A study on the logistics and performance of a real 'virtual enterprise'

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Abstract: Tenix won the ANZAC Ship Contract in November 1989 to build ten guided missile frigates for the navies of Australia and New Zealand. The ships are planned to have a service life of 25 to 30 years. Within this time period, there will be changes in the operational requirements for these vessels. The ANZAC Ship Alliance is a virtual enterprise formed by Tenix Defence, Saab Systems and the Australian Commonwealth with the aim to provide service support over the lifetime of the 'product'. It is a framework of a dedicated supply chain that coordinates the service supplies across company boundaries. A two-stage study showed that significant changes have to be made within the supply chain in order to adapt practices in individual companies. This paper describes the processes that occurred in the alliance, the techniques that were used to identify the information and work flow in the supply chain.

Keywords: virtual enterprise; network alliance; work flow; web-based collaboration.

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1 Introduction

Tenix won the ANZAC Ship Contract in November 1989 in the face of intense international competition. The ANZAC Ship Project is a collaborative project to build and support ten ANZAC class guided missile frigates – eight for the Royal Australian Navy and two for the Royal New Zealand Navy. The scope of the project includes tasks to design, construct, test and deliver the ten ANZAC ships and associated shore facilities for systems integration, testing and training purposes. Additionally a comprehensive Integrated Logistics Support package provides spare parts, training and maintenance and repair documentation. The 15-year contract is based on a fixed price of approximately $A 5 billion in current value terms, and is the largest defence contract ever awarded in Australia.

The ANZAC class frigate is designed to meet the requirements of the Australian and New Zealand defence forces. The first ship was delivered in 1996. Eight ships have now been delivered, with the last two to be delivered by 2006. The ships are planned to have a service life of 25 to 30 years. Within this time period, there will be changes in the operational requirements for these vessels. These will lead to major changes in the mission systems, platform systems, and manner in which the ships will be operated and used. The long project time means that people, skills, experiences, companies, society and government will change (Hall, 2000). On the other hand, the ship building industry operates on a project-based management structure. Subcontractors and contract staff are employed to fulfil the needs of the project at different times. The ship building team can change frequently. Information must be made available to the people joining the project at different times in a consistent fashion. In addition, the expected service life of the ANZAC ships is from 25 to 30 years. In this context, it is important that a well defined policy and process should be put in place to ensure that knowledge and decision references are applicable over such a long period.

The ANZAC Ship Alliance (ASA) is an organisation formed by an agreement between Tenix Defence, Saab Systems and the Australian Commonwealth with the aim to provide design and implementation of changes to the in-service ANZAC class frigates over the lifetime of the ‘product’. It is an attempt of all parties involved in the creation of the ANZAC fleet to provide a stable support environment ensuring that the ships are combat ready – they are ‘fit for the purpose’ at any given time with the best value outcome. The alliance is not a legal company entity. It draws its resources such as staff and asset from the member organisations as required. It is essentially a dedicated supply chain that provides fast and responsive changes to the ANZAC ships. CSIRO assisted the alliance to establish a framework for coordinating the supply chain and service team members from different companies across company boundaries. The two-stage study of the virtual enterprise showed that significant changes have to be made on the operations within the supply chain that are performed in order for the system to adapt to differences coming from individual companies’ practices.

Tenix had built up a long-standing relationship with the CSIRO via the Globemen Project. Globemen is an international project involving 22 companies and research institutions around the world. The project enables partners to work together in a VE environment to develop the theoretical background for global integration of enterprises and to carry out experiments involving real enterprises collaborating on real projects. The new ANZAC Alliance was recognised as having a business structure and objectives that could potentially benefit from the expertise developed via the Globemen Project. The Australian component of the Globemen project needed a practical test application on which to apply the lessons learned from Globemen.

This paper reports the results of the practical application. The issues of *creating* and *managing* the logistics and information infrastructure that are necessary to support successful operation of the virtual enterprise are examined. Much attention has been paid to methods of organising and developing a structural analysis on the requirements of information flow and functional requirements in the business processes of the virtual enterprise. The paper also describes the tools required for identifying information flow, the systems that people need to perform their tasks and the decision-making processes that map the roles and functions of partner organisations to the needs of the project structure.

2 The virtual enterprise logistics

The development in communication networks and systems in the last decade has significantly changed the way companies operate. Many manufacturing, industrial, service and commercial activities are organised into collaborative teams in networked organisations (Shinonome *et al*., 1997; Syntera, 1998). The operating conditions of the business environment are characterised by frequent changes in products, services, processes, organisations, markets, supply and distribution networks. Autonomous teams perform tasks in such networks (Shinonome *et al*., 1998). They form a temporary alliance to deliver a project or product; they dissolve when the job is completed. The teams work together as an entity for a goal but the relationships among themselves and the individual companies they come from often rely on trust and industry practices (Redman and Mo, 1999; Mosvik and Nelson, 1998). This type of temporary alliance is commonly known as a virtual enterprise. Well coordinated agility in all internal and external aspects of the virtual enterprise, therefore, is necessary for successfully achieving the goal.

As the technology for setting up information systems becomes more complex and capable, many companies have adopted the new business model of forming virtual enterprises for managing the complete life cycle of manufacturing from product design to after-sales services with collaboration of other business partners (Nemes and Mo, 1997). In the late 1990s, companies believed that video conferencing was the key to successful distance collaboration. They spent millions of dollars to improve their communication networks (Mo *et al*., 1998; Jiang and Mo, 2001). Unfortunately, without proper understanding of the fundamentals in a knowledge-driven virtual enterprise, company alliances were unable to solve their problems (Zheng *et al*., 2000). However, other aspects of virtual enterprise like project coordination, resources management, team building, document management and information control were not adequately managed (Van den Berg and Tolle, 2000). The results were disastrous. The cost of such an exercise was felt in the purchase, setup and customisation of the system; also, constant modifications according to the ever-changing business process environment were required. It is also necessary to take into account the loss of existing businesses due to deteriorated customer services and the loss of opportunity on new businesses. The business world needs to have the capability to set up their virtual enterprises in a very short time frame without making costly mistakes.

An important part to form customised virtual enterprises quickly is the alignment of the objectives of the amalgamated inter-enterprise business processes (Mo *et al*., 2003). The information system is the link to enable people in the virtual enterprise in making wise decisions. Without the right information at the right time, delays and, more seriously, costly mistakes can occur. The study of the logistics of virtual enterprises is about managing the information flow and data architecture across company boundaries to support the work in the virtual enterprise.

Most virtual enterprise developments have been concentrated on the ‘content’ of the information infrastructure rather than its ‘management’ (Mills *et al*., 1998). Hence, one can easily find a lot of nicely designed websites for companies and alliances on the internet. They are attractive to the general public as an information resource. However, if one challenges its use as the operation support system for engineering and business processes, these websites fail to meet the stringent demand of the knowledge users in the competitive business environment. It is crucial that a virtual enterprise should be supported by a systematic design methodology that adequately describes the logistics in the virtual enterprise and helps the management to develop well defined policies and processes across organisational boundaries (Lim *et al*., 1997).

Hence, the approach adopted in this study was the combination of the theoretical understanding of the system nature together with the top-down process of segmenting the complex enterprise system into a stepwise phase-oriented architecture for more detailed analysis. Using a top-down approach, the Purdue Enterprise Reference Architecture (PERA) methodology (Williams, 1994) helps the virtual enterprises capture their logistics from objectives to individual tasks. All virtual enterprise operating elements can then be specified. These elements include role functions, project execution guides, document repository, documentation, work flow control and entry portal. Using the PERA methodology to match functionality of commercial software systems to the needs of the virtual enterprise, the most appropriate virtual enterprise configuration can be designed and implemented.

3 The decision-making logistics

PERA handles the management of the virtual enterprise but it does not specify the content that affects the decision of individuals having different roles. In order to understand how an information infrastructure system is related to the decisions, the GRAI methodology is used (Chen *et al*., 1997). According to GRAI, there are three systems working in a manufacturing enterprise: physical, decision and information systems. These systems exist regardless whether it is a virtual enterprise or a single company.

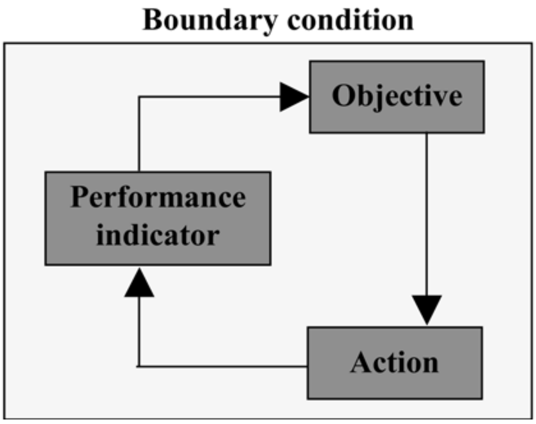
The decision system describes the phenomenon that decision centres in the enterprise are usually organised in a hierarchical structure. Decision centres are basically office bearers at different levels in the organisation. At the top level, decisions are policy in nature, whereas office bearers at the lowest level make decisions affecting individual machines or products only.

The physical system describes the machines, components and resources that the enterprise has at its disposal for generating profits and wealth. The activities of the physical system are affected by the decisions made in the decision centres. In fact, all events in the physical system can be traced back to certain decisions in the decision system.

An enterprise does business through its physical system. For example, in manufacturing enterprises, decisions must drive the machines to produce. To facilitate the propagation of decisions at the lower levels of the decision system and the physical system, the information system plays an important role in the enterprise (Doumeingts *et al*., 1995). If the right information about the decision made is transmitted to the right object in the physical system at the right time, the physical system will act accordingly as expected by the decision maker, otherwise, the physical system will have no idea of what is expected and, hence, it will not perform accordingly. In the virtual enterprise, this propagation of information is particularly difficult because of the cross-company boundary characteristics. The timeliness of information and its correctness during its propagation among partners is critical to the success of the project.

Within a decision centre, decisions will be made on the information that is presented to the decision maker and constrained by the boundary conditions. The criteria for the decision maker to select a particular action depend on the objective(s) that the decision maker has to fulfil. Such an objective can be external or internal within the boundary conditions of the decision centre. Whether that decision is made correctly is measured by comparing the outcome with the performance indicator at that decision centre (Figure 1).

Figure 1 The decision centre performance feedback cycle

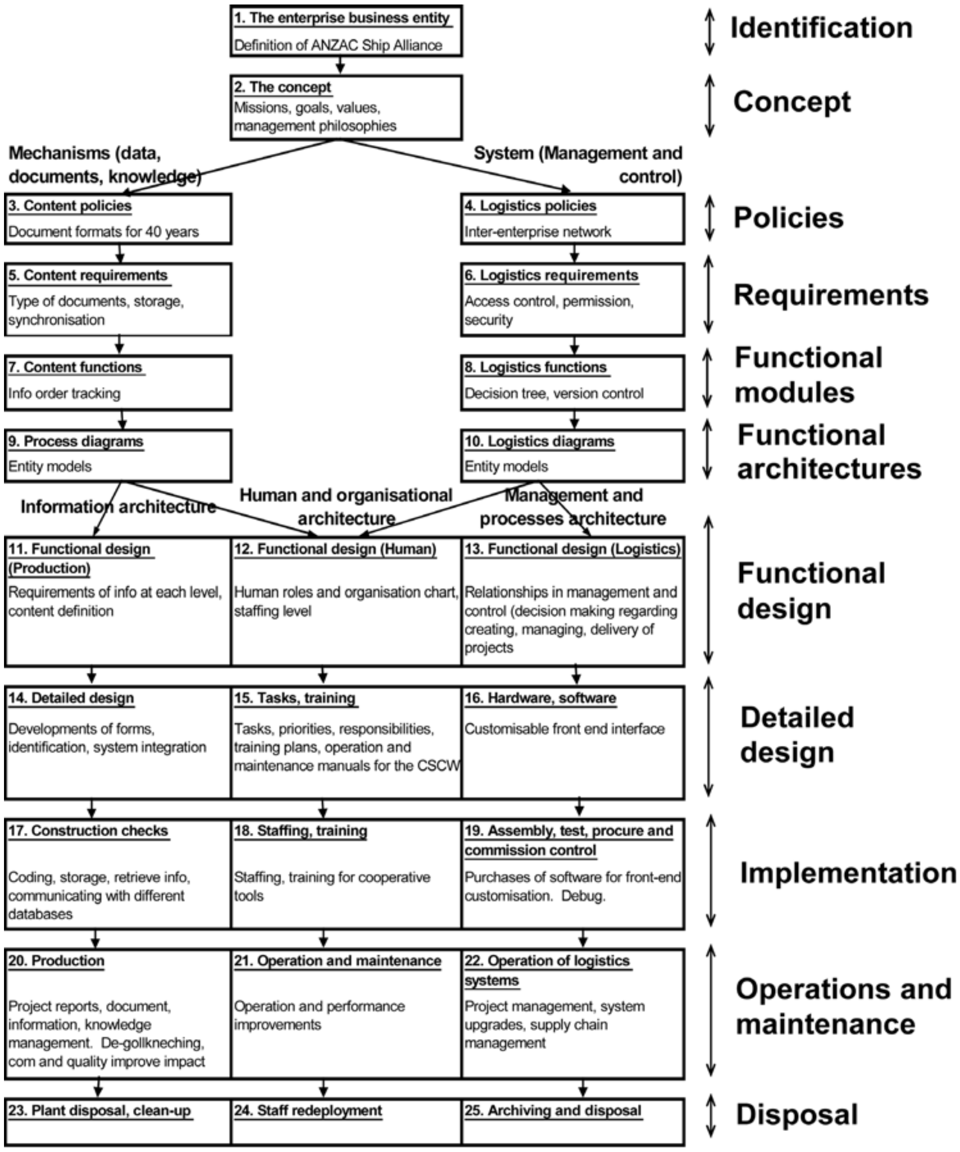


Performance indicators can be metrics of the system characteristics or a statement describing the desirable effect or outcome. The level of achievement will in turn help the decision maker to adjust the objective so that there is bigger chance of achieving the objective in the next decision-making cycle.

4 The virtual enterprise study

To establish the three architectural requirements of the virtual enterprise, three steps are involved. First, we developed the foundation PERA model through a one-day initial briefing session with the key executives of the ANZAC Ship Alliance (Figure 2). The foundation model served as an important guiding tool for formulating questions and for focusing the effort of investigation during subsequent meetings and process examination. Once the model was established, detailed information about the ANZAC Ship Alliance was solicited using two major instruments: questionnaires and interviews.

Figure 2 The PERA model of the ANZAC Ship Alliance



The second step was to design the questionnaire on the basis of the PERA model. It consisted of 25 parts. It should be noted that the Disposal phase was left out because the consensus among the partners of the ANZAC Ship Alliance will continue as long as the ANZAC ships are in service. Each part of the PERA model examined different aspects of the virtual enterprise including the specific objectives of the virtual enterprise in a particular area, the actions that were taken to achieve the objectives and the performance indicators that the enterprise adopted. In addition, the questionnaire also included questions that attracted answers explaining the operating environment within that part of the virtual enterprise. The questionnaire was distributed to all levels of personnel of the ANZAC Ship Alliance.

The third step was to conduct in-depth interviews with selected personnel. The objectives of the interviews were to clarify the answers and to verify the coherence between replies. Interviews were conducted in individual and in small-group discussions over five days in Melbourne, Adelaide and Perth. The focus was on how the decision centres operated within the boundary condition specified in that part of the interview, including their objectives ('What do you want to achieve?'), action ('What do you do in order to achieve the objective?') and performance indicator ('How do you know you have achieved the objective?').

Using the decision centre performance indicator model described in Figure 1, the interviews were able to unwrap the implicit agenda, hidden details and unspoken culture. Conflicting answers were found in many occasions when the CSIRO team examined particular functional blocks of the PERA model.

It should be emphasised that these conflicts came about because the study was being done in an early period of the ANZAC Ship Alliance formation. For example, conflicting answers were found within the discussion boundary of management philosophy of the alliance. Even though everybody agreed that "the alliance is a 'solution focussed' company", the action that the ANZAC Ship Alliance Management Office (ASAMO) should take varied significantly. The answers could be summarised in three different views at this early stage:

1 ASAMO will develop change solutions, but the detailed design will be undertaken by the industry participants drawing upon their existing and substantial knowledge of the ANZAC Class.

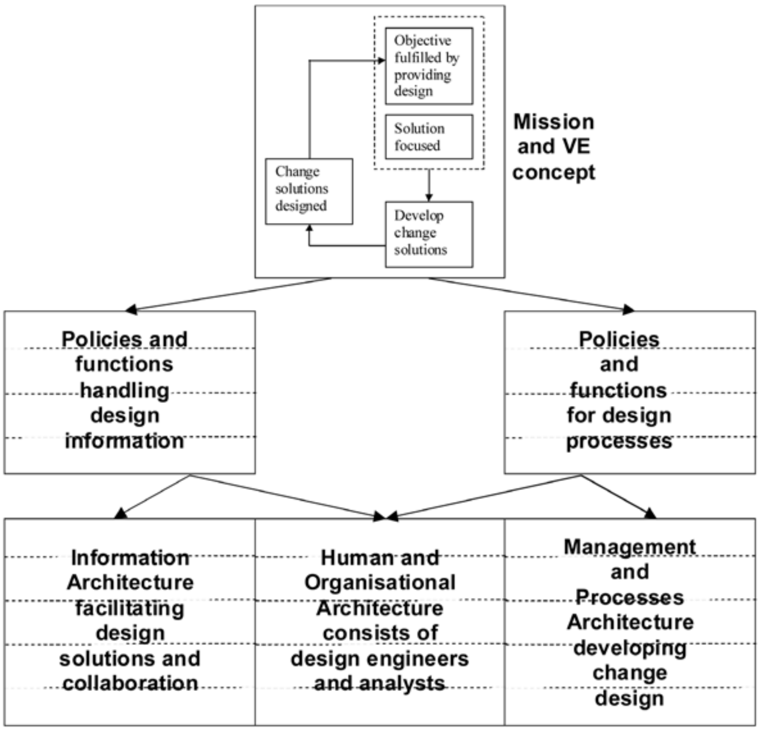
2 ASAMO will ensure that the change solutions and the detailed design undertaken by the industry participants are effectively implemented.

3 ASAMO will manage the overall programme of change and provide assurance for the change solutions and the detailed design are undertaken by the industry participants.

When the answers were put into the decision centre framework where the performance indicators were identified, the three different views could result in completely different organisational objectives. This finding is crucial to the study as the enterprise structure, activity plans, information system design, processes and many other aspects of the enterprise are determined by the organisational objective. The three different views are expanded on the PERA model.

In Figure 3, the focus is to develop change solutions, and the success for this action is measured by the solution being designed. The alliance has the responsibility to provide design of the changes. Hence, the design of the virtual enterprise architecture will be focused on enabling designs to be developed within the VE. Subsequently, the Information, Human and Organisational and Management and Processes Architectures are developed to support the VE as a 'Design VE'.

Figure 3 Evolvement of a 'Design VE' from a performance indicator focusing on designing change solutions



In Figure 4, the focus is to ensure that the industry partners (*i.e.*, 'shareholders') undertake change for the ANZAC ships. The measure of success in this case is the occurrence of the solution. The alliance has the responsibility of making the change. The ASAMO, therefore, does not only need the design capabilities that will catalyse the change, but also requires a certain degree of control over its 'shareholders' capabilities to implement the change. While the ANZAC Ship Alliance does not have real assets and authoritative management processes, its Information Architecture should be established similar to a full scale manufacturing enterprise, which means it is effectively a 'Manufacturing VE' by nature.

In Figure 5, the focus is on managing the change programme. The VE has no obligation to effect change to occur if the 'shareholders' refuse to make changes. It is an arm's length situation and the Human and Organisational Architecture reflects exactly the required staffing and skills for managing projects. Specialists will be called in if necessary and, hence, the VE is a 'Consultant VE'.

It is important that the members of the VE understand the primary goal of the organisation. After this part of the study, the alliance immediately held a series of workshops involving all levels of personnel to define exactly the organisational objective. The result was a clear statement that confirmed the alliance as a 'Consultant VE'.

Figure 4 Evolvement of a 'Manufacturing VE' from a performance indicator focusing on implementing change

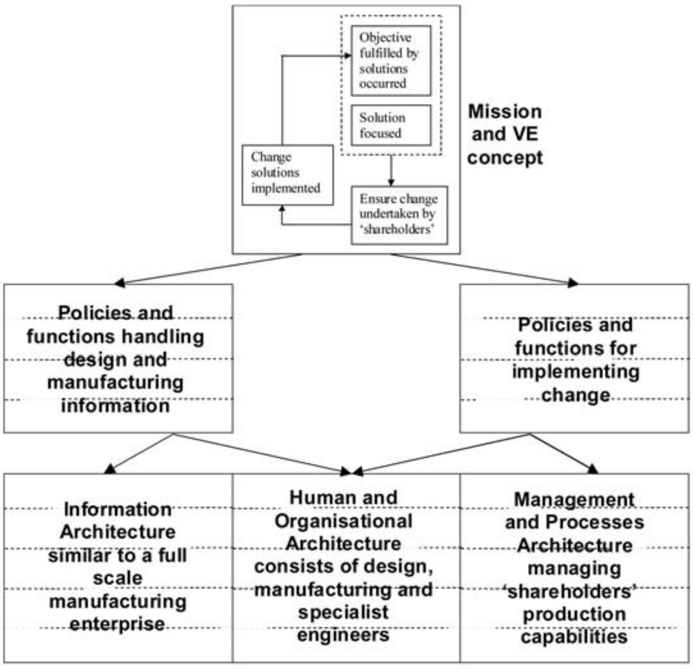
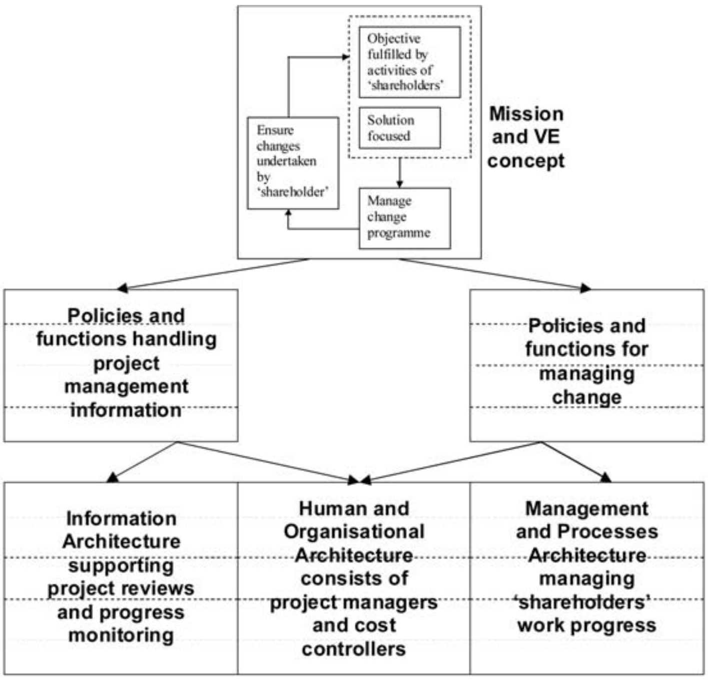


Figure 5 Evolvement of a 'Consultant VE' from a performance indicator focusing on managing change programme



5 Project level study

After the virtual enterprise logistics study, the ANZAC Ship Alliance agreed to use one of its major projects known as Harpoon to be the pilot project level study. The Harpoon project is a major modification on the ships and will extend over a period of five years until all ships are upgraded. The CSIRO team carried out a series of investigative activities in conjunction with the Harpoon project team. These activities took place at one of the major working sites of the project. Most of the meetings were held using teleconference facilities which linked members from different states of Australia.

In order to understand the logistics and performance at the project level, some background information about the working environment of the project is solicited from the alliance:

- The Project Management Office (PMO) is located in Melbourne.
- The Harpoon project team members are distributed in Perth, Adelaide, Sydney and Melbourne (800–3500 km apart).
- The Project Manager reports to the General Manager of the ANZAC Ship Alliance, whose office is situated at the ANZAC Ship Alliance Management Office (ASAMO) in Perth.
- Perth is roughly a 3 1/2 hour flight from Melbourne.
- The greatest time difference between project team members is three to four hours (depending on daylight savings).
- There is a need for information to be shared between offices including the following:
  - a Harpoon PMO and ASAMO
  - b Harpoon PMO and other projects
  - c Harpoon PMO and project team members' sites.

Hence, data communication over distance of a reliable type is required during the project. It was decided that the most immediate need in support to the Harpoon project team was to investigate document flow. The amount of documents that was transmitted was considered to be moderate at the time of investigation. There was an expectation that the data volume could increase significantly as the project develops.

The types of documents that were transmitted included the following:

- project documents (Project Management Plan, Risk Management Plan, *etc*.)
- work breakdown structures, schedules, cost accounts
- risk register, action items
- design documents (including documents from suppliers), review comments
- defence documents (standards, policies, *etc*.)
- alliance documents and templates.

These documents are all Microsoft Office documents such as the following: .doc, .xls, .ppt. Other types of documents (*e.g.*, drawings) may be transmitted later in the project.

Having understood the background of the project team, the next step was to map the functions to the need of the enterprise. We started from the organisational model (Figure 6). Next, the virtual enterprise life cycle was analysed by examining the phases in the PERA model and adapting to the ANZAC Ship Alliance operation protocol. The analysis showed that there were six phases:

1 Phase minus (Project Creation) – Project definition, mission, objective statements. This is equivalent to the PERA phases of 'identification' and 'concept'.

2 Phase 1 (Planning) – The estimated cost to develop the concept. This is equivalent to the PERA phases of 'policies', 'requirements', 'functions' and 'diagrams'.

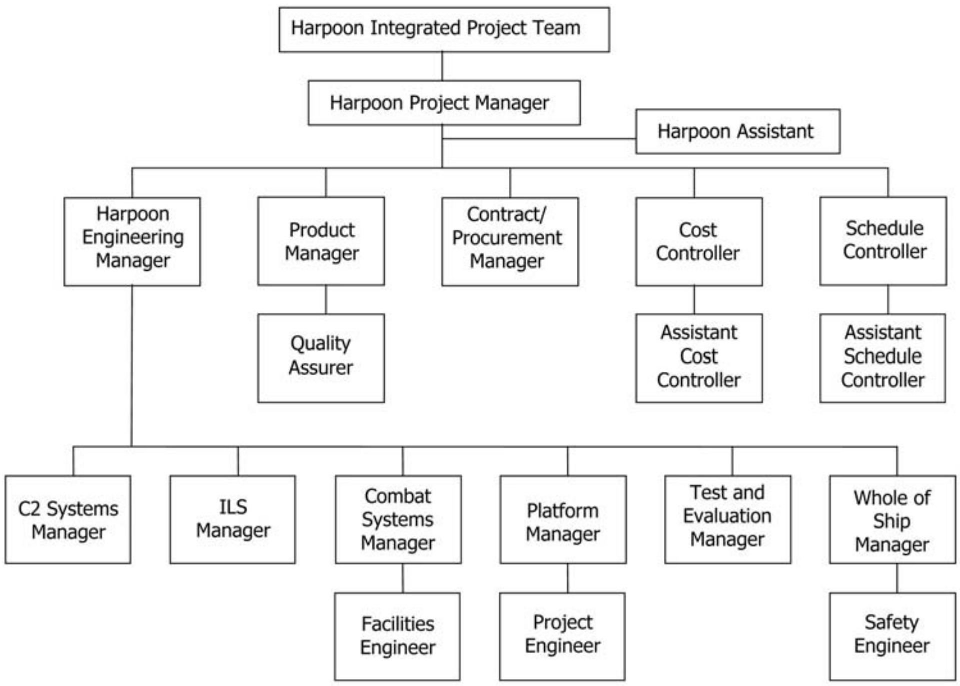
3 Phase 2 (ROM) – Concept development, policies, requirements and *R*ough *O*rder of *M*agnitude. This is equivalent to the PERA phase of 'preliminary design'.

4 Phase 3 (TCE) – Preliminary design, plans (management, procurement, configuration, *etc*.) and *T*arget *C*ost *E*stimate. This is equivalent to the PERA phase of 'detailed design'.

5 Phase 4 (Project Execution) – Detailed design, develop, procure, integrate, support, deliver. This is equivalent to the PERA phases of 'implementation' and 'operations'.

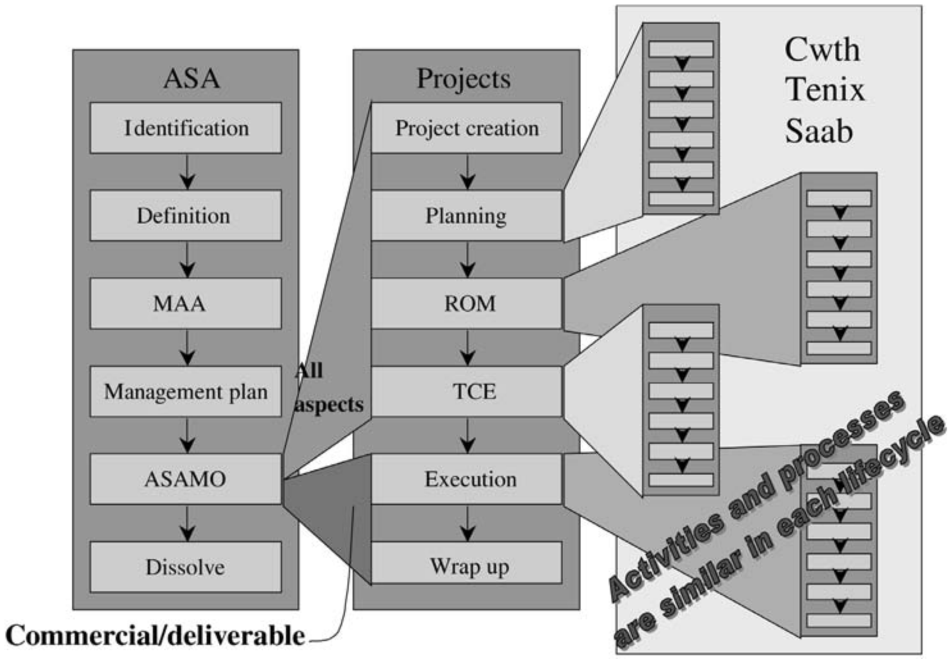
6 Phase plus (Wrap up) – Audit, archive. This is equivalent to the PERA phase of 'disposal'.

Figure 6 Organisational chart of the Harpoon project



The phases minus and plus were not originally included in the Alliance protocol but were later accepted as recognisable phases in this study. This result was further elaborated into a life cycle model consisting of the ANZAC Ship Alliance itself and its projects (Figure 7).

Figure 7 Life cycle model in the ANZAC Ship Alliance virtual enterprise



The document work flow and access control were then studied using a DocMap software (Figure 8). The DocMap software captures the document flow path during a series of review and approval procedures. For example, a 'review proposal' is created by the 'Project Engineers and Consultants' and reviewed by the 'Section Manager'. The document is then passed to the 'Navy Stakeholder' to comment and finally approved by the 'Engineering Manager'. By capturing the major document flow paths and understanding the types of documents involved, the documentary requirements in each phase were then identified (Table 1).

Each of the document processes was further modelled using a software known as FirstSTEP. For example, the 'Design Document Review' process model contains five major elements linked together in a process structure as shown in Figure 9:

1 design document preparation

2 submit design document for review

3 design document review

4 design document revision

5 design document endorsement.

Figure 8 Document work flow and access control analysis

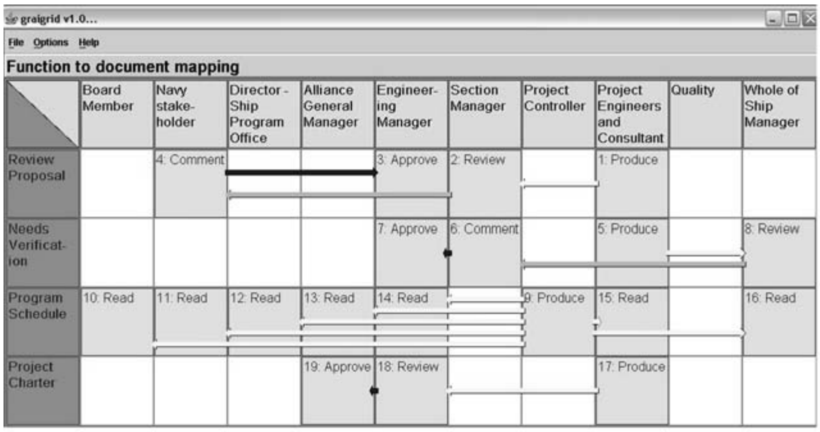
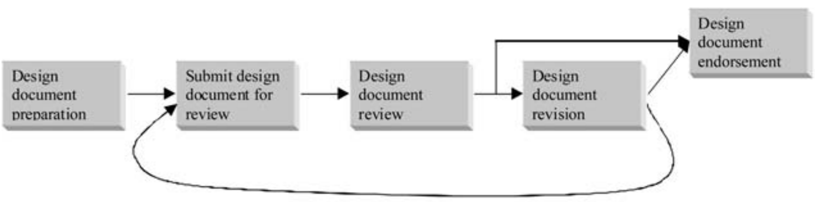


Table 1 Document requirements in each phase

	Phase –	*Phase 1*	*Phase 2*	*Phase 3*	*Phase 4*	*Phase +*
Bulletin	Y	Y	Y	Y		
Message/notice	Y	Y	Y	Y	Y	Y
MS Word	Y	Y	Y	Y	Y	Y
MS Excel/ COBRA	Y	Y	Y	Y	Y	Y
MS PowerPoint	Y	Y				Y
MS Project/ OpenPlan		Y	Y	Y	Y	
AutoCAD			Y	Y	Y	

Figure 9 Process model of 'Design Document Review' process



The modelling process is hierarchical. Further expansion of the process model can be seen in Figure 10. The expanded view of the design document revision highlighted two key areas. The number of revisions accepted is unlimited and the exact role of internal and external entities according to process functions. Each individual element of the model assisted the implementation of the web-based workbench in some way. Subsequently from these findings, a prototype was developed using Lotus QuickPlace by the CSIRO team (Figure 11).

Figure 10 Expanded view of ‘Design Document Revision’

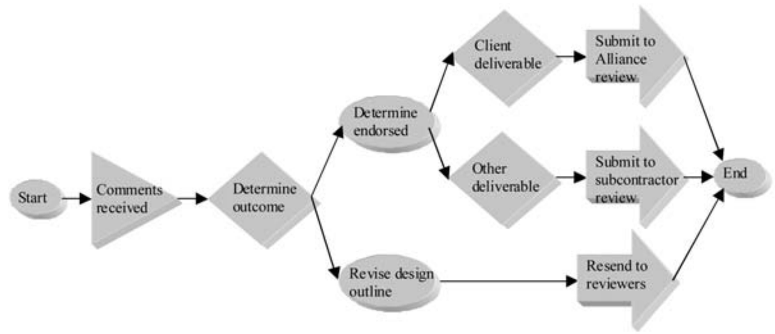


Figure 11 Harpoon project web-based collaboration workbench

6 Performance of the virtual enterprise

The experience of the ANZAC Ship Alliance as a ‘large’ virtual enterprise highlighted a few interesting factors that any virtual enterprise should observe in order to succeed. We assume that most virtual enterprises will be working on projects of significant value and resource commitment; otherwise, it would not be cost-effective to form a partnership. Under these circumstances, it is important to establish a framework of processes and systems to assist the operation of the virtual enterprise for the reason of extracting efficiency, even at a small percentage of savings.

Due to the nature of the virtual enterprise, partnering companies have their own practices and standard procedures when dealing with one another in various business matters. It is not surprising to find that there are many different file formats used for scheduling and costing. Information about where to find certain documents in the virtual enterprise was scarce.

There was also an expectation that members of the Harpoon project team should be doing 'business as usual' according to business practices established at their individual companies. If it turned out to be different from the established practice, questions were raised on whether it was a special rule or a process for Harpoon. Due to the lack of a common process, questions such as 'Is the document updated?' and 'Who endorses it first, and who is next?' were sometimes raised. The project team agreed that a funnelled mode of communication was adopted among the partner companies of the Harpoon project. The structure was effective but not always efficient. Understandably a significant amount of time was devoted to sort out procedural issues.

Communication from the project to ASAMO was satisfactory in general. However, there were areas where improvements were necessary. Although there was a review meeting monthly, the research team found the feedback loop from ASAMO to the project was not well established at this early stage of the alliance. For example, project information gathering and aggregation at project level kept lagging behind, making it difficult for the Project Manager to provide updated information to the ASA General Manager.

The above performance assessment is critical to the improvement process of the alliance. In the early days of the alliance, it was clear that the actions taken by the project team members were not uniform across companies. Hence, there were occasions that the supply chain logistics broke down unexpectedly. Therefore, project processes needed to be formalised and the associated QA plans developed for the following processes:

- collaboration and information sharing
- document review and endorsement
- project operation and management
- project reporting with project control panel
- risk tracking and communication.

As a starting point, the Harpoon project web-based collaborative workbench has assisted project team members to formalise some of the working processes within the Harpoon project. Further development of the workbench into a corporate-wide, web-based document management system properly structured and indexed would be necessary to provide an information repository accessible by all members in the virtual enterprise. The system should include the following:

- alliance policies, procedures and guidelines
- commonwealth documents and standards
- supplier and subcontractor profiles
- class-related skills and competencies.

The web-based document management system serves as the data repository for the entire virtual enterprise. It captures the explicit knowledge of partners and outcomes of cooperative interactions among members. It is an information library for all partners and, hence, represents the 'static' aspect of the virtual enterprise.

7 Conclusion

The ANZAC Ship Alliance is a 'large' operating virtual enterprise formed by three major partners for a defined mission of servicing ANZAC class frigates over their lifetime. A two-stage study of the alliance was conducted to investigate what the best organisational structure and processes should be. This study, which was built on a number of enterprise integration methodologies and tools, has successfully analysed the logistics of this real 'virtual enterprise' and examined the impact of performance indicators within each virtual enterprise functional block boundary conditions. The management of the virtual enterprise is not limited to the integration of information and physical environment; it is also critical that the views and concepts of the virtual enterprise are aligned among decision makers from the member organisations.

Concentrating on higher level issues, the study focused on the problems of supporting activities in a large project relating to the ANZAC ships. The study found that the application of the latest information and communication technologies is not sufficient to ensure the successful execution of the project. The virtual enterprise logistics study laid a useful foundation for the project level study and more detailed analyses on document flow processes were conducted using several modelling tools. The outcome of the study was a prototype web-based work flow system that provided immediate benefits to the project team.

Assessment of the performance both at the enterprise level and the project level led to recommendations on a number of system developments. The experience in this study showed realistic aspects of a specific kind of supply chain that has a dedicated mission. The alliance is effectively a dedicated supply chain that draws the resources, experience and expertise from supplier organisations (Tenix Defence and Saab) to provide the best value outcome for the Commonwealth. Other subcontractors may join this supply chain as the need arises, and this constitutes the essential characteristics of the virtual enterprise, that is to say, organisations join and leave all the time. The design of the organisation structure and processes to such a dynamic environment is a challenge for everyone involved.

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