies, it becomes increasingly apparent that internal changes are not sufficient to maintain competitive advantage. Lean enterprises typically outsource a high proportion of the value-added of their products and, therefore, rely on highly efficient supply chains. The aerospace industry is characterised by a highly complex supplier base that is global in nature and cuts across numerous industries. Up to 70% of materials are bought-out at the prime level (Cook and Graser, 2001; Murman et al, 2002). Therefore, prime contractors are limited in the amount of cost of they can influence through internally-focused lean initiatives. In recognition of this, many aerospace companies have begun to develop lean supply chain practices, including:

- Supplier certification/ preferred supplier programmes/ key supplier management
- Supplier development programmes
- Early involvement of suppliers in design
- Just-in-time supply
- Total care packages.

These practices are designed to improve quality and delivery performance, increase levels of partnership, co-operation and trust between customers and key suppliers and reduce total costs. Consequently, cost management outside the traditional boundaries of a firm becomes increasingly important as lean practices are promoted throughout the supply chain. Cost management should be applied across the entire life of a product and should spread across entire supply chain, creating pressure to reduce costs through the supply chain (Cooper and Slagmulder, 1999).

Whilst there is much written about supply chain relationships and efforts to improve supply chain interfaces in order to reduce total acquisition and ownership costs, there is limited
information available relating to the management of cost throughout the supply chain in order to achieve these aims (Seuring, 2002). Within the UK aerospace industry, the Supply Chain Relationships in Action (SCRIA) programme is widely promoted by the Society of British Aerospace Companies. The SCRIA programme was developed in order to improve the performance of the UK aerospace industry through closer co-operation and partnership (Sigma, 2002). The SCRIA Code of Practice promotes the minimisation of total through life costs (SBAC, 2003). However, there is no supply chain cost management methodology proposed. The lack of a comprehensive framework for systematic cost management in the supply chain is seen as a major reason for companies continuing to take short-term cost-cutting measures as a temporary reaction to declining profits (Kajuter, 2002).

This section begins by examining existing supply chain costing methodologies and their potential for cost reduction. The section then moves on to consider cost management for extended value streams, arguing that this is a more targeted cost management approach and has the potential for greater cost savings than general supply chain costing methods.

9.2 Supply Chain Management

Before examining some cost management approaches that have been applied for the supply chain, it is valuable to take a look at some definitions of “supply chain” and “supply chain management”. Although these terms are widely used in both the business and academic arenas, there is a high level of confusion and ambiguity about their exact meaning (Croom et al, 2000; Casson and Burke, 2002). There are many definitions of supply chain, two of which are presented below:

Christopher, 1992: “network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer”.

Saunders, 1995: “the total chain of exchange from original source of raw material, through the various firms involved in extracting and processing raw materials, manufacturing, assembling, distributing and retailing to ultimate end customers”.

Casson and Burke (2002) suggest that there are three types of supply chain:

1. Intra-plant supply chain: the internal supply chain within a firm
2. Inter-plant supply chain: the external supply chain within the same industry
3. Inter-industry supply chain: the external supply chain that includes other industries.

Supply chain initiatives within the aerospace industry, such as SCRIA, focus on the inter-plant supply chain – external supply chains within the aerospace industry.

Casson and Burke (2002) also argue that supply chains are normally defined by reference to the customer and that the concept of supply chain tiering is widely accepted. Figure 5 below shows a graphical representation of a supply chain.

**Figure 5: Supply Chain**

<table>
<thead>
<tr>
<th>Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Suppliers</td>
</tr>
<tr>
<td>Tier 1 Suppliers</td>
</tr>
<tr>
<td>Tier 2 Suppliers</td>
</tr>
<tr>
<td>Raw Materials</td>
</tr>
<tr>
<td>Suppliers</td>
</tr>
</tbody>
</table>

It is believed that supply chains will become the central unit of competition, behaving like virtual business entities, with final customers pulling inventory through the chain (Cox, 1997; Tan, 2001). It is also suggested that companies should not seek to achieve cost reductions or profit improvement at the expense of their supply chain partners, but rather seek to make the supply chain as a whole more competitive (Christopher, 1992). Consequently, supply chain management is seen as an important business competence.

Harland (1996) defines Supply Chain Management as “managing business activities and relationships (1) internally within an organisation, (2) with immediate suppliers, (3) with 1st and 2nd tier suppliers, and (4) with the entire supply chain”. This implies that supply chain cost management is included. However, there little research has been done in this area. This section will present the little research output that is available in this field and suggest how this may be used to support lean initiatives.
9.3 Supply Chain Cost Management Approaches

9.3.1 Activity-based Costing for Internal Supply Chains
Slagmulder (2002) suggests that Activity-based Costing (see Section 5 for a more detailed explanation) can be used as an effective means of recognising supply chain costs within a firm and identifying some cost reduction opportunities. This involves assigning costs to customers and suppliers as well as to products, as demonstrated in Figure 6 below.

Figure 6: The Activity-based Costs of Suppliers and Customers

![Figure 6: The Activity-based Costs of Suppliers and Customers](image)

Note: SG&A = Selling, General & Administrative Expenses
Source: Slagmulder, 2002

Slagmulder (2002) argues that without the proper assignment of purchasing costs, purchasing managers are motivated to select suppliers on the basis of purchase price. This can weaken a firm’s strategic position as components may be purchased from suppliers whose quality, reliability and delivery performance is below acceptable levels. This in turn can have an adverse effect on customer satisfaction. It would be more valuable for purchasing managers to evaluate suppliers on total cost rather than purchase price. Once identified, supplier costs can be assigned to products. Products containing large numbers of unique components that rely on speciality suppliers will be viewed as more expensive than products that contain standard components that can be bought on the open market. This has the advantage of encouraging designers to investigate options for parts standardisation and pursue a Design for Manufacture approach.

A similar approach is recommended for Selling, General & Administrative (SG&A) costs. These costs are usually spread evenly over all products based on sales revenue. As a result, customers appear to cost either nothing or to cost the same proportion as their sales revenue. Therefore, it is not possible to determine individual customer profitability. Using Activity-based Costing, it is possible to assign customer-related costs to the customer creating them. The enhanced knowledge of customer profitability can be used attract and retain high-profitability customers.
Slagmulder (2002) recognises that although supplier and customer focused Activity-based Costing extends cost management beyond the production area, it does not require joint action by buyers and suppliers to reduce costs. However, it may encourage companies to examine the issues involved and identify areas for waste elimination and cost reduction internally. It also may act as a catalyst for discussions between buyer and supplier firms even though it does not explicitly require this. This does not explicitly take a lean or value stream perspective. However, it could be used to support the cost reduction activities of specific value streams.

9.3.2 Supply Chain Costing
Seuring (2002) defines Supply Chain Costing as “a cost management technique that allows the analysis and control of all costs in a supply chain”. He classifies these costs into:

- Direct costs
- Indirect costs (or activity-based costs)
- Transactions costs (Seuring, p111, 2002).

Conventional cost management focuses on direct and indirect costs within individual firms. A broader perspective of cost management is required for the supply chain and consequently transactions costs are also included. Transactions costs are caused by the interaction of firms within the supply chain and can only be influenced jointly. Cost reduction opportunities exist at each of these levels. Seuring (2002) argues that increases in the costs at one level, especially the transaction costs level, may reduce costs at other levels. However, there are difficulties in separating out transactions costs from other indirect costs.

This approach is similar to that described in 9.3.1.

9.3.3 Inter-organisational Cost Management
Cooper and Slagmulder’s (1999) work on Inter-organisational Cost Management provides a valuable contribution to cost management throughout the supply chain. They identify three ways to reduce cost outside the boundaries of the firm:

1. During product design
2. During manufacturing
3. By improving buyer-supplier interfaces.
Supply Chain Cost Management during Product Design
The most widely advocated technique for cost management throughout the supply chain
during the product design phase is Supply Chain Target Costing. Supply Chain Target
Costing is an extension of Target Costing (as described in Section 4). This approach is seen
to be appropriate where outsourced items are high in value, there is complex production
across many firms and lean supply relationships are being pursued (Cooper and
Slagmulder, 1999). Consequently, it is valuable to examine its applicability to the aerospace
industry.

Supply Chain Target Costing is a mechanism by which competitive pressures can be
transmitted through a supply chain. The output of the buyer’s target costing system becomes
the input to the supplier’s target costing system, i.e. the component-level cost within the
buying firm establishes the selling price for the next firm in the supply chain. This can be
used as a basis for contracting with suppliers. Aerospace customers are beginning to
employ this approach. However, at present, the Target Costing process is still supported by
standard costing systems.

As described in Section 4, at the product design stage, there is the opportunity to increase
the value of a product through the use of value engineering. This can be done in two ways:

1. Increasing functionality without increasing price
2. Reducing cost without reducing functionality.

Target Costing is a technique for profit management, ensuring that future products generate
long-term profits. Ansari and Bell (1997) emphasise the importance of using Target Costing
in the supply chain as a means of building long-term supplier relationships and involving key
suppliers early in the design process, in order that all firms within the supply chain maintain
an adequate level of profitability. Within the supply chain, investigations can be undertaken
in order to identify specific cost reduction opportunities. The early involvement of key
suppliers can highlight opportunities for re-design of the product and/ or components that will
result in reduced total product cost. This method of working requires high levels of trust, co-
operation and partnering. Moreover, this type of “forward analysis” can also take place
collaboratively on off-line research.

Supply Chain Cost Management during Manufacturing
In a similar manner to the extension of Target Costing through the supply chain, Kaizen
Costing can be extended to the supply chain at the manufacturing stage. Kaizen Costing (as
described in Section 8) can be applied to a new product launch whose costs are too high or to an existing product whose selling price is falling faster than its costs. It is important to realise that at the manufacturing stage, the functionality of the product cannot be changed and, therefore, the emphasis is on cost reduction of the existing design (Cooper and Slagmulder, 1999). In the aerospace industry, improvements at the manufacturing stage that would require design changes are extremely difficult to implement due to validation, certification, safety and legal requirements. Therefore, efforts centre on manufacturing process improvements.

This pressure for cost reduction can be transferred to the supply chain. Buying firms can work with their suppliers to reduce costs by a specified amount over a specific time period or to reduce the costs of a specific product. This can be achieved by including suppliers in kaizen events conducted at the buyer firm or by the buyer firm assisting the supplier to achieve the required cost reductions. Within the UK aerospace industry, a number of prime contractors are making significant efforts to co-ordinate cost reduction activities within their supply chains. However, these efforts are not necessarily consistent and different prime contractors are taking different approaches. In an effort to address these issues, the SBAC is promoting Masterclass-Supply Chain Groups, which is a structured approach to continuous improvement and cost reduction within a host company and a number of its suppliers.

**Improving Buyer-Supplier Interfaces**

Improving the efficiency of buyer-supplier interfaces requires an examination of all the activities and processes associated with the transfer of goods and/or services between firms in the supply chain (Cooper and Slagmulder, 1999). These activities and processes include:

- Order placement
- Invoicing and payment
- Inventory management
- Transportation and logistics.

Cooper and Slagmulder (1999) claim that improvements in these activities and processes will not only result in reduced transactions processing costs but will reduce uncertainty and inventory levels. Table 11 below illustrates the types of initiatives that can be introduced in order to improve links and reduce costs within the supply chain.
Table 11: Initiatives to Improve the Efficiency of the Buyer-Supplier Interface

<table>
<thead>
<tr>
<th><strong>Buyer initiatives</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Demand management</td>
</tr>
<tr>
<td>2. Adequate order lead times</td>
</tr>
<tr>
<td>3. Reduce the amount of special ordering</td>
</tr>
<tr>
<td>4. Share forecasts</td>
</tr>
<tr>
<td>5. Use of purchase contracts</td>
</tr>
<tr>
<td>6. Payment on receipt</td>
</tr>
<tr>
<td>7. Increase communications accuracy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Supplier initiatives</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reduce delivery cycle times</td>
</tr>
<tr>
<td>2. Increase on-time delivery</td>
</tr>
<tr>
<td>3. Reduce production cycle time</td>
</tr>
<tr>
<td>4. Share performance metrics</td>
</tr>
<tr>
<td>5. Allow access to order status info</td>
</tr>
<tr>
<td>6. Increase control over buyer’s inventory</td>
</tr>
<tr>
<td>7. Increase accuracy of communications</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Joint initiatives</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Electronic commerce</td>
</tr>
<tr>
<td>2. Improvement of order-delivery process</td>
</tr>
<tr>
<td>3. Collaborative forecasts</td>
</tr>
</tbody>
</table>

*Source: Cooper and Slagmulder, 1999, Chapter 14*

In addition, Cooper and Slagmulder (1999) provide a useful framework for identifying the levels of cost management required at different levels of the supply chain. This is shown in Table 12.
Table 12: Cost Management Requirements at Different Levels of the Supply Chain

<table>
<thead>
<tr>
<th>Role</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prime Contractor</td>
<td>• Suppliers involved in the earliest stages of product development</td>
</tr>
<tr>
<td></td>
<td>• Joint design of the product and the major functions it contains</td>
</tr>
<tr>
<td></td>
<td>• High level of cost information sharing</td>
</tr>
<tr>
<td></td>
<td>• Concurrent cost management</td>
</tr>
<tr>
<td>Major Equipment Supplier</td>
<td>• Interactions enable costs to be reduced by re-designing the major function and, when necessary, the end product</td>
</tr>
<tr>
<td></td>
<td>• Sophisticated interactions between buyer and supplier design teams</td>
</tr>
<tr>
<td></td>
<td>• Inter-organisational cost investigations</td>
</tr>
<tr>
<td>Sub-contractor</td>
<td>• Focus of cost management is on finding ways to relax the buyer’s specifications so that the product can be manufactured at a lower cost</td>
</tr>
<tr>
<td></td>
<td>• Use of chained target costing and functionality-price-quality trade-offs</td>
</tr>
<tr>
<td>Suppliers</td>
<td>• Minimal cost management</td>
</tr>
<tr>
<td></td>
<td>• Lowest total cost provider chosen by the buyer</td>
</tr>
<tr>
<td></td>
<td>• Interaction primarily based on target costing, with the buyer’s target costing system identifying the price for the supplier</td>
</tr>
</tbody>
</table>

Source: adapted from Cooper and Slagmulder, 1999, Chapter 4.

Inter-organisational cost management heavily emphasises firms working together to reduce costs, in addition to cost reduction exercises within both the buyer and supplier firms. However, although this is a good starting point, this concept is still somewhat limited in that the emphasis is on interactions between the buying firm and the supplier firm. This means that it may only be used in parts of the supply chain, e.g. a prime contractor with its first tier suppliers, and may not lead to a fully integrated approach across the wider value stream.

There is also a danger that the use of the firm as the unit of analysis within supply chains will make cost management more difficult and require complex overhead allocation methods. The next section, therefore, will examine the concept of cost management in the Extended Value Stream as a possible alternative (i.e. the unit of analysis is the value stream not the firm).
9.4 Cost Management in the Extended Value Stream

It is believed that the value stream is a more useful unit of analysis than supply chain or supply network (Hines et al, p53, 2002). Although the term “value stream”, as defined by Womack and Jones (1996), incorporates all the activities require to transform raw materials into a finished product delivered to the customer, it is often used to mean the internal value stream(s) within a particular firm. Therefore, the term “extended value stream” is used to convey the meaning more clearly. Extended value streams track interactions between firms relating to the delivery of specific products whereas the terms “supply chain” and “supply network” analyse the interactions between firms but not necessarily in relation to the delivery of specific products. Figure 7 illustrates how the “value stream” concept differs to the “supply chain” concept.

Figure 7: Extended Value Stream

<table>
<thead>
<tr>
<th>Company A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Value Stream (VS) 1</strong></td>
</tr>
<tr>
<td>Key Suppliers to VS1</td>
</tr>
<tr>
<td>Tier 1 Suppliers to VS1</td>
</tr>
<tr>
<td>Raw Materials Suppliers to VS1</td>
</tr>
</tbody>
</table>

The concept of extended value streams is very useful as a means of analysing the aerospace industry particularly as:

(i) the industry is structured around aircraft programmes, which effectively represent one core value stream (Murman et al, 2002); and

(ii) firms within the industry can occupy different positions in the supply chain depending on their level of involvement with different programmes.

For example:

Take 2 aerospace companies, A and B;

At any one time:

- A may be a customer of B for Programme 1
- A may be a supplier to B for Programme 2
- A and B may be in a joint venture on Programme 3
- A and B may compete on Programme 4
- A and B may compete for the support contracts on any or all of the above programmes.
Therefore, if “supply chain” or “supply network” thinking is adopted, and the unit of analysis is taken to be at the level of the firm, then the aerospace supply chain or supplier network would appear hugely complex and any meaningful analysis would prove difficult. If, however, the extended value stream concept is used, analysis becomes simpler and also more meaningful.

Many lean supply initiatives are focused on Tier 1 suppliers, strategically important suppliers or under-performing suppliers but often fail to incorporate lower tier suppliers even though these suppliers may be vital to the success or otherwise of the final product (Johns et al, 2002). Inter-organisational Cost Management ideas could be adopted in these type of initiatives and result in benefits to the companies involved. However, the hypothesis proposed here is that an extended value stream approach to cost management will have the most significant impact on total cost. The adoption of Inter-organisational Cost Management ideas in an integrated manner throughout extended value streams has the potential to produce significant benefits. It also represents a huge challenge, requiring many companies to work together on joint cost reduction activities and the transmission of cost reduction requirements from one firm to another all along the extended value stream.

The aerospace industry has begun to adopt cost management practices that reflect a value stream logic. Due to the nature of the aerospace industry and its focus on aircraft programmes, product value streams can be readily identified. Certainly, the need for integrated cost management is becoming increasingly important not only for the production of aerospace products but in design for through-life affordability. It is recognised that it is no longer appropriate to procure equipment on the basis of purchase price alone and total care packages are becoming more the norm along with an emphasis on Total Cost of Ownership.

### 9.5 Total Cost of Ownership

The aerospace industry is moving away from procuring products on the basis of purchase price only. The industry is now concerned with life-cycle affordability and “design for best value life-cycle” (Murman et al, 2000, 2002). Previously, aerospace products were sold at relatively low prices, with companies exploiting the lucrative in-service support market for spares and MRO (maintenance, repair and overhaul). In the current environment, new ways of working are emerging based on the concept of Total Cost of Ownership. For example, aero-engine sales are often based on “power-by-the-hour” contracts. This has serious financial and cash flow implications for the Original Equipment Manufacturers (OEMs) as the...
incentive is now to keep requirements low and spares move from being a profit centre to a cost. Performance-based logistics support contracts for legacy equipment are becoming the norm, with the prime contractors providing a total supply chain solution to the customer.

The case of the UK Ministry of Defence (UK MoD), and in particular, its adoption of SMART Acquisition, is used to demonstrate how some of these concepts are being applied in practice.

9.5.1 SMART Acquisition

Over the past few years, the UK MoD has introduced a new approach for the acquisition of defence equipment. SMART Acquisition builds on the SMART Procurement Initiative and takes a life-cycle view of equipment acquisition - from requirements through manufacture, operations and support to final disposal. The primary aim of SMART Acquisition is “to enhance defence capability by acquiring and supporting equipment more effectively in terms of time, cost and performance” (UK MoD, 2002).

The Acquisition Handbook (UK MoD, 2002) spells out the objectives and key features of the SMART Acquisition approach, see Table 13 below.

Table 13: SMART Acquisition Objectives and Key Features

<table>
<thead>
<tr>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>• To deliver projects within the performance, time and cost parameters approved at the time the major investment decision is taken (Main Gate).</td>
</tr>
<tr>
<td>• To acquire military capability progressively, at lower risk, and with optimisation of trade-offs between military effectiveness, time and whole-life cost.</td>
</tr>
<tr>
<td>• To cut the time for key new technologies to be introduced into the front line, where needed to secure military advantage and industrial competitiveness.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key features</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Whole-life approach – embodied in a single Integrated Project Team (IPT) bringing together main stakeholders. The IPT exists for the life of the project, moving from DPA to DLO at the appropriate time. Industry is part of the IPT except where competition makes this impractical.</td>
</tr>
<tr>
<td>• Clearly identified customers.</td>
</tr>
<tr>
<td>• A willingness to identify, evaluate and implement effective trade-offs between system performance, whole-life costs, annual cost of ownership and time.</td>
</tr>
<tr>
<td>• An open and constructive relationship with industry, based on partnering and the identification of common goals including gain-share opportunities, underpinned by competitive contractor selection whenever this provides best value for money.</td>
</tr>
<tr>
<td>• A streamlined process for project approvals.</td>
</tr>
</tbody>
</table>
The Whole-Life approach is central to SMART Acquisition and this can be seen in Figure 8 below:

**Figure 8: The Acquisition (CADMID) Cycle**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Assessment</th>
<th>Demonstration</th>
<th>Manufacture</th>
<th>In-service</th>
<th>Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial gate</td>
<td>Main gate</td>
<td>Transfer to DLO</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The MoD’s drive to reduce the Total Cost of Ownership of defence equipment, reduce Defence Procurement Agency (DPA) and Defence Logistics Organisation (DLO) operating costs and provide value for money have significant cost management implications for the aerospace defence industry. The MoD is committed to achieving these aims by adhering to the SMART Acquisition principles with their focus on through-life management and partnering with industry.

The adoption of SMART Acquisition principles will require a new approach to cost management through the supply chain and across the life-cycle, extending the cost reduction focus from individual companies to entire value streams. This represents a huge challenge to all stakeholders and there is limited existing research to guide the way (Seuring, 2002).

Innovative contracts and partnering arrangements are currently being introduced for logistics support and fixed price performance-based contracts are becoming more widely used. An example of an innovative contract will now be described in order to demonstrate the radical change in the MoD’s approach to cost management in the aerospace defence supply chain and to illustrate the business practices that are likely to be applied in the wider aerospace industry.

**9.5.2 An Example of an Innovative Contract**

An innovative contract has been set up between the Defence Logistics Organisation (DLO) and a prime aerospace defence contractor for the support of a particular aircraft type which for the purposes of this report will be known as MilFly. MilFly is a mature product with an established support chain.

The support of MilFly is now conducted as a partnering arrangement between the DLO and the prime contractor. Previously, support had been provided on a transactional basis and the DLO was involved in a large number of individual contracts with various suppliers in the
MilFly supply chain. However, there was little visibility of orders from the DLO and unforeseen bulk orders often caused demand surges that the supply chain could not support. As a result, industry lead times were long resulting in operational problems for the MoD. However, the prime contractor was keen to offer a more complete service and as a result pursued a partnering arrangement.

The development of the MilFly logistics support partnering arrangement represents a radical change in approach from how logistics support contracts have traditionally been managed. This new approach enables the MoD to specify value more clearly and the partnering arrangement should improve both information and material flows throughout the MilFly supply chain. This will have significant implications for cost management through the supply chain as the MoD will no longer be conducting large numbers of transactions with individual suppliers but will empower the prime contractor to manage the complete service.

It is believed that the partnering arrangement will result in smoother, more predictable demand as the prime contractor now manages the demand for both spares and repairs and offers a guaranteed turnaround time for a guaranteed price. The prime contractor represents a single point of contact for the MoD and is responsible for the MilFly support chain.

The aim of the partnering arrangement is to drive down the MilFly Cost of Ownership. A guaranteed turnaround time reduces the number of capital assets required by the MoD and impacts on the future cost of procurement. A Cost of Ownership model was applied to MilFly from 1999. There is an annual review of the Cost of Ownership and this can be revised if there has been a “step change” since the previous year. Examples of “step changes” include changes in the usage levels of MilFly, significant changes in work volumes and new government regulations. In addition, there is a gainshare element which includes process improvement. A specialist team has been put in place to identify process improvement activities to achieve the desired level of savings. The team is comprised of representatives of the main stakeholders – the MoD, the prime contractor and two of the major equipment providers.

The contract covers the life of MilFly. However, prices are agreed for a three year period and are adjusted for inflation. A risk factor of 5% is included. Payments are based on the average cost per annum, unless a “step change” has been negotiated and agreed. In terms of gainshare, the prime contractor is to receive a cash payment of 20% of any Cost of Ownership savings over the three year period.
The prime contractor uses a similar approach to support another of its aircraft types and is currently trying to develop partnering arrangements for two of its less mature products. It is expected that the Cost of Ownership modelling will be easier in the future because comparisons can be made to the MilFly situation.

The MilFly support contract incorporates many innovative features and highlights the positive directions both the MoD and industry are taking to develop more effective relationships. This type of partnering arrangement focuses on eliminating waste from the value stream by reducing the number of contracts placed for logistics support. The prime contractor takes on the responsibility for managing a total care package and must demonstrate supply chain reliability in order to support MoD requirements and ensure supply. The adoption of partnering arrangements removes layers of complexity and bureaucracy by using a single point of contact. There is huge potential for cost and lead time reduction as a result of these new practices. In addition, the successful testing of partnering arrangements for the support of mature products will enable these arrangements to be extended to new products in the future.

9.5.3 Implications for the Aerospace Industry

UK LAI member companies recognise the need for collaboration between customers and suppliers, particularly at the New Product Introduction stage, in order to reduce total costs. It is expected that the style of working promoted through innovative contracts, such as the MilFly example outlined above, will become the norm throughout the aerospace industry. The Aerospace Innovation and Growth team (AeIGT) is advocating a new business model where value chains compete against value chains in order to minimise total acquisition costs (AeIGT, 2003). The AeIGT also calls for connectivity, where “all players in a supply chain work together with a common strategy to create value for customers and end users”. The aim of reducing total acquisition costs for aerospace equipment relies on all stakeholders working in an integrated manner to clearly specify customer value, to smooth the flow of information and materials through aerospace equipment value streams and to eliminate waste from products and processes. Cost reduction activities need to extend beyond individual firms in order to realise cost savings at the value stream level. Supply chain management, and consequently, supply chain cost management, becomes increasingly important as total care packages, partnering arrangements and risk/revenue-sharing become more widespread throughout the aerospace industry. It is probable that small to medium-sized enterprises (SMEs) will no longer have the opportunity to deal directly with the final customers. Their involvement is more likely to be through the prime contractors as part
of an extended value stream and, therefore, sustained participation in lean initiatives and supplier development activities organised by the primes is of significant importance to SMEs.

Inevitably, innovative practices generate significant challenges for the industry. It is important that sophisticated methods of Life-cycle Costing (as described in Section 4) and Cost of Ownership calculation are developed in order to support a through-life management approach and to expand the use of innovative contracts and solutions and partnering arrangements. Currently, there are issues regarding the use of Life-cycle Costing and Cost of Ownership, particularly as the basis for contracting, due to difficulties in the collection of data and the use of different cost models. Failure to resolve the Cost of Ownership data collection issues has the potential to undermine the whole-life approach. A joint, pro-active approach to resolving these issues could result in an effective business model which could be used throughout the aerospace supply chain to generate real reductions in total cost, to minimise risk at all levels and to equitably share performance improvement benefits.

Incentives and gainsharing opportunities will be critical to the success of lean initiatives throughout the aerospace industry (Ward and Graves, 2003). The failure of customers to recognise both the financial and non-financial benefits of improvement activities may hinder moves to adopt partnering arrangements and innovative solutions which require close cooperation and high levels of trust. The development of a clear framework for the identification and sharing of the benefits of lean activities throughout aerospace value streams needs to be addressed.

9.6 Summary

The aerospace industry is characterised by high levels of outsourcing at the prime level, with up to 70% of cost residing in the supply chain. Consequently, there is a need to control costs within the supply chain to achieve reductions in total cost while simultaneously protecting the economic viability of supply chain companies.

There is an assumption that supply chain management practices will result in total cost reduction. However, there has been limited research conducted in the area of supply chain cost management. For the aerospace industry, a strong emphasis on systematically reducing total costs within extended value streams should result in greater benefits than more general cost reduction activities in the supply chain. Inter-organisational cost management techniques, including the extension of target costing, performance monitoring
and continuous improvement, as discussed throughout this report, promise to deliver significant benefits. They will yield even greater benefits if they are adopted in an integrated manner throughout extended value streams. They have the potential to support the aerospace industry as it moves towards contracting on the basis of Total Cost of Ownership. However, it is important that more sophisticated methods of calculating Cost of Ownership are developed along with methods for quantifying and sharing benefits throughout the extended value streams.
10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Summary of Findings

The adoption of lean principles and practices in the aerospace industry since the early 1990’s was a response to shrinking defence budgets and falling passenger demand. It was expected that lean practices would increase the competitiveness of the industry, improve productivity and quality, and reduce total product costs. The current aerospace climate reinforces the need to build on the lean foundations that have already been put in place. “Islands of excellence” need to be replaced by fully integrated lean value streams, supported by appropriate cost management and accounting approaches. Preliminary UK Lean Aerospace research concluded, however, that although aerospace companies may know the direction they are taking with regard to the implementation of lean practices, they are unclear about the direction that accounting practices should take to support lean ideas (Crute et al, 2003).

Experience has shown that in some ways lean operational developments have moved ahead of management accounting practice. There is also current concern that traditional costing and accounting systems are not necessarily appropriate to support efforts to apply lean principles. There has, however, been no clear analysis of what type of cost management and accounting aerospace companies might best adopt.

This report has attempted to address this issue directly. It has described precisely how problems may arise from the continued use of traditional costing and accounting systems in a lean environment. These problems can largely be reduced to three factors:

1. Full absorption costing on traditional volume-related bases can lead to distortions in product costs which may cause erroneous product mix decisions in parts of the industry
2. Full absorption inventory valuation as used in financial accounts and used for monitoring overall profitability performance may give signals that conflict with the benefits gained from introducing lean manufacturing methods
3. Management accounting performance measures, especially standard cost variances and labour productivity measures, may encourage local optimisation rather than an optimal flow in response to customer need.

The report also suggests specific ways to solve these problems.
It was found that limited research was available that examines in-depth the costing and accounting requirements of lean enterprises. This report outlines most of what exists already and acknowledges that it represents some valuable initial insights, although such work that does exist is largely conceptual in nature rather than empirically based, except for a number of case studies. It is also still evolving with some key authors still updating and amending their proposals. Moreover, both questions about the continued relevance of some accounting practices from non-accountants and the proposals of the few accountants focusing explicitly on “lean accounting”, tend to emphasise costing and accounting at the manufacturing stage and on the elimination of waste within the accounting process itself. While such matters are important, and this is a good foundation to begin looking at making changes to the costing and systems, a broader perspective is required for the aerospace industry. The huge levels of investment required during the new product introduction phase combined with long lead times and long product lives indicates that a major effort is needed to design accounting and cost management procedures that assist in cost reduction efforts at the design and development stage. While there is a growing body of accounting literature that addresses this issue, it has not been emphasised sufficiently in the limited lean accounting work to date and, with regard to aerospace in particular, it is of vital importance.

This report, consequently, has examined cost management and accounting approaches, tools and techniques that may be appropriate for lean aerospace enterprises across both planning and manufacturing phases of operation and offers definite proposals for appropriate costing and accounting methods under three key headings:

1. New Product Introduction,
2. Manufacturing,
3. Extended Value Streams, i.e. between interacting firms in supply chains for specific value streams.

10.1.1 New Product Introduction
It is widely recognised that there are significant opportunities to reduce total product costs during the New Product Introduction phase. As just stated, up to 80% of costs may be committed by the end of the detailed design stage. This report has outlined two methods – life-cycle costing and target costing – that can be applied with the aim of reducing product costs throughout the life-cycle. Although the two approaches have a different underlying philosophy, they are both compatible with each other and complementary to lean ideas. Both target costing and life-cycle costing have a whole-life and value stream focus. Target costing
explicitly focuses on providing value to the customer through a process of continuous improvement, innovation and cost reduction during the design process. Accounting can help to direct this cost-cutting approach if functional costing is also developed to analyse both cost and customer value by the attributes of the product. Life-cycle costing aims to identify cost behaviours over the life-cycle of a product and this analysis may then be used to identify cost reduction opportunities. Linking life-cycle analysis with target costing ensures that balances between capital costs and operating costs are considered in the product design.

Both approaches are applicable in the aerospace sector. Aerospace product life-cycles are extremely long and it is important that in-service support and disposal issues are considered in the early stages. Target costing models are already used to some extent within the aerospace environment, although the approach needed will be a variation on the Japanese auto-industry method as it may not be possible to identify a true market-derived target price. The move to total care packages, prime contracting and “power-by-the-hour”-type contracts increases the need for target costing and life-cycle costing approaches. The ideal approach, then, would be a combination of the two methods – an extension of target costing to all life-cycle phases. This would enable the aerospace industry to proactively protect and enhance profitability throughout the value stream and across the life-cycle.

We stress, however, that a full integration of target costing with a complete life-cycle analysis is the ideal. In practice, it is difficult to establish target costs for all life-cycle phases, particularly in the aerospace sector where life-cycles are extremely long. The forecasting and prediction of costs, the changing nature of customer requirements over time and the impact of technological advances will remain significant issues for the use of such techniques as life-cycle costing and target costing within the aerospace industry. These problems may be lessened, however, by using target costing and life-cycle costing initially for just the first generation of a projected generic series of aircraft, with allowance made in the construction of the asset for flexibility for future development. Target costing and life-cycle analysis with associated value engineering would be undertaken each time that a significant model change is to be made.
10.1.2 Manufacturing
During the manufacturing stage, following Kaplan, we distinguished between various different purposes for which accounting information might be required to support lean ideas. It was concluded that it was very important to keep these different purposes separate if clear implications for accounting were to be developed.

Firstly, we addressed product costing and the literature that argues that traditional full absorption costing using simple volume bases to allocate overhead costs could provide very misleading figures for the cost of different products. In general, we totally agree with this view, but, when we look at its relevance to aerospace, the argument will lose some of its force if by product one means sizeable aircraft, spacecraft or major systems. Then it is most likely that the physical “manufacturing” of these assets will be kept separate with separate accounting. This would then be tantamount to organising the production process by value streams. To the extent to which this is true, aerospace firms will not have a serious overhead cost allocation problem for costing this type of large, project-related product. The costs will all be assigned to the project.

Where, however, in aerospace, one is addressing the cost accounting needs for the production of smaller systems, original components and materials or after-market components, the products being produced may well call upon common overhead services and more care will need to be exercised in allocating costs to different products. Activity-based methods should be considered if initial tests show that they would result in significantly different figures from existing methods. Such problems would be resolved, or considerably lessened, if even the production of such items were organised on a value stream basis as some operational researchers propose, but reorganisation in this way should depend upon operational arguments and not accounting ones. Our view is that where possible a value stream basis to production organisation will enable a better adoption of lean production methods such as cellular manufacture, but accounting must follow and support operations, not the other way around. As this report is addressing how accounting can support lean operations, we assume that most firms wanting to be lean will move to a form of value stream organisation and, then, the overhead problem in product costing becomes less severe. However, firms producing a high variety of components are unlikely to be able to avoid the cost allocation problem completely.

Second, we addressed accounting for operational monitoring and control. Our conclusions there indicated that non-financial indicators were needed to supplement accounting reports.
The list should, however, be sparse and, where possible, linked with financial measures. We then argued that, it was important to address the basis of financial accounting (i.e. the production of profit and loss accounts and balance sheets) as they are used internally to monitor profitability and, when constructed on traditional lines did give conflicting signals of the benefits to be gained from “going lean”. We addressed the reason for this and several approaches to a solution, concluding that aerospace firms should seriously consider the use of “backflushing” where they had not already done so. Once more, this proposal related to the exercise of financial control over and measuring periodic profit for normal volume production of smaller systems and components and not the production of major aircraft.

Third, we addressed how accounting can support continuing improvement efforts. A variety of different approaches were discussed. We have no strong preferential ranking of these methods. All can be useful and link directly to the lean principles of waste elimination and cost reduction.

10.1.3 Extended Value streams
Cost management and accounting systems also need to have an external dimension. The aerospace industry is characterised by high levels of outsourcing at the prime level, with up to 70% of cost residing in the supply chain. Consequently, there is a need to control costs within the supply chain to achieve reductions in total cost while simultaneously protecting the economic viability of supply chain companies.

There is an assumption that supply chain management practices will result in total cost reduction. However, there has been limited research conducted in the area of supply chain cost management. Initial work in this area tended to focus on ensuring that buy decisions were made on full ownership costs rather than just costs of acquisition or customer and sales outlet analyses. These forms of analyses often also used the firm as the unit of analysis. For purposes of cost reduction and continuous improvement, the concept of extended value streams may be a more appropriate unit of analysis within the aerospace industry. Inter-organisational cost management techniques, including the extension of target costing and kaizen costing, promise to deliver significant benefits if they are adopted in an integrated manner throughout extended value streams. They have the potential to support the aerospace industry as it moves towards contracting on the basis of Total Cost of Ownership. However, it is important that more sophisticated methods of calculating Cost of Ownership are developed along with methods for quantifying and sharing benefits throughout the extended value streams.
10.2 Implications for Accountants and Financial Personnel

The adoption of lean thinking by organisations and the pressure for cost reduction across the life-cycle and throughout the supply chain has huge implications for the future role of finance personnel. It seems clear that finance personnel will be expected to adopt a pro-active culture, where they act as business consultants within their organisations, understand the core business in-depth and add value by supporting continuous improvement efforts.

The involvement of accountants in improvement activities has the potential to create significant benefits for organisations that are adopting lean practices. Finance and accounting staff have the skills to educate employees with regard to the financial implications of their actions. Finance and accounting personnel can also contribute greatly where there is a need for quantitative analysis. They can work more closely with engineers at the design and development stage and can become involved in the development of operational control measures, both financial and non-financial, across the business and for the finance area itself. This would support both operational and financial improvement.

It is also important that companies also apply lean thinking innovatively within the finance area. Lean principles, tools and techniques can be used to integrate business and manufacturing cultures, to eliminate wasteful accounting processes and to encourage the continuous improvement of finance activities. The adoption of lean ideas by finance personnel enables all employees to focus on core business activities and to drive improvement at enterprise level.

There are significant challenges to be overcome as a result of lean operations impacting on financial support requirements. There may be conflicts between the needs of operations personnel and the needs at corporate level. Finance personnel face the challenge of continuing to support traditional practices while simultaneously attempting to serve the needs of lean operations. Another major challenge is posed by the systems available to support the production of financial, costing and management accounting information. The existence of numerous legacy systems within organisations, combined with the implementation difficulties associated with Enterprise Resource Planning (ERP) systems, may slow down efforts to align financial, costing and accounting systems with lean principles.
10.3 Recommendations

Following a wide ranging review of the literature and considering how a range of proposals relate to the aerospace industry, various key recommendations can be made. We are aware that companies in the industry are far from one homogeneous set and so we are unable to be definitive as to what each company must do. Much depends upon the situation of each company and, obviously, how far it has already moved to make its costing and accounting consistent with lean objectives. Consequently, these recommendations are offered as a set of matters senior managers and financial directors can use as a management audit checklist. They should be examining their systems, bearing their own company situations in mind, to check to what extent their companies’ systems need to be updated in the light of the crusade to become lean. These recommendations do, however, suggest how there needs to be a different emphasis in accounting at the major project (prime contracting) end of the industry as distinct from smaller systems and component production.

**Recommendation 1: Adopt a systematic Target Costing approach, supported by Value Engineering and Functional Costing**

As 80% of costs are committed at the design stage of major projects, at the prime contracting and major systems end of the industry, current approaches to getting the balance between cost and value need to be reviewed bearing in mind the benefits that a rigorous and systematic approach to target costing approach can give. The main opportunity to gain the cost reduction benefits of lean thinking come at the design stage.

Engineers and accountants should be encouraged to work together to develop functional costing to support target costing exercises and make target costing itself lean by (a) indicating priorities for value engineering and (b) developing cost tables for key product attributes. Accountants can help, in the main, by showing how different forms of costs, other than direct materials and labour, are determined by which cost drivers and ensure that that information is fully considered in value engineering exercises.

**Recommendation 2: Embrace Life-cycle Costing and Analysis**

Target costing should be conducted on a full life-cycle basis as far as is feasible. This should include a consideration of costs in all phases of the life-cycle and would include development and testing costs, costs of manufacture for variations in design, construction cost, operating costs, maintenance costs, etc. Where new airframes are being developed as the basic vehicle for a range of future model variations, it will be impossible to undertake reliable
assessments of future operating costs for the whole of the envisaged airframe life (of, say, 30 years), but then the notion of “development flexibility” can be included as a product attribute and an attempt made, in the design process, to balance the needs for flexible adaptation with cost. Life-cycle costing would then incorporate the life of the first model in a future generic model series plus the flexibility for adaptation. At least each subsequent model development should be target costed.

**Recommendation 3: Align Product Costing and Operational Control with Value Stream Organisation**

In line with advocates of lean operations, we agree that firms should examine whether to organise their operations by separate value streams. This report is not, however, about how to be lean per se, but how to make accounting consistent with lean operations. Suffice it to say here that if the regular production of components, etc., is organised by value streams, there ought not to be a severe product costing problem and so product mix decisions ought not to be distorted. This is because all costs, including production and non-production overheads will be easily traced to each product. But, it is important to note that for this statement to be valid all non-production as well as production activities must be organised by value stream. It will not remove all of the overhead allocation issue if only manufacture is organised on a cellular basis. We can see that there may be good operational reasons in some situations where value stream organisation is not practical. In that case companies should review their product costing systems with regard to overhead allocation in the light of Activity Based principles. This is not to say that we believe that ABC should then become the basis for routine and regular costing, but that a knowledge of exactly what drives overhead costs should inform the product mix decision.

With regard to the control of the assembly of major aircraft, space vehicles or major systems, it will be necessary to “crosswalk” the cost analysis by functionality into a cost analysis by cells or departments undertaking the work. If assembly and the associated cost records are analysed by project, as they are likely to be, there should be no major problems in determining actual product cost as the vast majority of the product costs will be charged against that project (product). There may be a need to allocate costs of some central services, like the paint shop or chemical treatments, but we do not consider it too serious an accounting problem to assess a basis for identifying a fair usage of the facility by each project.
Recommendation 4: Complement Financial Measures with Non-Financial Measures for Operational Control and Continuous Improvement

The current trend to use non-financial measures to support operational control by financial statements should be continued, but the list of non-financial measures should itself be lean (sparse) to avoid conflicting messages.

Recommendation 5: Implement Backflush Accounting to Support Pull Production and Just-in-Time

The accountants for volume production items should consider whether to change the basis of their financial accounting systems (i.e. P&L accounts and balance sheets) used for monitoring internal performance so that credit is not given for work-in-progress until the sale is confirmed. This can be achieved with a back-flushing system if the back-flush of all costs to products, including materials costs, is held back until the sale is confirmed. An approximation to this might be gained by adopting Throughput Accounting, but this allows for credit for materials held during production. If one is going to try to apply pressure on gaining throughput to the point of sales, it seems that one should also allow no credit for materials held until sales is achieved. Moreover, it is not throughput per se that is desirable, but throughput in time to meet customer demand. In addition, back-flushing can more easily be reconciled with the needs of external reporting.

At the prime contractor level, however, we do not think it necessary to change the basis of financial accounting for major projects (i.e. the profit and loss accounts and balance sheets for such projects or the sum of them).

Recommendation 6: Supplement Continuous Improvement Activities with Appropriate Costing Methods

One central tenet of being lean is to undertake continuous improvement. While every effort will be made at the design stage to design cost out, the effort to remove waste must continue through the assembly and operating stages of the life-cycle. The operating stage becomes very relevant with the introduction of contracts to deliver services from the asset rather than the asset itself. Accountants should review the various methods that they might use to aid the search for improvement and cost reduction and attempt to apply some of them as seems best suited to their own context. Indeed the accounting function itself might be assessed partly upon its degree of success in using such methods to identify where costs can be reduced and waste eliminated.
**Recommendation 7: Encourage the Reduction of Total Acquisition Costs by Extending Cost Management through the Supply Chain**

All of the proposals in this report should be extended through the key parts of the supply chain. This should involve:

(a) Analyses to improve supply relationships between buying and supplying firms or between aerospace firms and customers. This might be supported by full cost of procurement calculations to avoid buying just on acquisition cost and the analysis of profitability by customer.

(b) Most firms have probably undertaken exercises like those just suggested in (a), such that it is now more important is to identify the full value stream and undertake target costing, check on financial reporting and cost allocation and, especially, promote continuing improvement throughout the whole value stream using the tools discussed in this text. This represents the biggest challenge to the industry in developing accounting methods to support lean operations.

**Recommendation 8: Promote a New Approach for Education and Training to Support Lean Cost Management and Accounting Methods**

The proposals in this report have significant implications for education and training.

Firstly, it is important that educational organisations, such as colleges, universities and accounting institutes align their teaching materials with the lean methods that are being adopted within the manufacturing sector, including aerospace.

It is also vital that, within companies, accounting and finance personnel are trained in lean principles and practices and encouraged to participate in improvement activities across the business. An important aspect of this training involves the implementation of lean ideas in the finance area itself in order to simplify routine accounting tasks and free up time for value-added improvement activities.

In addition to the educational and training requirements of management accountants and finance personnel, it is important that senior management and non-finance personnel understand and support the need for changes to cost management, accounting and measurement systems to underpin their efforts to create a lean enterprise.
ACKNOWLEDGEMENTS

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APPENDIX 1:
MASKELL’S LEAN ACCOUNTING QUESTIONNAIRE (1996)

APPENDIX 2:  
MASKELL’S LEAN ACCOUNTING QUESTIONNAIRE (2002)

APPENDIX 3:
MASKELL’S 4-STEP MATURITY MODEL

Sources:


<table>
<thead>
<tr>
<th>Step 1: Low-hanging fruit</th>
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<tbody>
<tr>
<td>Maintains current accounting and control methods but eliminates obvious waste within the processes</td>
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</table>

<table>
<thead>
<tr>
<th>Need in place:</th>
<th>What to do:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Process view</td>
<td>• Eliminate detailed labour reporting</td>
</tr>
<tr>
<td>• Clear understanding and dissemination of strategy</td>
<td>• Eliminate variance reporting</td>
</tr>
<tr>
<td>• Processes coming into control</td>
<td>• Reduce cost centres</td>
</tr>
<tr>
<td>• Cellular, demand-flow approach to manufacturing</td>
<td>• Standardise financial accounting</td>
</tr>
<tr>
<td>• Change management process</td>
<td>• Accountants actively participate in major change project</td>
</tr>
<tr>
<td>• Empowerment</td>
<td>• Significantly reduce AP and AR transactions through partnership</td>
</tr>
<tr>
<td>• Good external relations</td>
<td>• Study, simplify and standardise the month-end process</td>
</tr>
<tr>
<td>• Education of accounting people in activity-based analysis and performance measurement</td>
<td>• 5s and visual systems within the accounts department</td>
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<td></td>
<td>• Cross training within the accounting department</td>
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<td></td>
<td>• Pilot activity analysis</td>
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<td></td>
<td>• Strategy level performance measurements</td>
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<td></td>
<td>• Measure accounting department’s effectiveness</td>
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<td>• Communication of lean accounting approach</td>
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</table>
### Step 2: Removing Transactions

Eliminates much of the detailed shop-floor tracking as lead times reduce and WIP becomes immaterial; accounts receivable and payable move into purchasing and customer service.

<table>
<thead>
<tr>
<th>Need in place:</th>
<th>What to do:</th>
</tr>
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<tbody>
<tr>
<td>Short lead times</td>
<td>Eliminate detailed job step reporting</td>
</tr>
<tr>
<td>Processes under control</td>
<td>Eliminate WIP tracking</td>
</tr>
<tr>
<td>Low WIP inventory</td>
<td>Eliminate variance reporting</td>
</tr>
<tr>
<td>Consistent inventory levels</td>
<td>Backflushing for component materials</td>
</tr>
<tr>
<td>Accurate BOMs</td>
<td>AP incorporated into purchasing process</td>
</tr>
<tr>
<td>Capable medium term planning</td>
<td>Eliminate 3-way matching in AP</td>
</tr>
<tr>
<td>Inventory record accuracy with cycle</td>
<td>AR incorporated into order fulfilment process</td>
</tr>
<tr>
<td>counting and root cause analysis</td>
<td>Significant simplification of financial</td>
</tr>
<tr>
<td>Education in activity-based costing</td>
<td>accounting systems</td>
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<td></td>
<td>Implement full performance measurement system</td>
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<td></td>
<td>Eliminate departmental reporting</td>
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<td>Eliminate most cost and financial reporting</td>
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<td>Cross training outside the accounting department</td>
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<td></td>
<td>Eliminate physical inventory</td>
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<td></td>
<td>Wide use of activity-based analysis and</td>
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<td></td>
<td>process improvement</td>
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<td></td>
<td>Job evaluation based upon performance</td>
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<td></td>
<td>measurements</td>
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<td></td>
<td>Activity-based costing used for cost and</td>
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<td>profitability analysis</td>
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<td>Develop formal strategy deployment methods</td>
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<td></td>
<td>More communication of lean accounting</td>
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<td>approach</td>
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</table>
### Step 3: Eliminating Waste

Company operations no longer need to be in step with accounting periods; month ends are irrelevant to the sale of products, manufacture or distribution.

<table>
<thead>
<tr>
<th>Need in place:</th>
<th>What to do:</th>
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</thead>
<tbody>
<tr>
<td>• Visual production scheduling (kanban)</td>
<td>• Eliminate detailed work orders</td>
</tr>
<tr>
<td>• Integrated, on-line financial transactions</td>
<td>• Eliminate month-end reporting</td>
</tr>
<tr>
<td>• Full implementation of focused, non-financial performance measures</td>
<td>• Pay suppliers on receipt of materials</td>
</tr>
<tr>
<td>• Fast, pro-active measurement with clear goals, objectives and targets</td>
<td>• Eliminate integration between the cost accounts and the financial accounts</td>
</tr>
<tr>
<td>• Stable, low inventories throughout</td>
<td>• Eliminate detailed budgeting</td>
</tr>
<tr>
<td>• Integrated computer systems</td>
<td>• Automate financial accounting</td>
</tr>
<tr>
<td>• Accountability and empowerment at team level</td>
<td>• Move accountants into operations locations</td>
</tr>
<tr>
<td>• Continuous and breakthrough change management</td>
<td>• Activity-based or value stream cost management approach</td>
</tr>
<tr>
<td>• Communication and trust</td>
<td>• Strategy deployment in use throughout</td>
</tr>
<tr>
<td>• Education of accountants in business operations and activity-based management</td>
<td>• Financial incentives based upon performance measurement (tangible bite into achievement of targets)</td>
</tr>
</tbody>
</table>

### Step 4: Lean Accounting

Move to minimal transactions – production completion or product shipment transactions are used to backflush all the relevant information through the control systems.

<table>
<thead>
<tr>
<th>Need in place:</th>
<th>What to do:</th>
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<tbody>
<tr>
<td>• Accountant working at operational level throughout</td>
<td>• Eliminate most of cost accounting</td>
</tr>
<tr>
<td>• Activity-based management and strategy deployment throughout</td>
<td>• Backflush from shipment</td>
</tr>
<tr>
<td>• Mature policy deployment methods</td>
<td>• Backflush through to supplier payment</td>
</tr>
<tr>
<td>• Breakthrough improvement at team levels</td>
<td>• Electronic funds transfer</td>
</tr>
<tr>
<td>• Very short lead times and zero inventory</td>
<td>• Value-based pricing</td>
</tr>
<tr>
<td>• Co-operative relationships with customers, suppliers and third parties</td>
<td>• Target costing and value engineering</td>
</tr>
<tr>
<td>• Concurrent engineering design methods</td>
<td>• Quality function deployment</td>
</tr>
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<td></td>
<td>• Strategic gain-sharing</td>
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