6 Case Study: JAM Project Demonstrator Structure – Part 2

6.1 Introduction

As stated in the previous Chapter, this Chapter presents the results of a Costings Analysis carried out to compare any financial benefits of the JAM Demonstrator Structure built using Jigless Assembly compared with the current means of assembly.

Four different Cost Models were intended to be developed to be able to evaluate the financial comparisons between the JAM Demonstrator Structure built using Jigless Assembly versus the current method of assembly.

The Costings Analysis was performed only on the Principal parts of the JAM Demonstrator Structure, i.e. the Front Spar, both Track and Inter Ribs, both Sub-Spars and the Skin.
6.2 Costings Analysis

The objectives of the costing exercise in JAM, and the reason for the following cost models was:

- To demonstrate the financial benefits (if any) of Jigless Design, Manufacturing and assembly concepts
- To provide costing support to the rest of the project

As these requirements would have been difficult to meet with a single cost model, it was proposed that several models would be developed. It was envisaged that four closely related activities would be needed.

1. A baseline cost model of the current A320 Fixed Leading Edge Sub-Assembly
2. A cost model of the JAM Demonstrator Structure
3. A feature based wing model to estimate the effect of jigless design, manufacture and assembly on the cost of a wing
4. A higher level financial analysis to estimate the financial impacts of jigless design, manufacturing and assembly on the business costs of the aircraft

The costings analysis consisted of the principal parts of the Leading Edge Sub-Assembly: Front Spar, Inter ribs, Track Ribs, Sub-Spars and Skins, see Figure 6.1, below. Small parts such as brackets and bolts have not been included, as they are unlikely to have a significant influence on the cost.

For the baseline cost model of the current assembly costs were obtained for all of the parts along the Leading Edge. For the cost model of the JAM Demonstrator Structure, several strategies have been used to estimate the cost, which are explained in the relevant section below.
Due to commercial sensitivities all results will be displayed in percentage terms and no actual money values have been included. However, the analysis is based on raw data and is as accurate as was possible within the limits of the time and cost estimates.

The raw data for the current assembly was supplied by BAe Military Aircraft and Aerostructures and the data for the JAM Demonstrator Structure was a combination of information supplied by BAe Airbus, AMTRI and an extrapolation of the raw data for the current assembly.

### 6.3 Baseline Cost Model of the Current A320 Fixed Leading Edge Sub-Assembly

The baseline cost model was an Activity Based Cost Model of the Manufacture and Assembly. These are recurring costs as the structure is already in production and hence no non-recurring or development costs exist in design, manufacture or assembly.
Thus,

\[ AB_C = M_C + A_C \]

where,

\[ AB_C = \text{Activity Based Cost} \]
\[ M_C = \text{Machining Costs} \]
\[ A_C = \text{Assembly Costs} \]

### 6.3.1 Machining Costs

The machining costs are represented in the diagram below:

![Diagram showing percentages of different parts: Front Spar 40%, Track Ribs 17%, Inter Ribs 11%, Sub Spars 18%, and Skins 14%]

Figure 6.2 Machining Costs of the Current A320 Fixed Leading Edge Sub-Assembly

The percentages represent actual machining costs of all the parts except the Front Spar. The Front Spar machining cost is a cost estimate obtained from a Feature Based Cost Model, which has been developed at Airbus UK. This estimate has been used, even
though the actual cost exists, because the Feature Based Cost Model has been used to estimate the machining cost of the JAM Demonstrator Front Spar and so it was prudent to use the Feature Based Cost Model for the current Front Spar also in order to ensure both were compared on a ‘like-for-like’ basis. The Feature Based Cost Model is described in more detail in the section on the Feature Based Wing Model.

6.3.2 Assembly Costs

The assembly costs are further divided into the following constituents, represented by the equation :-

\[
A_C = CR \times \sum_{M1}^{Mn} LH + f(M_C, TREC, TRAC) + g(TDC, TPC, TMC)
\]

where,

\[
\begin{align*}
A_C &= \text{Assembly Costs} \\
CR &= \text{Charging Rates} \\
LH &= \text{Labour Hours for Processes } M1 \text{ to } Mn \\
M_C &= \text{Material Costs} \\
TREC &= \text{Treatment Costs} \\
TRAC &= \text{Transport Costs} \\
TDC &= \text{Tool Design Costs} \\
TPC &= \text{Tool Numerical Control Programming Costs} \\
TM_C &= \text{Tool Manufacture Costs}
\end{align*}
\]

The costings analysis is only being carried out on the re-engineering of the JAM Demonstrator Structure. Therefore, the second term in the above equation can be neglected since a re-engineering will not significantly affect or alter the materials, treatments or transport, by definition.
Chapter 6 – Case Study: JAM Project Demonstrator Structure – Part 2

The JAM project is about reducing the amount and cost of product-specific tooling in the assembly of aerostructure and hence, the third term relating to the ‘tooling costs’ would seem to be very important as this is the figure that is trying to be reduced. However, the tooling costs have been very difficult to obtain for a number of reasons, not least, the tooling itself was designed and built before the start of production of the aircraft and so the costs have been amortised. Any ‘tooling cost’ would be an estimate of how much it is now worth.

These issues are discussed further in chapter 8.

Given that this is the case, it is not essential to obtain the tooling cost because as its non-recurring costs have been amortised and only recurring costs remain, such as maintenance and calibration, the cost(-savings) of the JAM Demonstrator Structure will have to be over and above that of the tooling costs, i.e. the tooling is already present so the non-recurring and recurring costs of any new assembly must be cheaper than the recurring costs of the existing system, within a certain ‘payback period’ (see later section on Higher Level Financial Analysis).

This leaves the first term, labour hours. In general, the main thrust of improved productivity, including the JAM project, is to transfer processes away from manual labour at assembly to machines at the machining stage because machine-based processes tend to be more repeatable and flexible than assembly-based processes. The labour cost is usually one of the highest, if not the highest, component of an organisation’s costs.

The following diagram shows the proportion of the labour costs for each of the three stages in the current A320 Leading Edge assembly. Stage 1 is where the Track and Inter Ribs are located and fastened to the Front Spar, and the Sub-Spars attached to the Track and Inter Ribs; Stage 2 is where the Skins are located and fastened to the Track and Inter Ribs and Stage 2X is where minor finishing operations are completed.
6.3.3 Current A320 Fixed Leading Edge Sub-Assembly

Recurring Costs

Hence, the total recurring costs for the current assembly are the summation of the machining and assembly costs :-

Figure 6.3 Assembly Costs of the Current A320 Fixed Leading Edge Sub-Assembly

Figure 6.4 Recurring Costs of the Current A320 Fixed Leading Edge Sub-Assembly
6.4 Cost Model of the JAM Demonstrator Structure

The cost model for the JAM Demonstrator Structure was also an Activity Based Cost Model, similar to that for the current assembly. However, with this structure there is an extra Design Cost, as well as the Manufacture and Assembly costs, because extra design activity is required to facilitate the modifications proposed by the concept (see below). There would also be non-recurring costs in addition to the recurring costs in order to develop and commission the concept. So for the JAM Demonstrator Structure, the activity based cost would be:

\[
ABC = DC + MC + AC
\]

where,

- \(ABC\) = Activity Based Cost
- \(DC\) = Design Costs
- \(MC\) = Machining Costs
- \(AC\) = Assembly Costs

In order to display the cost estimates for the JAM Demonstrator Structure as percentage values where needed, the previous percentages of the current assembly will be normalised so that the percentages for the JAM Demonstrator Structure will be a ratio of the current assembly and it can be seen whether there is an overall cost reduction or increase.

6.4.1 Design Costs

The two main areas of design change that need to be considered are the designation of Primary and Secondary Location holes in the principal parts and the addition of Spot Faces on the underside of the Front Spar to locate its horizontal plane.
These extra holes and spot faces for the JAM Demonstrator Structure would be generated through a one-off project to draw and test the additional holes. Therefore, this 'new', re-engineered design would only incur a one-off impact, which can be costed separately, as a non-recurring cost.

Within Airbus, there would be generally two methods of implementing the one-off design project :-

- For a particular product funded externally by Airbus as a cost improvement exercise
- In-house as a cost-reduction exercise funded internally by AIRBUS UK to remove cost on each product and increase profit

The work required with the second approach has been estimated by consulting Cost Estimators and Design Engineering Specialists at Airbus UK, with reference to the drawings of the re-engineered JAM Demonstrator Structure. The time needed, based on past experience, was as follows :-

- Design = 4 day’s work (includes associated paperwork etc.)
- Static Stress = 2 days
- Fatigue = 3 days

This time is solely for the particular section of the A320 Fixed Leading Edge that makes up the JAM Demonstrator Structure. It was further advised that the time required for the complete length of the Fixed Leading Edge would be a factor of 4 to 5 times greater. This is not a linear progression, as much of the information gathering required will have taken place, even though the section only includes two out of the total twelve Track Ribs. At a maximum, this comes to a total of 45 days work.

The above assumes no serious complications with the position of the holes, i.e. it is proving the strength of the components for certification purposes, not that the holes make the components too weak and then need redesigning, which would require a lot more time.
6.4.2  Machining Costs

The cost estimate of the machining of the principal parts (Front Spar, Track and Inter Ribs, Sub-Spars and Skins) needs to be separated along their methods of manufacture.

The use of the Feature Based Model to produce a cost estimate for the Front Spar has been highlighted earlier.

The estimates of costs for machining the Track and Inter Ribs was obtained in a similar way to that of the Design Cost estimates above. ‘Machining and Treatments’ Support and Cell engineers who work with and provided the actual machining costs for the existing Track and Inter Ribs were consulted as to how much extra it might cost to drill the Primary and Secondary Location holes in the principal parts. A final conclusion with regard to the drilling of the Ribs could not be definitively reached. A few of the holes could be drilled in-situ on the current machines but if the ribs were going to be removed for drilling to a more accurate facility then all the holes might as well be drilled on that facility. Taking this scenario, an estimate of the non-recurring and recurring costs was offered.

The Sub-Spars and Skins are fabricated so they need to be costed together. In the original JAM Demonstrator Structure one Primary Location hole was used to locate each of the Sub-Spars and Skins, with the remaining pre-drilled pilot holes in the Sub-Spars and no further holes in the skin.

Since the concept was initially developed, the actual Skins now arrive to the assembly with all pre-drilled pilot holes. As this is the case, it could be argued that the amount of non-recurring and recurring work needed to drill one hole full-size for location is small. To account for this extra drilling in the Skins and all of the drilling in the Sub-Spars, it is proposed that 10% extra cost be put on the assembly of JAM Demonstrator Sub-Spars and Skins, compared to the current assembly.

This ‘estimation factor’ is necessary because drilling more accurate holes in the Sub-Spars and Skins proved to be a more complicated issue than first thought. On further investigation, it was discovered that the new fabricating facility employed on the Eurofighter can drill holes in sheet metal with an accuracy of +/- 0.05 mm for any hole in relation to another hole on the skin, hence, there is the capability to drill all holes full-
size - obviating the need for pilot holes and drilling out. However, this requires a complete redesign of the parts to accommodate issues such as re-jigging for the machines that are used, tightening-up of the assembly features, etc. There may also be the issue that this capability is more applicable to the relatively smaller structures of the Eurofighter than the larger structures of Airbus aircraft, which would have a greater propensity for thermal growth and hence require closer temperature control at machining and assembly.

Although this is out of the remit of the re-engineering as the Sub-Spars and Skins would require a redesign, it would seem remiss not to consider the opportunity of transferring this capability from Eurofighter to Airbus. Though it is difficult to estimate the fabricating and drilling costs of the Sub-Spars and Skins without completing a full, engineering analysis.

The following diagram shows the proportion of the recurring machining costs for the JAM Demonstrator Structure.

![Pie chart showing Machining Costs (Recurring)]

Figure 6.5 Machining Costs of the Re-engineered JAM Demonstrator Structure
6.4.3 Assembly Costs

The assembly costs are again further divided into the following constituents, represented by the equation:

\[ A_C = CR \times \sum_{M_1}^{M_n} LH + f(M_C, TREC, TRAC) + g(TDC, TPC, TMC) \]

where,

- \( A_C \) = Assembly Costs
- \( CR \) = Charging Rates
- \( LH \) = Labour Hours for Processes \( M_1 \) to \( M_n \)
- \( M_C \) = Material Costs
- \( TREC \) = Treatment Costs
- \( TRAC \) = Transport Costs
- \( TDC \) = Tool Design Costs
- \( TPC \) = Tool Numerical Control Programming Costs
- \( TM_C \) = Tool Manufacture Costs

The second term in the above equation can be neglected again since a re-engineering will not significantly affect or alter the materials, treatments or transport.

For the JAM Demonstrator Section the tooling costs now become the designing and commissioning of the build tool and robot drilling system. The build tool is designed to be a lot cheaper and simpler than the current fixtures used today. The robot drilling system is comprised of two CNC drill heads one under and one above the structure mounted on guide rails. The precision is intended, by design, to be in the wing structure rather than the robots so that the robots can be relatively simple devices but with the use of both active and passive alignment systems.

To try to estimate the cost for this system the services of AMTRI were enlisted. AMTRI, the Advanced Manufacturing Technology Research Institute, provides a broad range of support services related to the design, construction and use of manufacturing
machinery and machine tools. Recently, they have had a lot of experience in similar work on the AWBA project (Automated Wing Box Assembly). The AWBA project set about to automate the process of Wing Box assembly in order to reduce lead time, and make possible assembly of parts too large for conventional manual assembly. AMTRI's role was to carry out conceptual design of the whole assembly, and to design and build key parts of the assembly system. These included a main gantry system, a rib carrying and placing robot and skin wrapping system. In addition AMTRI designed advanced tooling to hold and clamp the ribs to the spars, and raft equipment to transport the spars in, and wing boxes out of the production cell.

The following diagrams show the proportion of the constituents of the non-recurring labour and hardware costs for the quote estimate of the build tool and robot drilling system, as prepared by AMTRI.

![Labour Costs (Non-Recurring)](image)

Figure 6.6    Labour Costs of the Re-engineered JAM Demonstrator Structure
Chapter 6 – Case Study: JAM Project Demonstrator Structure – Part 2

Figure 6.7    Hardware Costs of the Re-engineered JAM Demonstrator Structure

Thus, the total non-recurring costs for the build tool and robot drilling system are the summation of the labour and hardware costs :-

Figure 6.8    Non-Recurring Costs of the Re-engineered JAM Demonstrator Structure
The remaining element in the assembly costs is that of labour hours. For the JAM Demonstrator Structure these hours should be significantly reduced as the assembly process has been designed to be semi-automated.

It is difficult to estimate labour hours for the JAM Demonstrator Structure, as the processes are completely new. Therefore, the best methodology to apply was decided to be to extrapolate the processes of the current assembly, as many of them are unchanged, and the new process times were estimated as realistically as possible. The labour time for each task of the current assembly was known and the number of sub-tasks were divided and estimated within that time – this served as a basis for the labour time estimates of the JAM Demonstrator Structure.

The following diagram shows the proportion of the recurring labour costs for each of the three stages for the JAM Demonstrator Structure. Stage 2X remains unchanged as no modifications were proposed at this stage. It should be noted that although Stage 1 and Stage 2 appear in the diagram this if for illustration purposes only and in the JAM Demonstrator Structure the two stages are performed in one operation.

![Labour Costs (Recurring)](image.png)

Figure 6.9 Recurring Costs of the Re-engineered JAM Demonstrator Structure
6.4.4 JAM Demonstrator Structure Non-Recurring and Recurring Costs

Hence, the total non-recurring costs for the JAM Demonstrator Structure are the summation of the design, machining and assembly costs:

![Non-Recurring Costs Chart]

It can be seen that the largest proportion of the non-recurring costs is the assembly costs. This represents the development and commissioning of the build tool and robot drilling system, which entails a large capital expenditure and investment. However, once the system is in place, recurring costs should be small and the system should help reduce the recurring labour costs.

The other large proportion of the non-recurring costs is the design costs. This represents quite a large amount as the drawings of the structure must be redrawn and the components stress and fatigue proven for the entire length of the Fixed Leading Edge.
The total recurring costs for the JAM Demonstrator Structure are the summation of the machining and assembly costs, as there will be no recurring design costs. As predicted, the assembly costs have been reduced and the machining costs increased.

The machining costs have risen from the current assembly to the JAM Demonstrator Structure by 38% to 47%. Conversely, the assembly costs have lowered from 62% to 53%.
6.5 Comparison of the Costs of the Current Assembly vs. the JAM Demonstrator Structure

The costs of the current assembly can now be compared against the estimated costs of the JAM Demonstrator Structure. As indicated previously, the costs of the current assembly have been normalised allowing the comparison of costs without using any actual values. This is displayed in the figure below.

The normalisation means that the costs of the current assembly effectively become unity, i.e. ‘1’.

It can be seen that the non-recurring costs of the JAM Demonstrator Structure are a factor of 32.24 times the recurring costs of the current assembly. However, this is a non-recurring cost and should be recovered by the reduction in recurring cost over time (see later section on Higher Level Financial Analysis).

The shaded/dashed bar in the Current Assembly section represents graphically the non-recurring costs of the current assembly. As described previously, these non-recurring costs would principally be made up of the tooling costs, which have since been amortised and ‘written-off’. Thus, the bar has been included to give an idea of the ‘hidden’ non-recurring costs of the current assembly that the non-recurring costs of the JAM Demonstrator Structure would be realistically compared against if both systems were being built today. Although no figures have been able to be acquired for the non-recurring costs of the current assembly, it is likely that they would be higher than the non-recurring costs of the JAM Demonstrator Structure because of the complex nature of the tooling for the current assembly compared with the simplified tooling and robotics of the JAM Demonstrator Structure.
The recurring costs of the JAM Demonstrator Structure are a relative factor of 0.94, which is less than the current assembly. This is a more helpful comparison of the costs of the two different systems as it is comparing types of the same cost. The factor of 0.94 represents a saving of 6% for the JAM Demonstrator Structure on each A320 Fixed Leading Edge Sub-Assembly produced.

This may seem like a small amount but the cost saving soon accumulates when it is considered how many Fixed Leading Edges are produced per month per year (see later section on Higher Level Financial Analysis for production rates). There would be more intangible benefits also as the jigless design, manufacture and assembly process would undoubtedly improve the quality of the product, meaning there would be fewer concessions with the actual build more closely resembling the intended design.

Furthermore, the value of 6% probably represents the lower limit of the cost saving that could be expected and achieved with the JAM Demonstrator Structure. The scope of the cost savings were somewhat limited by the fact that the exercise was a re-engineering and therefore the opportunity to make major changes and hence significant cost improvements was curtailed.
6.6 Feature Based Wing Model

This cost model was set up as a research exercise to establish the current state-of-the-art in Feature Based Costing. It was hoped that the results of this cost model would be to create a simple Feature Based Cost Model of the Fixed Leading Edge. In doing so, the Feature Based Cost Model could be used to assess the cost impact of using features in Design, Manufacture and Assembly, as well as, the costing of conventional Part Geometries in terms of sizing and weights. The Feature Based Cost Model could then be integrated in some way into the Feature Library for Jigless Assembly, which was being developed.

It was found that Feature Based Costing is still in its relative infancy. The commercial Costing Packages available today are only just beginning to look at the costing of manufacturing and assembly features, rather than merely costing a unit part. The features being analysed are very generic in nature, e.g. number of holes, faces, etc. and to be really useful, a Feature Based Cost model would have to be able to estimate the specific cost of a certain feature depending on its size, manufacturing requirements, etc.

Much work has and continues to be done on Feature Based Design. There remains a gap between Feature Based Design and Feature Based Costing, as the latter has tended to concentrate on their manufacturing cost which are easier to calculate. However, research is progressing on methodologies to evaluate the cost of manufacturing and assembly features at the design stage.

At Airbus UK, a proprietary Feature Based Cost model has been developed to estimate better the manufacturing costs of parts in time for the A380 and other aircraft. This, too, is a generic model and counts the number of features, such as holes, and estimates their cost of processing, e.g. drilling, inspection, etc. One of its major advantages is that it standardises the way in which cost estimates are generated. Previously, different cost estimators would use different techniques and consult different people to come up with varying estimates for the same task. Using the Cost Model, the same result should be obtained if using the same data and the accuracy of the result should improve. However, this still relies on the validity of the assumptions and the methods used to obtain the estimates.
Further work is still required to find out more about this Feature Based Cost model and other Feature Based Cost research. It is intended that a large part of this work will contribute to the future development of the Feature Library for Jigless Assembly, in order that cost estimates of design, manufacture and assembly features may be included in the Library in some form or another.

6.7 Higher Level Financial Analysis

The Higher Level Financial Analysis aims to estimate the financial impact of jigless design, manufacturing and assembly on the business costs of the aircraft. This will be carried out using two models: Payback and Internal Rate of Return. The Payback method is a useful relative measure of risk, faster payback meaning less risk, but it does not measure profit, nor is it clear how to determine a suitable payback period. The Internal Rate of Return method is a more sophisticated method as it shows not only how long a project needs to continue in order to return an investment but also the magnitude of this return.

The Payback method shows how many years it will take before a capital project, such as this, ‘pays back’ the amount invested. Normally, the payback period is calculated from after-tax cash receipts from a project, rather than accounting profits; thus, only cash expenses are deducted from sales receipts, not depreciation.

In this particular costings analysis, the ‘cash returned’ will be the money saved by using the JAM Demonstrator Structure rather than the Current Assembly, i.e. the difference in the recurring costs, and the investment will be the design, manufacture and assembly costs of the JAM Demonstrator Structure, i.e. the non-recurring costs.

The following diagram illustrates this. The diagram shows the payback curves for six, eight and ten workstations, where a workstation corresponds to one JAM Demonstrator Structure Fixed Leading Edge Sub-Assembly. Even numbers are required in order to make two sets of wings for a complete aircraft, port and starboard. The Y-axis gives the magnitude of the costs incurred. Again, this value has been normalised and for this particular graph, ‘-1’ represents the initial investment cost of ten
workstations, from which all other values are referenced from. It has been supposed that the capital investment (non-recurring costs) will take one year to fully develop and implement, after which the cash returned (recurring cost savings) will begin to payback that investment.

The production rates used to calculate this are twenty-three A320 aircraft per month in 2001 increasing to thirty per month in 2003\(^1\). For ease of calculation, a constant rate was taken for each of these years and an average interpolated between the two years of twenty-six and a half aircraft per month for 2002.

The same production rates have been used to extrapolate further for years 2004, 2005 and 2006. Hence, assuming a yearly constant increase of three and a half aircraft per month over each of the three years, there will be thirty-three and a half aircraft produced per month in 2004, thirty-seven aircraft produced per month in 2005 and forty and a half per month in 2006.

In order to meet the production rates detailed above, it has been calculated that six workstations would be required for the years 2001 and 2002; eight workstations would be required for years 2003, 2004 and 2005; and ten workstations would be required for the year 2006.

\(^1\) Financial Times – Aerospace Survey 2001, ‘Europe Reinvented: Airbus has come of age’, February 2\(^{nd}\)
It can be seen that the payback period is the same for all numbers of workstations, this is so because linear expressions were used.

The analysis assumes equal levels of production across shifts and working at maximum capacity. However, there are clearly many other issues that need to be considered, which include:

- **VOLUME** - What volumes economically justify a jigless approach?
- **CAPABILITY** - Is there the technological capability at the facility to achieve the required tolerances and other factors necessary for jigless assembly?
- **CAPACITY** - Is there enough capacity at the facility to accommodate jigless assembly?

Nevertheless, the analysis does show that for an example three-year project beginning at the start of the year 2001, the payback period will be around two years and the breakeven point will be from the beginning of 2003. If more workstations are used, after 2003 the cash returned will be greater.

The second method of analysis is Internal Rate of Return (IRR). Money now is worth more than the same amount of money in the future because the money can be invested in the meantime to yield a return. Hence, money gained in the future must be discounted back to present values. The Net Present Value is the comparison of cash payments and cash receipts at the start of a project’s life – the expected future cash flows are discounted back to the present (that is, back to the end of the first year). The IRR method determines, by trial and error, what is the (unknown) discount rate which, when applied to the same cash flows, will produce a Net Present Value of exactly zero. This discount rate is the project’s ‘internal rate of return’. To see whether or not a project is worthwhile, the firm must compare its IRR with the hurdle rate (or criterion rate), which is the required rate of return on a capital project.

The following table shows the results of the IRR analysis for the initial capital investment required of six workstations for the year 2002, using the same conditions described above for the Payback method.
The IRR has been calculated by matching the discounted cumulative recurring cost savings of the JAM Demonstrator Structure (cash receipts) with the initial investment at present values (cash payments) – in order that the Net Present Value comes to zero. The discount rate at which this was achieved is then the Internal Rate of Return.

<table>
<thead>
<tr>
<th>No. of Workstations</th>
<th>Project Period</th>
<th>Number of Years</th>
<th>Internal Rate of Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Start 2001 – End 2006</td>
<td>6</td>
<td>9.4 %</td>
</tr>
</tbody>
</table>

Table 6.4 Internal Rate of Return for Re-engineered JAM Demonstrator Structure

It can be seen that with an initial investment of six workstations to meet demand, the Internal Rate of Return over a six-year period is 9.4%. This is a reasonable return on investment as it is well above the current rate of inflation. However, this investment will take at least six years to be paid back and from 2004 onwards the production rates are extrapolations. There is no guarantee that production demand will continue rising in this linear manner.

Additionally, along with the Payback method, the IRR method does not take into account factors such as production schedules, for instance, more than six workstations may be required as there are other tasks to be completed in parallel or bottlenecks to be smoothed out.
6.8 **Summary of Costings Analysis**

The costings analysis presented above is relatively simplified looking only at the principal parts. Many factors have not been included or considered. In particular, there is an issue of error propagation along the Fixed Leading Edge: over the short section of the JAM Demonstrator Structure dimensions are easy to measure and not affected too greatly by temperature gradients but over the entire length of the Fixed Leading Edge the errors of these properties will increase. However, this phenomenon has been specifically accounted for in the design of the re-engineered JAM Demonstrator Structure, by the methods highlighted previously and detailed in the main report, so that these effects are localised and temperature gradients are not a major problem.

The costings analysis is only as valid as the assumptions it is based on and as accurate as the estimates made of time and cost. As the JAM project is a research exercise it is particularly difficult to estimate the times for new, innovative processes.

Further, more detailed work is clearly required on the costings analysis if the JAM Demonstrator Structure were to be approved and implemented. This would form part of a full, engineering and manufacturing analysis that would need to be carried out if this were to happen.

Nevertheless, this simplified costings analysis does indicate that there would be a 6% recurring cost saving for the JAM Demonstrator Structure, plus a large saving on new tooling, for each A320 Fixed Leading Edge Sub-Assembly produced and that it would take around two years to pay back the initial investment of the project at current production rates. This would give an Internal Rate of Return of 9.4 %, using six workstations for a minimum project time of six years.