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A Work Breakdown Structure that Integrates Different Views in Aircraft Modification Projects

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Short title: Integrated WBS for Aircraft Modification Projects

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Abstract:

The Work Breakdown Structure (WBS) defines the work scope of a project. The way a WBS is defined depends on the person and his/her viewpoint. The aircraft modification business carries out a great variety of projects. Although the core skills and tasks are similar, there are very few projects that are exact repetition of previous work. The reuse of information is difficult without a good structure to archive and manage project information.

This paper presents an integrated WBS approach for managing the work scope in aircraft modification projects. The model is the result of an in-depth study and analysis of the working methods in an aircraft modification industrial company. This WBS is designed to incorporate the information needs and the views of the different functions involved in aircraft modification. It provides the structure for the reuse of information, such as cost and schedules, in the diverse range of aircraft modification projects. In this model, the top tiers of the WBS are configured from a pre-defined industry specific template. The lower tiers are defined with a flexible structure to support the different views of the knowledge users and providers in the project. The information need for all the life stages of the project is fully covered.

The integrated WBS is being implemented in an enterprise wide computing solution that is used for cost estimating in the collaborating company. The same approach could be used to enhance knowledge reuse where there is a great diversity in project contracts.

Keywords: Work Breakdown Structure, Aircraft Modification, Project Management, Cost Estimation, Enterprise Integration, Information Modelling, Knowledge Management, Business Process Reengineering.

1 Introduction

The aircraft Maintenance Repair and Overhaul (MRO) market has been growing during the last decade, and this trend is to continue. Commercial jet transport MRO market during 2001 will reach a worldwide total revenue of about US$42.2 billion. This value is expected to grow to a value between US$52.9 and US$65.7 billion (before inflation) in the next ten years [1]. Aircraft modification and heavy maintenance is to account for about a third of the work, and this does not include military aircraft.

Third party aircraft modification companies work on a wide range of aeroplanes and modification types. Aircraft modifications range from small changes in cabin décor to complete passenger to freight conversions for any type of aircraft, in both civil and military aviation. Modifications are carried out for many different reasons; such as extend aircraft life, change aircraft functionality, comply with new safety and environmental regulations, and improve reliability, mission capability, or passenger comfort [2,3]. Modification contracts may cover a number of aircraft or just a one-of-a-kind job. Short runs to carry out very specialised type of jobs are very common and most modifications are carried out on a make-to-order basis.

Contract bidding is an important process for any aircraft modification contractors. After a customer requests a bid proposal, the job has to be evaluated, information collected and an initial assessment of the job is done. This analysis is the basis of the ‘bid/no bid’ decision. If the decision is to bid, then some resources will be committed to the project definition stage. In the competitive aircraft modification market, only about 15% to 30% of the bids result in successful contracts. It is therefore important to minimise the costs incurred during the bidding phase. Cost estimating relies

heavily on in-house expertise, as no published data is generally available.

As there are very few jobs that are exactly the same. It is rare to be able to exactly copy information from a previous project. If the information is structured into the appropriate packages required by the different departments, it might be possible to reuse elements of information from previous projects. Past information could then be used as a basis to extrapolate to the needs of the new proposal.

Detail bid analysis information is normally archived by the individuals and seldom shared. A Work Breakdown Structure (WBS) that could be used as the basis for information collection and reuse could enhance knowledge sharing. A unified process and the use of a common WBS forms the basis for estimates to be compared with historical estimation data [4,5]. Information reuse can reduce the resources and lead times required for creating bids.

The first part of the paper presents aircraft modification characteristics from a contractor point of view. The second part shows the way project scope changes through the life stages. The final part explains the integrated WBS concept.

2 Research approach

An action research approach was used for the development of this study. The need for a contribution to knowledge and the applicability of the research were the main aspects considered. The research could be broadly divided into three stages or cycles: The starting point for the research was the interest in improving cost estimating for aircraft modification. The first cycle of

the research concentrated in analysing the bid preparation processes and developing an understanding of the aircraft modification characteristics. The second research cycle studied the evolution of aircraft modification project through its life cycle, with main interest in understanding the link between scope and cost and providing a solution to the need for different views of the cost through project life cycle and the reuse of the cost information such as for cost estimating. The last stage of the research was carried out to refine the model and improve its usability. After each cycle the findings were implemented in the collaborating company. Observing the results of the implementation carried out after each cycle led to the following research cycle [1].

The research used qualitative collection methods and six case studies. It was carried out only in one collaborating company due to the commercial implications of accessing confidential cost information. However, the collaborating company is a well established enterprise and results are considered representative for the whole business. The models developed during the research are considered generic and should be applicable to other aircraft modification businesses. The research was validated through the presentation of small steps to the different personnel within the collaborating company, where more than fifty people were interviewed. The agreement and validation of the steps within the action research approach confirmed the validity and applicability of the research results progress.

3 The aircraft modification life cycle

Aircraft modifications usually involve one or more of the following tasks: design, manufacturing, installation and support.

The aircraft modification life cycle can be divided into the following typical stages: feasibility study, definition, execution, termination/completion and operation. The first four stages are the main stages of the aircraft modification project. Since most of the aircraft modification projects are make-to-order, it is useful to group these stages into two phases depending on the time when the contract is awarded. The first is the bid preparation phase, covering the feasibility study and the definition stages. The second is the project execution (realisation) phase, which covers the execution and termination stages. The aircraft modification life cycle is presented in Figure 1. This can also be considered as a typical aircraft modification project plan, with the product support as additional activity after the project is completed. This model presents the different activities that are required to specify and complete the modification product.

After the bid is presented to the customer, there may be some contract negotiations. If the bid is accepted, the project moves into the execution phase. In the aircraft modification business, contract award and project execution may take place months or years after the bid was presented. A different team rather than the one that prepare the bid may have to be assembled to carry out the project. If the project information is compiled in a standard way, then anyone within the company can rapidly understand and reuse the invested efforts.

The first activity after the project is awarded is detail design. This includes the planning for all the design activities, the creation of production drawings and all the documentation to support the design. The detail design stage follows the preliminary design and the information generated in bid preparation is a useful input for this process.

After the design drawings and information are released, plans for manufacturing, installation and procurement are defined. Estimates are revised and budgets are assigned to each activity. The detailed tasks and activities to be carried out by the shop operators are further defined and schedules for them created. The procurement plan is also defined and integrated with the manufacturing and installation plans.

Test design and certification plans are also done at the same time as the installation and manufacturing plan and detail design. Test engineers have to design the tests that demonstrate to the customer that the aircraft can perform to the expectation. The tests have to demonstrate to the aviation authorities that the modifications carried out comply with the regulations. A detailed plan has to be developed for the tests to be carried out. All the relevant documentation has to be issued and submitted to the aviation authorities to obtain the necessary approval before the tests are carried out. Depending on the type of modification, test and certification can be very expensive.

Manufacturing fabricates the different parts required for a modification and assembles them into sub-assemblies and modification kits that are to be installed in the aircraft, for example a cargo door. In some cases, the partial sub-assembly of the modification kits is not necessary, the parts will be installed directly into the aircraft. One characteristic of the modification manufacturing and

sub-assembly is that it is carried out before the aircraft is actually on the ground. Aircraft downtime has to be minimised, as the aircraft is not generating revenue when it is on the ground. This means that the modification kits or parts are actually finished before it is possible to see the aircraft.

As the modification organisation is a third party organisation and not the Original Equipment Manufacturer (OEM), it is necessary to obtain drawings from the OEM. The drawings available may be from a different version of the aircraft. For example the aircraft concerned may be thirty years old but the drawings from that old version may not be available and it is only possible to have drawings of a later version. Also the aircraft may have had previous work that is not known to the modification organisation. All this means that deviations to the original drawings, which are used as the basis for the modification design and manufacturing, may only be identified when the aircraft is in the hangars and has been stripped down. Deviations may also be caused by particular operating environment and service history. These situations differentiate aircraft modification from new aircraft manufacturing. New aircraft parts are manufactured to drawings and assembled to plans. Deviations discovered on old aircraft may require costly additional work.

If the modification is to be introduced to a series of aircraft, the first one is used as a trial. The trial aircraft installation is carried out before the production series to ensure that installation problems are identified and corrected before work starts in the rest of the series. Testing and certification are carried out using this aircraft to demonstrate compliance with the customer and certification requirements. If additional work is necessary, they could be identified before the production run starts. Trial aircraft installation, testing & certification should not overlap or have only a minimum

overlap with the production aircraft.

Concurrent with the trial aircraft installation, testing & certification, the product support package is designed. The task is to document the effects that the modification has in the operation of the aircraft. The technical publications department updates the aircraft manuals including the flight manual and the weight balance manual. The Integrated Logistics Support (ILS) is defined and future maintenance, training, spares and rotables required are identified. The product support design are finalised after the results from the testing & certification are known.

Once the product has been tested and certified the production run is carried out according to the final configuration achieved. The production modification may be applied to an entire fleet of aircraft or just to a few aircraft. It is also possible that there are no production runs as the modification is one-of-a-kind. In many cases short runs are commissioned. It is very important to keep non-recurring costs as low as possible as it is unlikely to amortise the cost over a long production run.

After the last production aircraft is delivered the aircraft modification project finishes. However, sometimes product support is provided by the aircraft modification organisation such as 24hr on-line support or spares and rotables provision.

4 The Work Breakdown Structure (WBS)

The use of the Work Breakdown Structure (WBS) concept for project management was first formalised by the US Department of Defense and NASA in 1962 [7].

According to reference [8]: “A work breakdown structure is a product-oriented family tree composed of hardware, services and data which result from project engineering efforts during the development and production of a defence material item, and which completely defines the project/program. A WBS displays and defines the product(s) to be developed or produced and relates the elements of work to be accomplish to each other and to the end product.”

The WBS provides a way of decomposing the work required to achieve the final project deliverable. This is done in a hierarchical fashion, decomposing the work from major tasks to smaller ones. By doing so, the complexity of the project tasks is reduced as the tasks are broken down until they reach a manageable size. The lowest level elements of the WBS used for project management are usually called work packages.

The WBS defines the project tasks and therefore it defines the scope for the work required for the project. The correct use of a WBS contributes significantly to the probability of project completion [9]. The capability to identify all the tasks required for a project has a big impact in the project. Missing tasks is critical and may have disastrous consequences. In the aircraft modification business most contracts are fixed price, thus the modification organisation bears the risk of the project. If tasks are missed during the bid preparation phase, the organisation has to pay for the missed tasks. The profitability of the project will be affected.

The way a WBS is constructed and therefore a project is defined can be done in many different ways. The different possibilities reflect the preference of the people creating the WBS. Globerson

[9] showed how the WBS of a project could be developed in different ways depending on the view taken. Different approaches to the hierarchical decomposition of a project could be taken. The following approaches or views may be considered:

- Product-oriented
- Process or functional
- Organisational
- Logistics
- Timing or project life cycle
- Geographic location of people or divisional organisations
- Economic benefit, type of cost
- Project management style (centralised, etc..)
- Location of work in the product

The way the WBS is constructed depends on the view used. The view or views used usually depend on the business of the organisation carrying out the job, such as manufacturing, services, construction, city council, etc. and the characteristics of the specific organisation. At the lowest levels the work packages may be the same work. However, depending on the view, the higher levels are different and this has an influence in the way the project is managed.

The concept of what is considered the WBS is defined in different ways in the literature. The key is what should be included in the second level of the WBS, starting with the first level being the total project. Sometimes the WBS is considered to be the Product Breakdown Structure (PBS). In most cases the WBS is considered to be the combination of the PBS together with the major tasks that

must be performed to create the product, such as project management, which is not part of the product but an essential process required to create the product. Some authors call this the Project Breakdown Structure [10] to emphasise that it is the combination of product and process or tasks.

Other views are used to break down projects that use different elements in the top levels. These views are given other names such as Organisation Breakdown Structure (OBS), Cost Breakdown Structure (CBS), Contract Breakdown Structure, Location Breakdown Structure and Project Life Cycle Structure. To represent the different views or approaches to project structuring and management, the WBS defined previously is usually combined with other views such as the OBS or the CBS, thus obtaining a multidimensional approach [11].

The WBS structure has an integrative role in the project, as lower level tasks are associated and integrated into the higher level ones. Different persons within the organisation can use it to obtain the information that they need. For example top management is interested in the top levels to gain an overall project perspective while middle level managers use the information to manage the items they are responsible for. The WBS also provides a holistic view of the project so that everyone can have a total picture of the project and what the other people within the organisation are doing.

The WBS is probably the most single valuable tool for project management. The WBS defines the scope and structure of the project and establishes the foundation for:

- Planning (cost estimating, scheduling)
- Budgeting

- Responsibility assignment
- Project control
- Information management (technical and others)

Any project information, such as cost, schedules, people, technical documents or any other type of information can be stored using the WBS structure. The WBS usually works with a numbering system to identify the different elements in it. The integration of the tasks into different levels is facilitated by the numbering system. Project information is collated and processed according to the numbering system. The number of levels in the WBS varies depending on the needs to divide the tasks into smaller ones, but not all the elements will have the same number of sub-levels. The WBS can be presented in two different ways:

- Charts with tree structure
- Indented text with a numerical classification

5 The aircraft modification work scope and its different views and steps

The scope of a project can be defined in many different ways. Depending on the person and the personal needs, the tasks are defined in one way or another. As Kliem and Ludin [12] explained, when building a WBS people tend to perceive tasks in different ways, depending on their perspective such as client, project manager, senior management and project team members. The different perceptions of how the WBS should be built could create conflicts and seeking consensus is a cumbersome process. One consequence is that the different disciplines and persons may end up working with different WBS's. For instance, each department within an organisation may end up working with a different WBS that suits the needs of that department very well but loses the

integrative picture that the WBS should provide. In this section, the different people that should contribute to the definition of the WBS for an aircraft modification project are analysed.

Therefore, managing the way a WBS is defined is not easy. Different languages are used by people that carry out different activities. Also, different expertises may need different levels of detail. There is a need for cooperation when building a bid and it is difficult because of the contradictory requirements that exist sometimes. When the project requires many different types of expertise this becomes more complicated.~~s~~ The main existing approach to building the WBS is to collate the people from the different trades during the planning of the project and then agree a WBS. This needs to be done each time a project is carried out. In this way, the cost element structure is co-built with a sort of neutral language. In terms of the reuse of information, the most common approach is to use past projects or project templates for producing new WBS's. However, if the variation in projects is very large this is difficult. These approaches do not solve the problem of considering the different views and needs.

When looking at the need to close the loop and reuse cost information to compare with estimates, so that learning and corrections can be applied, there are many difficulties in make-to-order companies. There are different reasons for this, disjoints in data formats between cost estimating and execution of projects appear to be the main problem. Data collections do not comply with estimating formats, changes during production, intermediate estimates or different people involvement are some of the reasons that difficult this link [13].

A WBS is not a static structure. In the aircraft modification process it is extremely important to

consider the dynamic nature of the WBS with the project life cycle. There are many uncertainties that are implicit within the process of aircraft modification. For example in a newly manufactured aircraft all the parts to be manufactured and assembled are known. A template or standard that defines the different parts and systems of an aircraft can be defined and used throughout the aircraft construction. That is, however, not as straight forward in the aircraft modification business. For example in the modification of an avionics system, the tasks required are different depending on the aircraft make, model, version and other factors. Depending on the aircraft design some parts may have to be removed, but because each aircraft is different the parts to be removed may be different for each aircraft. Modifying one part in some cases may affect a certain system and sometimes may affect a different one, again depending on the aircraft design. Therefore the same task at the high level work scope may require different sub-tasks for different aircraft. To illustrate this further, imagine that a car garage needs to make a modification to the carburettor of a classic car, and a bigger one is to be installed. Depending on the position of the carburettor in the car and the space available, the parts next to the carburettor may need to be moved or a more substantial re-design is needed. In some cars the engine may need to be moved, in other cars it may be a different part. Also, in some cases the existing pipes may be suitable for the new carburettor, in others a redesign could be required. This depends on the specific car. The exact work definition cannot be defined until some design work has been completed. In the aircraft modification business, all this is done without actually seeing the aircraft, decisions have to be made based on the drawings that are available. Thus, trying to completely scope a modification job at the very beginning before detailed information is available is not possible. At different stages of the project, different information is available to increase the accuracy of the WBS definition.

The WBS and the project work scope life cycle of an aircraft modification project is analysed in this section. The different people and the different views that they have of the tasks are brought together with the stages of the aircraft modification life cycle. Figure 2 shows the integration of these two perspectives. The differences and changes in the WBS and the inputs required through the life cycle of the modification project are studied. The people involved in the development of the WBS are divided into the departments to which they belong and it reflects the structure of the collaborating company. To help in understanding this model it is necessary to clarify that estimations for design activities are usually carried out by the designers while the estimations for manufacturing and installation are carried out by the estimating department.

5.1 Job description

The first activity to define the scope of a project is to collect all the information about the product to be developed and the project. The WBS does not exist yet but it is vital to be able to capture all the information necessary to create one. The result is a descriptive list with the characteristics of the modification product and the tasks required to complete it. The information includes type of modification, equipment to be installed, type of certification or testing required, etc. The collection of this information occurs during the feasibility study of the project. This activity is carried out primarily by the marketing department, although commercial, engineering and other departments may also participate.

5.2 Bid scope

The bid scope stage of the project life cycle is to create the bid proposal. The output is the WBS that is used for the bid. The building of this WBS involves people from different departments and

is an iterative process that requires continuous refinement.

Without an integrated WBS, each department develops its own WBS to match its viewpoint on the job to be carried out. From a whole organisation point of view, the highest level of the WBS thus consists of those of engineering, manufacturing and installation. In this way, the WBS is effectively taking a functional point of view using the OBS in the top levels, and the work tasks as the lower level elements. This WBS design is effective for the department carrying out the task, but it is difficult to visualise the project as a whole and relate its work elements to the deliverable items. Typically, during the scope definition, three different functional views can be identified: engineering design, manufacturing and installation plus the additional view for commercial. The WBS is made up of the design, manufacturing and installation tasks and the deliverables are not visible from a customer viewpoint. The commercial view is oriented towards customer identifiable deliverables, as this is the basis to negotiate the project price. As an example, let us consider a modification job that involves the installation of a certain avionics system. The designer could structure the work as the relocation of antennas and integration of the avionics system with the existing system. The installation estimator may just consider the system to be installed together with another avionics system that has to be installed in the same area. This provides the optimum breakdown for the design and installation tasks. However, the commercial manager has to consider the installation of the specific avionics systems separately as it is the viewpoint for him/her to sell or negotiate the price with the customer. In order to make the first two WBS to converge with the last one, the designer has to add the tasks for the antenna design with the integration task to obtain the price in the view of the commercial manager. Also, the installation estimator has to break-down his tasks to ensure that he can attribute the proportional part of the cost to the specific avionics

systems. This way of creating the WBS does not provide the best structured view of the project.

The authors have developed an integrated WBS for aircraft modification that could be used from the beginning of the scope definition through to the end of the project life cycle. The integrated WBS uses typical aircraft modification deliverables as the top level structure. The design, manufacture and installation tasks make up the lower level elements. The system depicted in this paper is being implemented into a cost estimating and control system in the collaborating company. With networked information technology, everyone working on the same project can work to the same WBS, which can be updated as required throughout the project life cycle. The steps for the bid scope definition are as follows:

- **Initial WBS**: The bid manager first creates an initial WBS. This is based on the understanding of the project collected during the job description activity. Using his experience, the bid manager selects the tasks that are required for the project from the integrated WBS. He can then identify if any archived information exists from previous similar projects, so that the same elements can be selected for the new WBS. The integrated WBS works as a checklist when selecting the different WBS elements. The elements selected at this stage are at the higher levels of the WBS. These elements are the starting point for the designers and estimators to understand the type of job and the tasks required.
- **WBS definition**: Once the initial scope has been created with the initial WBS, the design engineers can then work in creating the concept of the technical solution. This solution concept provides more information about the tasks to be carried out. The designers can then define further details in the WBS. Elements may be added to the initial WBS at the higher levels. As more details about the previously scoped tasks are known, additional sublevels to these ones can be added. The

WBS provides a project level integrated view for all the different design tasks. After the WBS is defined the design activities are usually broke down to a greater level of detail to manage the engineering efforts.

- **WBS update**: The update occurs when the technical solution is fully developed. At this point design information such as schemes, design specification or Statement of Work (SoW) are available. Based on this information the manufacturing and installation estimators can scope the tasks required to deliver the design. The estimators add the WBS elements required for manufacturing and installation and specify the lower levels of detail for these activities. They may also identify activities that may have been missed by design. This WBS update mainly includes the manufacturing and installation views of the tasks.
- **WBS contract update**: Normally, only the top levels of the WBS are presented to the customer, unless further decomposition is explicitly asked for. After the bid is submitted, it is possible that changes are required during contract negotiations. These changes may be related to the cost, schedule, technical solution, or other factors. If the changes are related to the scope of the project, such as the customer wanting to add new items or dropping some of the existing ones, then the information about the changes have to be reflected to design, manufacturing or installation. The process of defining the work scope is then repeated to incorporate these changes.

It is important to note that there are many iterations before the WBS is stable for the final bid proposal. This is because the design and estimation processes are happening concurrently and design information is being generated while the estimation is going on. The looping of these processes is dependent on the information available. As more design decisions are made, more items are added or a greater level of detail is defined. The verification and approval of the final

version of the WBS happens at the last stages of design and estimation checks and the bid review.

5.3 Execution scope

The bid preparation WBS created at the bid scope definition stage is to support the cost and schedule estimating activities. When the contract is awarded, a WBS has to be defined to support the execution of the project. This is the basis for detailed work planning and forms the baseline for performance measurement and control. The tasks defined during the bid proposal are the basis to define the ones to execute the modification project.

To deliver the project to schedule and cost, it is necessary to carry out the planning and budgeting of the different activities to the necessary level of detail. A post-contract estimate (the estimate after the contract is awarded) is usually carried out as the first step for budgeting. Based on this estimate, the tasks are budgeted and responsibilities are assigned. Although the work package level is sufficient for management control, the work scope has to be broken down into lower levels during the manufacturing and installation planning to define the job cards. The definition of the execution WBS can be divided into two stages:

- **Project WBS**: The exact modification is determined by the engineering design of the job. Engineering design is an expensive, non-recurring activity and has to be carefully controlled. Design activities are planned and budgeted to a low level of detail and the work packages are defined. The WBS for the execution of the project is defined to the same level of detail. The tasks in the bid proposal WBS are further broken down and are defined usually to the fifth level of detail. These tasks would include activities such as the creation of specific drawings, with their numbers obtained from the Drawing Control List (DCL).

- **Project WBS update**: The estimators use the engineering solution to define the manufacturing and installation estimates. The WBS is broken down as more design information is available. This breakdown may or may not be necessary depending on the level of detail completed during bid preparation. If the size of the project is large, it is usual to carry out a further decomposition of the WBS. If the project had been specified to enough level of detail during bid preparation, as it would usually happen with small projects, it may not be necessary to further define the scope of the job.

Once the project WBS is defined, the project plan is derived from it. Scheduling and performance management is carried out using the baseline WBS. The execution scope and WBS are defined with the additional information and act as a check to ensure that all activities are budgeted for. There may be tasks that are not included in the proposal WBS but identified at this stage. Although the profitability of the project is affected as the price has already been agreed in the contract, correction actions to minimise the impact can still be taken. If those tasks are not identified until the work is in progress, the opportunities for corrective actions are more limited.

5.4 Scope control

The scope of the project is a critical issue and has to be controlled continuously. It is the nature of planning that projects will deviate from the original plans. These deviations can be in scope, cost or schedule and need to be recognised as soon as they occur. Changes in the aircraft modification project can be generated through three different sources: request for engineering modification, additional work either identified by the people executing the work or requested by the customer. The request for engineering modification should not have an effect on the scope of the project as this activity was known, although it may need a budget or schedule change. If the customer

requests additional work, then the extra work is estimated, authorised and added to the project WBS. In the case when additional work is identified and within the contract boundaries, the scope needs to be changed and the tasks should be included in the WBS and identified as additional tasks. So if there is a similar task in the future it will not be missed. The additional elements of the WBS identified should be included in the WBS at the level that corresponds to that task.

5.5 Scope analysis

The final stage in the scope life cycle is the analysis that is carried out at the end of the project. The WBS used in the bid, the project baseline scope and the final scope of the project are compared and the reasons for the changes, if any, analysed and documented. Recommendations may be suggested for activities of the scope or alternative tasks. The customer acceptance of the work carried out is also part of this process.

6 The integrated WBS

As it has been highlighted in the previous sections of the paper, the construction of a project WBS depends on many different factors. Different views and requirements at different project stages by different people will produce different WBS's. The optimal WBS representation for one purpose may create inefficiencies for other uses. The integrated WBS developed by the authors contains the elements that are required by the different perspectives in an aircraft modification project. The fact that different individuals with the same background, or furthermore the same individual depending on the circumstances, will construct the WBS in different ways is a problem for knowledge reuse. The diverse nature of the aircraft modification business with so many uncertainties and varieties makes it difficult to create a structured approach to manage projects and the WBS. The integrated

WBS has been designed as a template that can be used in any type of aircraft modification project. The concept of the integrated WBS is that the top levels of the WBS are fixed elements selected from a generic aircraft modification project template. The lower elements are then introduced for the different stakeholders of the project. Thus there are two sections in the structure. A rigid part at the top and a flexible one attached to the bottom that is specific to each project (Figure 3). In this way, the holistic view of the project is represented by the rigid part of the WBS which provides the complete picture of the project. This part also provides the basis for knowledge reuse. Information can be attached to the different elements of the WBS. When a project in the future requires an element of the WBS, it is possible to retrieve the information that is stored from previous projects under that same element. This information can then be analysed and extrapolated to the new project.

The elements of the WBS have been defined in the WBS dictionary to be used by all the people in the organisation. This dictionary also contains a numbering system to uniquely identify each element. The top elements of the integrated WBS are presented in Figure 4.

Information across the organisation can then be shared through the use of the WBS. Cost, schedule and technical information can be attached to the different elements of the WBS. In this way people can better understand the work that other people are doing and the constraints that they have, therefore improve communication and maintain the complete scope of the project. For example a drawing location or a schedule can be attached to the WBS element to which it belongs. An estimator can then access this information by going to the WBS element.

The integrated WBS has two integrative functions. The WBS has been developed in an integrative manner with the views of people from different departments collated, integrated and agreed. The second integration is its design to be used in all the activities across the complete life cycle process of the aircraft modification project.

7 Conclusion

Aircraft modification business covers a wide variety of project types. Many uncertainties are associated to this business. It is therefore essential to reuse as much information as possible to plan for and manage these uncertainties in projects. The WBS defines the scope of an aircraft modification project. Identifying the right scope of a project is essential as it can have a significant profit impact if is not done correctly. The WBS is also the backbone to attach information such as cost and schedules for project planning and control. The different views and perceptions of the job by the different stakeholders make it difficult to have a holistic view of the project and to reuse information. The WBS is also dynamic and it evolves during the project changing to meet the needs of the people involved.

This paper has contributed to understand the dynamic nature of the WBS through a project life cycle. A concurrent engineering approach for information generation and sharing has been taken and an agreed integrated WBS has been developed that incorporates the different views and needs of the people involved in an aircraft modification project. This integrated WBS has also been designed to fulfil the changing information availability of the different stages of the project life cycle. The integrated WBS concept provides the base for the integration of views, while it offers

the possibility to develop the different views required in a project by the use of the lower flexible part of the integrated WBS.

The integrated WBS has been implemented in a networked computing system that can be used simultaneously across the collaborating company and ensures that everybody is working according to the same scope at any point in time and provides visibility of the different tasks of the project.

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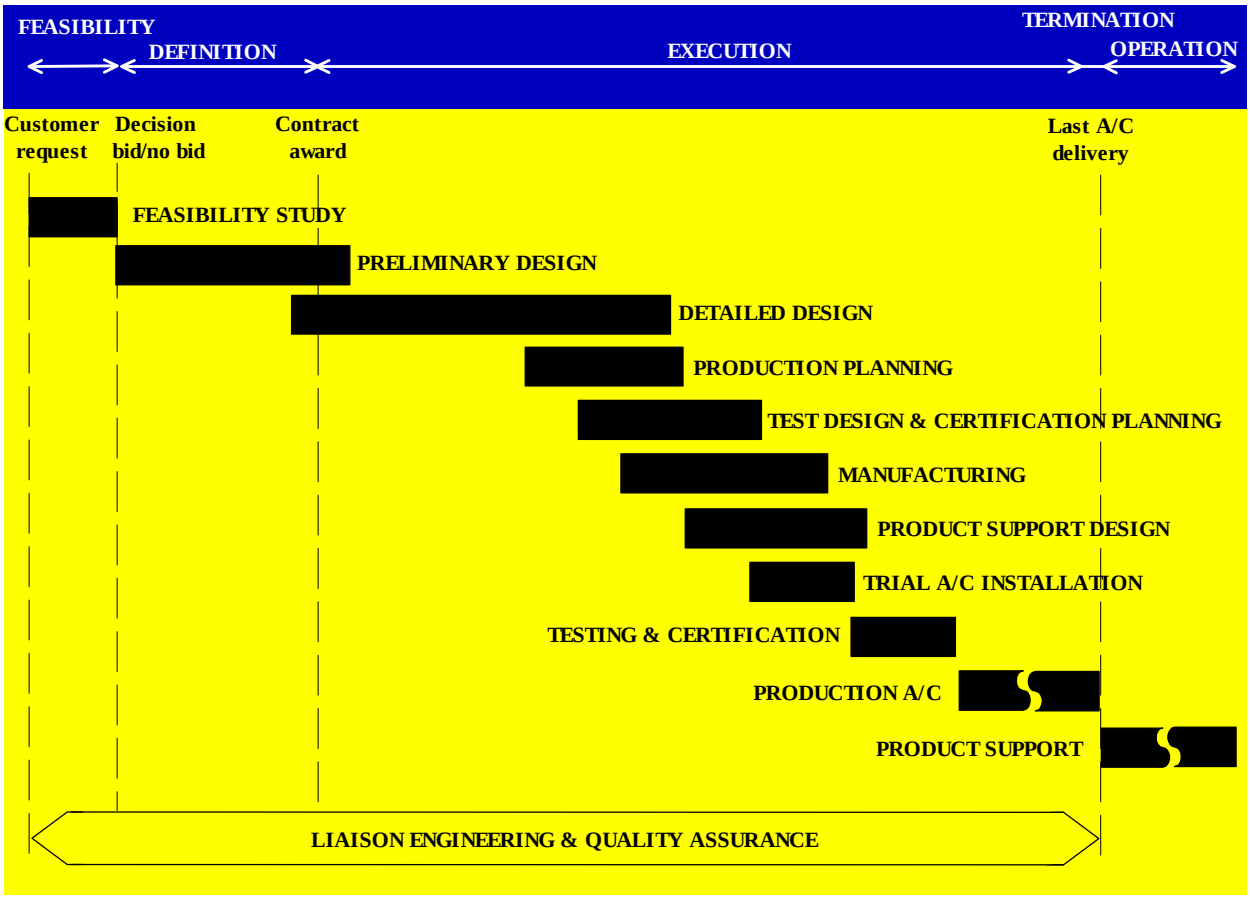

Figure 1: The aircraft modification life cycle

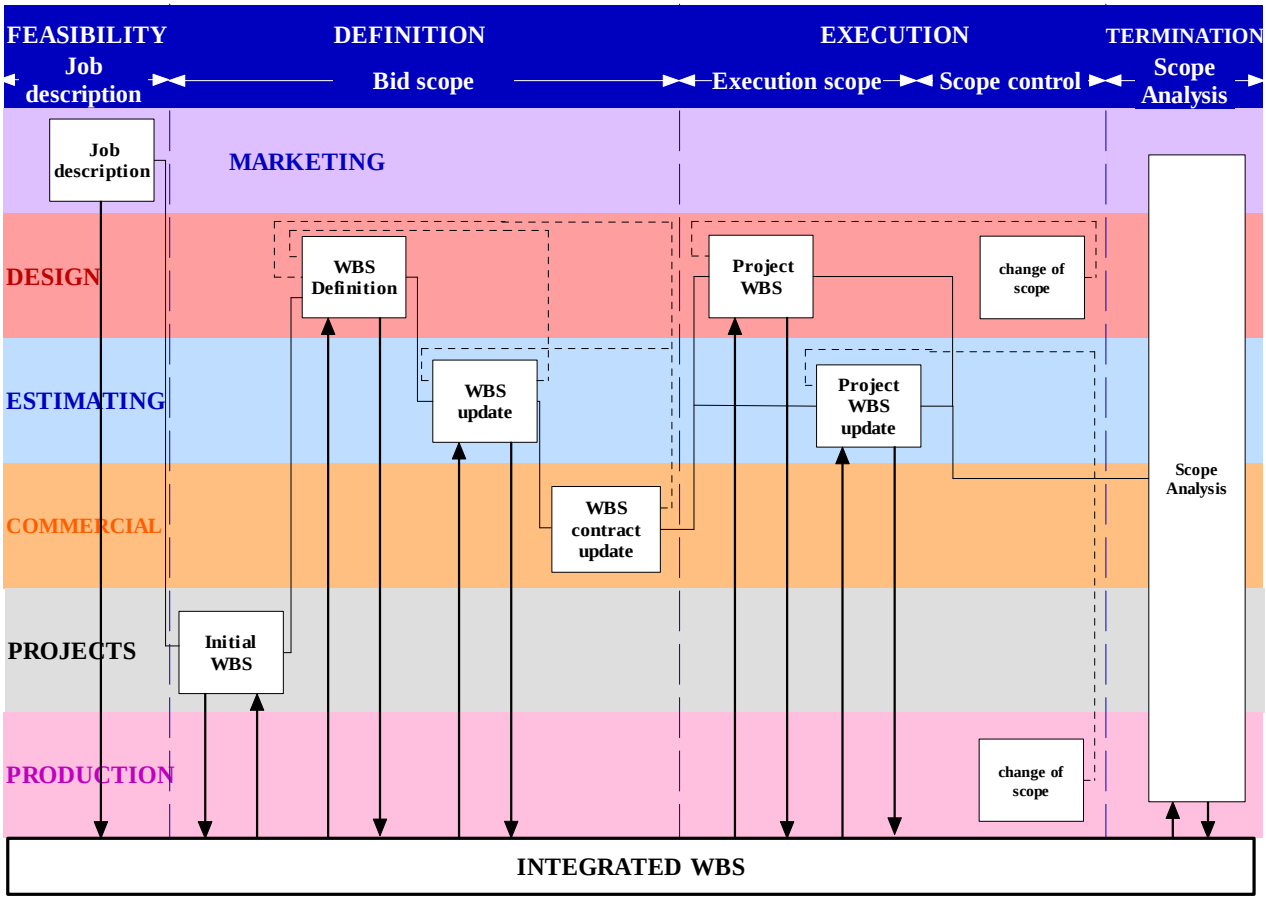

Figure 2: The project work scope life cycle

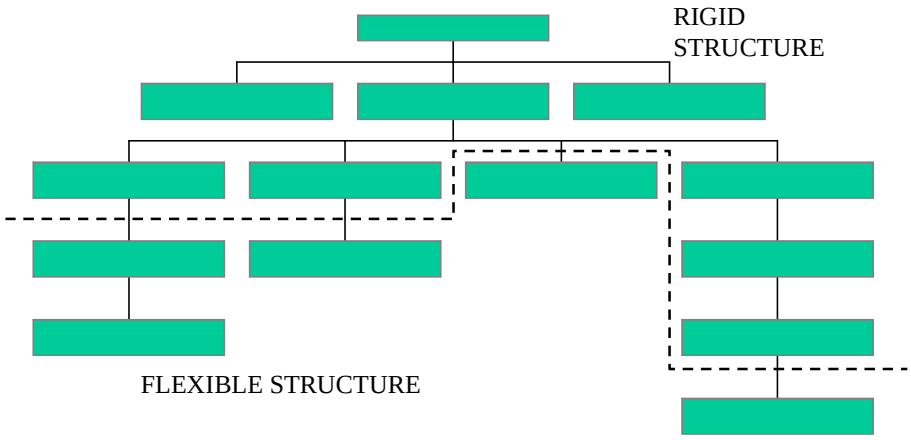

Figure 3: Flexible and rigid structure of the integrated WBS

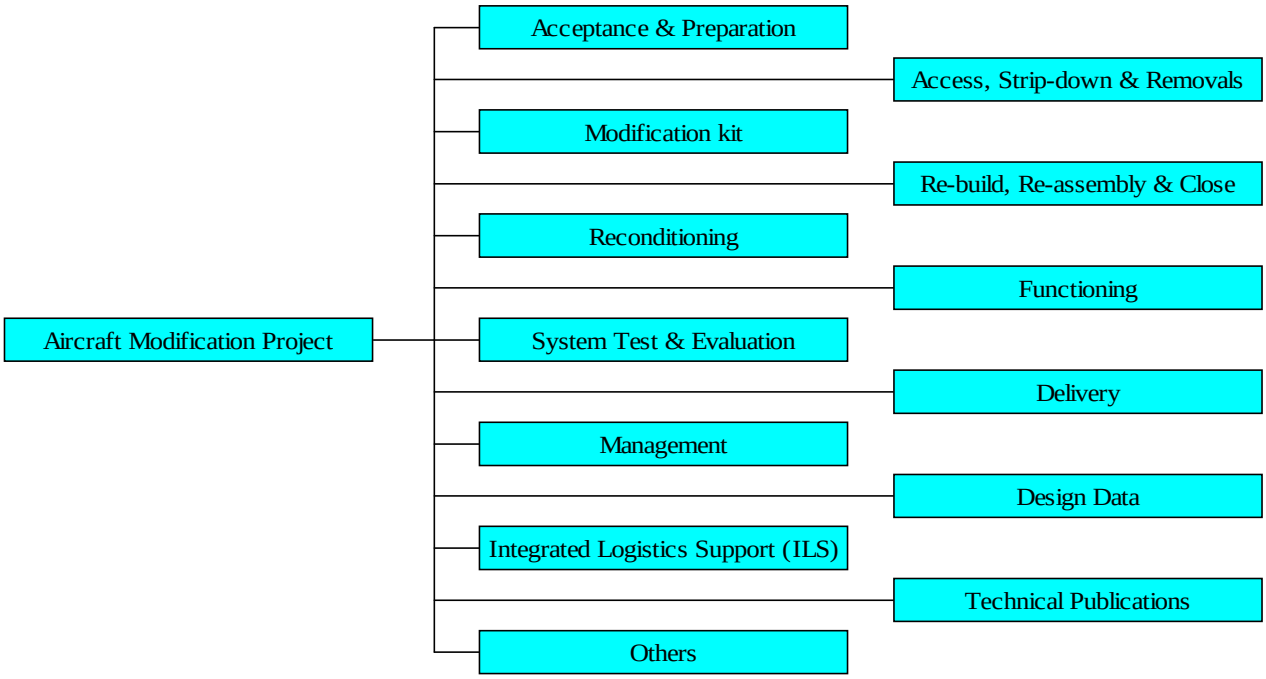

Figure 4: Top level of the integrated WBS