Reframing the Dynamics: A Case Study of the Interaction between Architectural Computing and Relationship-Based Procurement at the National Museum of Australia.

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for the degree of Doctor of Philosophy.

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Abstract

The National Museum of Australia (NMA) (1997-2001) by architects Ashton Raggatt McDougall (ARM) in association with Robert Peck von Hartel Trethowan was commissioned by the Australian Commonwealth Government for the Centenary of Federation in 2001. It was conceived as a gift to the people of Australia and now stands on Acton Peninsula in Canberra, the nation's Capital. It is a visually complex manifestation of the design architects' (ARM) dialogue with the ambiguities of Australian history and national identity. The architectural realisation of these complexities was facilitated through advances in computer technologies and a complementary non-traditional procurement method, both at the leading edge of Australian architectural practice of the time.

Completed three years earlier was probably the most debated work of architecture of the 1990s, the Guggenheim Museum (GMB) (1991-98) in Bilbao, Spain, by Frank O. Gehry and Associates (FOG&A). This satellite museum of the Guggenheim Foundation of New York was heralded as the quintessential example of a kind of architecture only possible because of advances in computer technologies. Both visually complex museums were conceived as flagship projects and consequently share many political, functional, and cultural expectations. Both were procured outside the usual adversarial designer/builder paradigm of western architecture and featured the innovative use of three-dimensional (CAD) software for design, documentation and analysis.

The NMA project used a government instigated procurement method which was embraced by a group of design and construction companies who formed a joint venture known as the Acton Peninsula Alliance. This non-traditional or relationship-based procurement method required ARM to reassess their approach to generate and disseminate design data and their traditional relationship with other design and construction professionals. As part of this process, ARM were required to devolve some of their design authority to a project delivery team via a Design Integrity Panel and an Independent Quality Panel; both innovations integral to the Acton Peninsula Alliance.

The NMA project reframed many of the enduring professional relationships of Australian architecture and in so doing extended the skill set and expectations of the architects and others to include a more substantial engagement with 3D CAD and a procurement system which was less subject to many of the common impediments inherent in the more traditional processes.

Through a series of interviews with the architects and other stakeholders, a qualitative methodology was used to investigate the NMA as a case study which uses the GMB as an internationally recognised comparison. This thesis examines how these two projects have been successfully completed within time and budgetary constraints in an environment where flagship projects have had a history of highly publicised difficulties. It reveals that the successful realisation of the NMA was due to the relationships built or reframed as a result of this cooperative approach in conjunction with high levels of engagement with computer technologies. This is in contrast to the seamless flow of data and high levels of prefabrication integral to the success of the GMB.

Declaration

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made. I give my consent to this copy of my thesis, when deposited in the university library, being made available for loan and copy.

John Paul Swift 18 August 2006
Adelaide

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Dedications

To Melinda, Laura and James

Preface

Having witnessed the many diverse ways that computers in architecture were being employed in both education and practice, it became increasingly evident to me that there was a discrepancy between their intended use and their application. Hence, my interest in the subject of this thesis was originally stimulated by this divergence. During the very early stages of my research it became apparent that there were many factors outside that of the user's personal preferences or the design of graphical user interface that played a role in how computers for architectural design and production were applied.

The subtle idiosyncratic differences in the approaches of people to the software (as my pre-thesis observations showed) were sometimes due to a lack of understanding or an unwillingness to engage with the software as more than simply an *electronic pencil*. In short, software was used to emulate manual drafting and not to explore the advanced functionalities that were available but were not seen or understood as relevant to architecture. At the same time as my early observations, Computer Aided Design (CAD) in the aviation, automotive, naval and manufacturing industries were having major industry changing effects on form making and the speed and automation of production. It seemed difficult to reconcile the use of CAD in architecture with its use in other design/production professions without a better understanding of what other factors influence this divergence.

My research would show that the pragmatic approach of the Architectural Engineering and Construction (AEC) sector would prove to be a substantial influence on the use of CAD and other computer technologies. As a result, my interest was refocused to the use of architectural computing for more than basic 2D drawings and 3D visualisations; the two most dominant uses in architecture. This new direction meant that the research became increasingly concerned with how people relate through the technical, personal and professional media and how these human and non-human factors complement each other and interact to produce unique, rewarding and successful outcomes.

This thesis which was originally inspired by watching people using computer technologies, evolved through purely technical considerations, and finally returned to questions concerning people's use of computer technology in architecture.

1 Introduction

Some remarkable and pioneering works of architecture have been realised with the assistance of Computer Aided Design (CAD) and allied production processes. The National Museum of Australia, Canberra, (hereafter termed NMA) (Figure 1 and Figure 2, p.2) by architects Ashton Raggatt McDougall in association with Robert Peck von Hartel Trethowan, 1999-2001, is one such work.

The NMA was a gift to the nation from the Australian Commonwealth Government. It is situated on Acton Peninsula at the edge of Lake Burley Griffin[1]. The debate (sometimes heated) surrounding the project in both idea and design gave the NMA a prominent national profile. This flagship project was realised against a backdrop of highly publicised historical and contemporary failures to deliver such projects. It also carried the added significance of being the first architectural project to use a procurement method which departed from the traditional adversarial system favoured in Australian construction[2]. It was also significant as it extended the spectrum of possibilities for what Australian flagship architecture could be, by implementing advanced architectural computing software coupled with this innovative non-traditional procurement method. The NMA project reframed many of the enduring professional relationships of Australian architecture and in so doing extended the skill set and expectations of the architects and others to include a more substantial engagement with three dimensional (3D) CAD and a procurement method which was less subject to many of the common impediments inherent in the traditional processes.

Hence this thesis is about the computer technologies and non-traditional procurement methods, the relationships facilitated by them, and how they were intertwined and interacted to produce the NMA. It examines the successful delivery of this flagship project to reveal the most significant factors in the process. It explains how a cooperative procurement environment combined with the transfer of complex design information via computer technologies helped the NMA avoid any substantial cost or time overruns.

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[1] Lake Burley Griffin was a major element in the master planning of the City of Canberra (1911). The lake is named after the city's planner, the American architect Walter Burley Griffin (1876 -1937). The Acton Peninsula has a visually prominent connection with some of the key elements of Griffin's plan, however this prominence was not exploited (as it was the site of a hospital) until it was used for the NMA project in 1999.

[2] *See* Chronology of non-Traditional Procurement in the 'Acton Final Report Part D' (Peters *et al.* 2002).

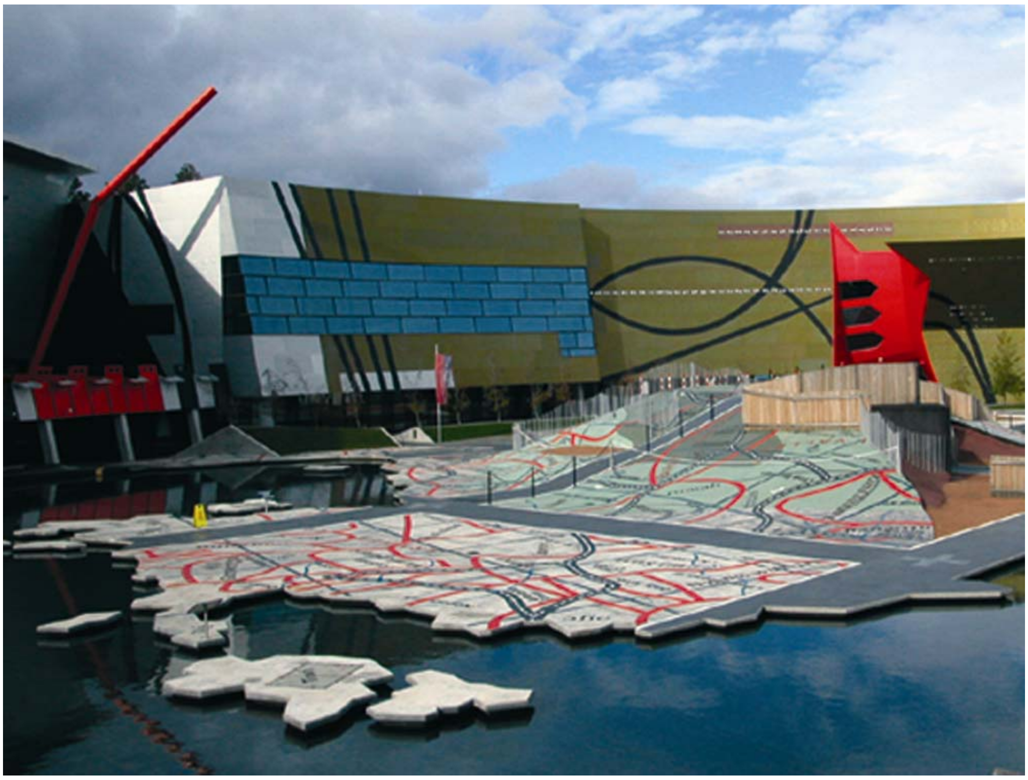

Figure 1 NMA, Central Courtyard (Garden of Australian Dreams).

Figure 2 NMA, Main Hall.

The NMA was realised at a time when architectural projects began to employ technologies used successfully in other design and production industries. The most publicised and celebrated example of this technology transfer was the Guggenheim Museum, Bilbao, Spain, (hereafter termed GMB) by Frank O. Gehry and Associates (FOG&A) 1992-97 (Figure 3 and Figure 4, p.4). The GMB was completed three years before the NMA opened, and it substantially changed the view of what was possible for complex high profile flagship architecture. It was also delivered on time and under budget.

The GMB is an often cited example used to illustrate the impact of computers in architecture, and was probably the most debated work of architecture of the 1990s. It used both software and hardware from outside the traditional architectural toolbox[3], and it used an innovative *design assist* approach[4]; a method developed by FOG&A for the early stages of the Disney Concert Hall, Los Angeles (1987-2003).

The NMA and GMB share similarities in form, context, and in a use of computer technologies and innovative procurement methods to shape the work environment. As this thesis will show, these disparate factors provided a rich and varied matrix of opportunities and constraints which were negotiated by ARM and FOG&A in dissimilar ways.

ARM, the design architects[5] for the NMA, generated a digital model which defined the proposed physical parameters (external and internal surfaces) of the architecture. This departure from the traditional two-dimensional (2D) design and documentation approach was facilitated in part by a relationship-based (non-traditional) procurement method. This method encouraged others in the project team to engage with this new way to define architectural information via a 3D CAD model generated as a combination of external and internal faces. This design surface approach was one of many 'firsts', including the first use of project alliancing in Australia outside infrastructure projects.

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3 CATIA (Computer Aided Three-dimensional Interactive Application) is a modelling package originally designed by Dassault Systems for the Aerospace industry. *See* www.catia.ibm.com.

4 *See* Tombesi (2002), Requests for Proposals: Involving the Industry.

5 Robert Peck von Hartel Trethowan were partner architects for the purpose of the Acton Peninsula Alliance. ARM, (Ashton Raggatt McDougall) a Melbourne based team of architects, were the designers of the NMA.

Figure 3 GMB, View from the bridge.

Figure 4 GMB, Atrium.

The significance of the NMA project and the innovations it employed attracted interest for this reason. The Commonwealth Government, one of the interested parties and the primary funding body, made research funding available to a team of academics in a Cooperative Research Centre (CRC) to investigate these innovations. This group consisted of the Commonwealth Science Industrial Research Organisation (CSIRO), the Royal Melbourne Institute of Technology (RMIT) and the Queensland University of Technology (QUT). This research culminated in the 'Acton Final Report' (Peters *et al.* 2002). The report's authors used qualitative and quantitative methods including interviews with the workers on site, attendance at site meetings and a series of questionnaires. The resulting report considers two of the aspects of the NMA in depth. The first was the exchange of information using information technology (IT) and the second the procurement method. However, the research did not consider computer technologies other than web based information delivery systems[6]. Nor did this research consider the wider contextual environment of the NMA project or the possible role of computer technologies in advancing efficiencies in the Architecture Engineering Construction (AEC) sector.

Consequently, this thesis addresses the overlapping areas which were not considered in Peters *et al*., of computer technology as used to generate and document a geometrically complex work of architecture, and the interplay between procurement methods which delivered it. The internal process which drove the NMA also provided some level of publicly available reporting. The Commonwealth Government published via the Acton Peninsula Alliance[7] the final reports of the Independent Quality Panel (DCITA 2002b) and the Design Integrity Panel (DCITA 2002a). The final report of the Independent Quality Panel assessed the quality of the building using predefined measures. The final report of the Design Integrity Panel reported on the process the panel employed to reach the conclusion regarding the sustainment of design integrity throughout the project. Neither of the panel's reports was extensive. They were intended as milestones or endpoints for the project's accountability process and to aid similar future projects.

As a result of the level of funding provided by the Commonwealth for the NMA project a report was generated by the Commonwealth Auditor General's department (Auditor-General 2000).

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[6] The Acton Final Report (Peters et. al. 2002) did not consider the technology that *generated* the data (design information) for dissemination via the project web.

[7] The Acton Peninsula Alliance was the design and construction team responsible for delivering the NMA project.

This report deals with issues of probity concerning the financial management and implications for the Commonwealth Government as well as some commentary on the conduct of the project. However, this report was published before the completion of the project.

Other literature has been published on the NMA, mainly concerning the architects' inspiration. Only a small percentage of publications featuring the NMA consider the technology other than in an overview or cursory examination (Gibson 2001; Jencks 2001; Macarthur 2001; Perlman 2001; Reed 2002b).

The majority of the existing literature relevant to this thesis, but not concerned directly with the NMA or GMB to date, focuses on either CAD usage for production, design or general purpose computing (mainly for communications). In broad terms, the literature that deals with CAD modelling is about CAD for production, advanced form generation, theoretical architecture, or advanced CAD functionality including Building Information Modelling (BIM). Some of the literature focuses on the overlapping notions that advances in computer technologies have facilitated a total approach to architecture. This has been argued strongly by several authors (Cachola Schmal 2001; Kolarevic 2001; Steele 2001; Kolarevic 2003b; Mitchell 2003; Kalay 2004). There is also a body of work considering computers as offering previously unavailable efficiencies, particularly in light of advances in other industries. Most prominent amongst these is what could be termed a call to arms; 'Refabricating Architecture' (Kieran and Timberlake 2004). This work advances a particular view of how architecture will change to suit the new technologies.

The literature that looks at contemporary procurement is mainly concerned with non-traditional procurement methods as an emerging area of interest which can be used to improve time and budget performances. This literature usually views computer technologies in terms of general purpose business machines with a prime role as an aid to communication (Mitchell 2003).

Literature dealing with how procurement is reframing the traditional dynamics of the architect's role or the impact on the AEC sector is generally scant. The only substantial text that addresses the connection between computer technologies and procurement is 'Why Building Information Models are not Working Yet' (Sanders 2004). In this text Sanders argues, consistent with the findings of this thesis, that there needs to be a procurement environment commensurate with prevailing technology, driven by the clients of architects, if the efficiencies that Building Information Modelling offers are to be successfully taken up by the AEC sector.

This thesis will show that the alliance procurement method used at the NMA contained many innovations that intersected with the architectural expression and consequently the design integrity. Traditionally, the responsibility for design integrity was the province of the architect. It goes on to show how the Acton Peninsula Alliance decentralised control over the design integrity and thus increased the need for a more universal design description and greater consensus. Therefore it required a greater interaction over design elements by negotiation with others not traditionally involved with design issues. This new environment reframed the dynamics of the architect's traditional role as lead designer with regard to the rest of the project team.

Traditionally the personal relationships established in construction projects were heavily coloured by the adversarial nature of the procurement environment. However, due to the cooperative nature of the Acton Peninsula Alliance, a more conciliatory and personal mode of discourse was adopted between parties. In establishing a set of relationships surrounding the Acton Peninsula Alliance, the alliance partners avoided the potential difficulties of applying new technology-based techniques to old procurement methods not designed to complement them. This relationship-based procurement method used concurrently with sophisticated computer technologies proved to be synergistic.

The NMA project shared some similarity with the GMB project. The procurement approach used on that project also deviated from competitive tendering by contractors for a fully documented project. FOG&A used an innovative system modelled upon the requests for proposals method as described by Tombesi (2002) which asked for design input with regard to constructability at a preliminary design stage. FOG&A created their own method of generative design specifications in a limited partnership with other design professions, not dissimilar to the way the NMA was procured. The Acton Peninsula Alliance's use of the design knowledge of others was a consequence of the structure of the alliance. An important distinction between the impacts of procurement methods on design was that FOG&A ultimately controlled the design integrity of the GMB. This difference was facilitated by the use of a single CAD package (LeCuyer 1995; Stein 1997) which was interoperable with the systems used by the other major design consultants, contractors and fabricators. This meant that by using additional software applications, FOG&A could quantify how much the project would cost at an unusually early stage. Hence, there was no need for the same level of on-site design cooperation that was seen at the NMA.

The procurement methods used at the NMA and the GMB required ARM and FOG&A to adopt differing approaches on how to interact with other major design professions. Hence, on both projects the architects devoted substantial time and resources to understanding or helping to create their new environment.

Neither the NMA or the GMB projects exceeded their budgets or time frames (Farnsworth 1997; Peters *et al.* 2002). Both were realised at a time when many comparable politically symbolic projects ran very publicly over budget and time. These similar projects exceeded their originally allocated resources by considerable amounts and during their construction generated more public interest in the reasons for the delays than in the quality of the projects themselves. The Federation Square project by Lab Architecture Studio, (Figure 13 and Figure 14, p.31) in Melbourne, Australia (Goad 2000; Balendra 2003; Davey 2003) and the Disney Concert Hall in Los Angeles, USA by FOG&A (Goldberger 2002; Lacoya 2003; Russell 2003; Pastler 2004) are two such examples. Both were complex designs which carried high private and public expectations, but were created using a system that did not mitigate the deleterious effects of the traditional adversarial method.

This thesis argues that the introduction and use of technology in the AEC sector has changed the way in which the industry works. Advances in computer technology alone cannot adequately explain the successful delivery of a very complex building like the NMA with none of the impediments that normally accompany a project of this type. Nor can computer technologies be blamed for Federation Square or the Disney Concert Hall. It was the use of computer technologies, coupled with a procurement method which valued the input of others and encouraged new and more productive ways for the parties to interact, which made the NMA and the GMB successful.

Hence, this investigation into the interweaving between computer technologies and procurement has been carried out via research questions framed to allow for a greater degree of flexibility than a traditional hypothesis. Consequently, the multi-dimensional nature of the NMA project required a multi-thematic approach to be adopted to provide a wide spectrum from which to draw data. Accordingly, the following research questions are posed to reflect this range of considerations. The research questions are,

1. What relationships were facilitated by the procurement method used at the National Museum of Australia?
2. What connections exist between procurement methods and the computer technologies that were used on that project?
3. What lessons are to be drawn from this experience for contemporary architectural practice in Australia?

Accordingly, this thesis is structured as follows.

Chapter 1, 'Introduction', has set out the purpose and scope of the research questions and broadly situates them within the field of knowledge as expressed in the relevant literature.

Chapter 2, 'Contextualising the NMA', gives a description of the political background to the project, and its inspirations and design. It also gives a description of the GMB for comparison.

Chapter 3, 'Literature Review', considers the literature available, highlighting the specific areas of interest outlined in the Introduction, and to place this thesis in an area of research deficit.

Chapter 4, 'Methodology', addresses the conceptual approach, the instrumental devices and the methodological practices used. The literature review pertaining to methodology is situated within this chapter to aid in explaining the methodology's design and the constraints placed upon the researcher.

Chapter 5, 'Synergy at the NMA', explores the research questions through a series of interviews with the architects and others involved in the NMA project (see Table 3, p.146). These interviews are used as the primary means to (a) contextualise the technology used to realise the NMA; (b) show the exploitation of the knowledge of others through the relationships fostered by the procurement method; (c) show the impact on cost, quality, and time of a and b, and (d) show the unfamiliar role of the architect under the Acton Peninsula Alliance (relationship-based procurement method) as seen at the NMA.

Chapter 6, 'Conclusions', provides a summary of the advantages and disadvantages for the parties involved in each of the projects. Finally, it suggests some possible opportunities for future related research and a personal reflection (epilogue).

2 Contextualising the National Museum of Australia

This chapter situates the National Museum of Australia (NMA) in a wider context. It is divided into three sections. The dialogue that accompanied the NMA project through concept, delivery and early operations is described in 'Political Context' (p.11). The motivations and techniques are explained in 'Inspirations and Design' (p.34), which also provides an account of the design decisions that informed the form of the NMA. These sections also provide a brief overview of some relevant contemporary international projects and the impact of ARM's work previous to the NMA, contextualising that project as part of a continuum. Finally, 'The Guggenheim Museum Bilbao' (p.51), places that project in its context as a comparison to the NMA.

2.1 Political Context

This section discusses the political and social context of the NMA project in addition to a chronology of events. It deals with the establishment and urban plan of the Australian Capital Territory, Canberra, the political issues that influenced the NMA project and the press coverage and academic debate that surrounded the way Australia's history was framed in relation to the NMA. It addresses issues that were predominantly outside the architect's control, but nevertheless informed and influenced the project to varying degrees.

The Australian Capital Territory (ACT) is a 2,358 square kilometre self-administered autonomous region located within the state of New South Wales, 300 kilometres west of the lower to mid-east coast of Australia and the city of Sydney. The ACT was a product of the Federation Conventions of the late 1800s. Following Federation[8] (1901), the newly formed Commonwealth acquired land from the colony of New South Wales[9] in 1911. The ACT was conceived as a *Capital Territory* to locate Australia's national Capital City,

[8] The Commonwealth of Australia Constitution Act 1900 was passed by the British Parliament, and was signed by Queen Victoria on 9th July 1900, and so became law. The Act declared that on 1st January 1901, the colonies of New South Wales, Victoria, South Australia, Queensland, and Tasmania would be united and known as the 'Commonwealth of Australia'. In August 1900 a referendum was held, and the people of Western Australia voted to join the Commonwealth.

[9] Prior to Australia's Federation the continent was divided into autonomous colonies (the modern states). In 1901 the independent states established a Federation administered by a Federal (or Commonwealth) government.

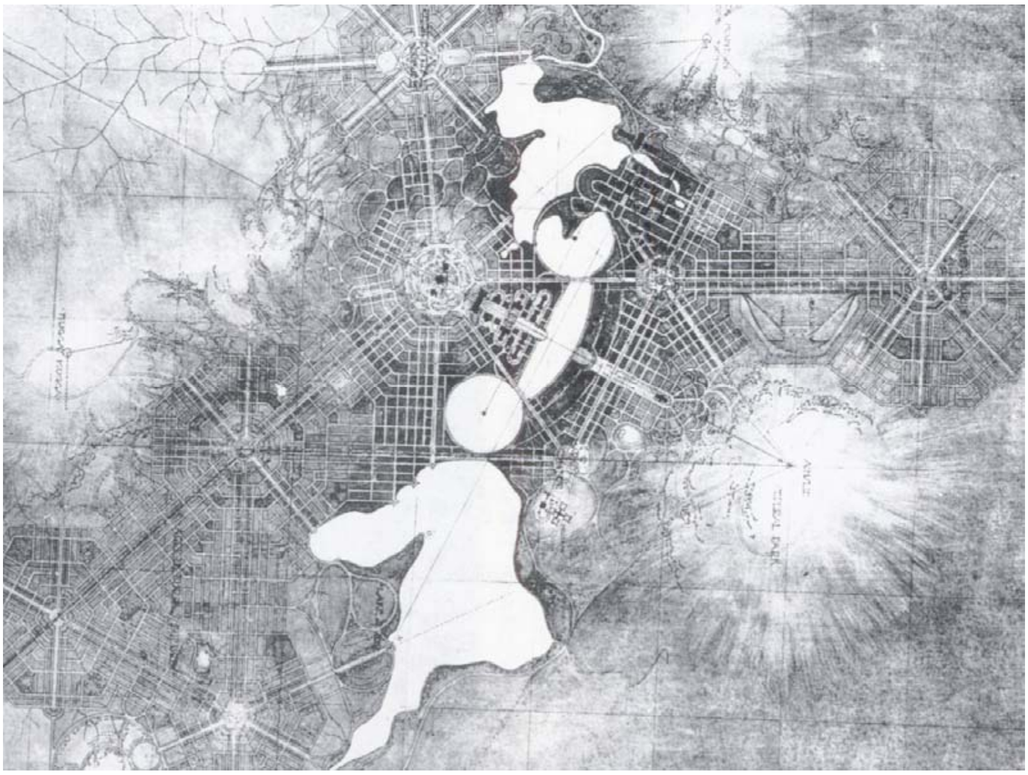

Figure 5 Original Griffin Concept Plan, ACT.

Canberra. Compared to Australia's largest cities, Sydney[10] and Melbourne[11], Canberra has a modest population of 310,000 (Australian Bureau of Statistics 2003). The selection of Canberra as the national Capital was the product of an agreement between the largest and most populated states[12], New South Wales and Victoria. This agreement favoured neither state capital, Sydney nor Melbourne (respectively), as the two competing cities to become the nation's capital (Commonwealth of Australia 2003).

Unlike the state capitals, Canberra did not have an existing infrastructure to sustain a national capital, therefore a competition was launched in May 1911 (Commonwealth of Australia 2003) to select a design for the new capital's urban plan[13]. The American architect and urban planner Walter Burley Griffin, won the international competition in 1911 to master plan the Australian Capital

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[10] Sydney's population was estimated in 2006 as 4,198,500.
See (http://www.abs.gov.au/AUSSTATS).

[11] Melbourne's population was estimated in 2006 as 3,689,700.
See (http://www.abs.gov.au/AUSSTATS).

[12] A compromise was reached whereby a capital city would be created within the boundaries of New South Wales, provided it was no closer than 100 miles from Sydney. The name Canberra was officially proclaimed for the city on 12 March 1913.

[13] Canberra is the only capital city in Australia, the design of which, was the subject of an international competition (Commonwealth of Australia 2003).

(Johnson 1980; Reid 2002). The 'Griffin Plan' (as it is known), which was dominated by an articulated lake called Lake Burley Griffin, is still considered to be the foundation of Canberra's urban plan, administered by the National Capital Development Commission (NCDC). However, the story of Griffin's work in Canberra was one of political interference (Commonwealth of Australia 2003).

Canberra's master plan was conceived by Griffin as a series of nationally significant buildings set in extensive grounds. The connection between the major urban design elements were reinforced and made legible by the axial layout of roads and vistas allowing the architecture to be showcased. Canberra's major connecting roads combined with concentric circular street layouts centred around their intersections form the basis of the Griffin plan (Figure 5, p.12). These major centres are Russell Hill (military headquarters), Parliament Hill (parliament house) and Civic (Canberra town centre). As a *capital*, Canberra shares both an urban planning and an architectural legacy with similar capitals like Washington DC, capital of the United States of America planned by Major Pierre Charles L'Enfant[14].

The pavilion-like relationship between Canberra's public buildings and their locations visually set apart from their landscape has lead to some high profile criticism that it is a city of mausoleums[15]. Griffin's pavilion-like approach to Canberra's urban plan prompted Jennifer Taylor[16] to describe Canberra as "Q*uite literally, a vast garden containing buildings as individual objects"* (1990 p.93). Most of Canberra's monuments, institutions and public buildings are set apart from their neighbours which demand the attention of their citizenry. The High Court of Australia, 1981 (Edwards, Madigan, Torzillo and Briggs, Figure 6, p.14) and the Parliament House, 1998 (Mitchell, Giurgola and Thorp, Figure 7, p.14) are two such examples. These buildings, along with the National Library, the National War Memorial, the National Gallery, Old Parliament House and the many other Commonwealth Government's headquarter buildings, are indicative of the formal relationship between Canberra's architecture and its surroundings.

[14] Pierre Charles L'Enfant, (b1754–d1825), French-American soldier, engineer, and architect.

[15] Former Australian Prime Minister the Right Honourable Paul Keating MP (Prime Minister 1991-96) in a speech launching the Australian Labour Party's arts policy for the March 1993 election made some contentious comments about his view of Canberra's approach to architecture including the proposed new national museum project having potential to be another *"Canberra mausoleum"*.

[16] Jennifer Taylor is an adjunct Professor of Architecture at the Queensland of Technology and author of several books on Australian Architecture. A full list of biographies appears on p.287.

Figure 6 High Court Building, Canberra, ACT.

Figure 7 Parliament House, Canberra, ACT.

Ashton Raggatt McDougall (ARM) in designing the NMA intentionally departed from Canberra's traditional building type and the reverential relationship it has to its other landmark buildings. The introspective NMA is unlike its bold neighbours, and unlike the traditional museum type, a difference articulated by Ian Perlman[17]:

> Nobody will compare it [the NMA] to its international peers, symmetrical treasure boxes like the British Museum. The Bilbao Guggenheim is often cited, but that whimsical assemblage of space and matter is the very inverse of the cerebral NMA, whose complexity is as deliberate as Finnegans Wake and the secret games of the Velazquez painting, Las Meniñas (2001 p.91).

Taylor, considering some architectural responses to Canberra's character, remarks *"Architects sometimes react in an uncharacteristic manner to its vast scale and national importance*" (1990 p.115). ARM did not intend the NMA to imitate Canberra's existing institutional buildings. Hence this unconventional approach has been described by Jencks as the antithesis of Canberra's architecture.

> Lost in the mountains, a planned capital city lacking its city. What there is of it is gray, bland, suburban, and uptight-characterized by the kind of evasive generalizations one expects from corporate politics. The NMA is the reverse: colourful to the point of brashness, urbane and urban, gregarious, beautiful in a few spots, and very particular about ethnic identity and historical grievances (2001 p.24).

The physical location of the NMA signifies it as an institution of national importance. The location chosen for the NMA was on a highly visible 11 hectare site 3 kilometres west of Civic (Canberra's town centre). This site however, was not the first choice for what had become a long awaited national museum and was procured by the Commonwealth Government in a land exchange deal with the ACT Government for Commonwealth land at the Kingston foreshores (Senate 2000).

A number of reports considering a national museum were commissioned from the establishment of Canberra as the national capital to the final NMA report in 1996. Ironically, museums were founded in the Australian colonies with names such as Australian Museum (in Sydney) and National Gallery of Victoria (Young 2001 p.2). This 1996 report (Advisory Committee on the New Facilities for the National Museum of Australia 1996), unlike its predecessor, recommended Acton Peninsula as a possible site. Despite the Committee's

[17] Ian Perlman is a Sydney based architect and author.

final recommendations, there still persisted an opinion that the Acton Peninsula site could not adequately contain the envisaged museum.

> Professor David Ride, who was a member of the interim council and, later, the Council of the National Museum, found it ‘difficult to imagine how that [original] concept, requiring broad acres, native vegetation and open vistas, can be accommodated in a contained site (that could be as small as 11ha), limited by heritage-listed buildings and plantings (Gardiner-Garden 1997 p.11).

The 1996 report marks the end of a long political process to realise a national museum for Australia. The concept of a national museum has been in the political arena since before the Federation of Australia. Henry Parkes, sometimes referred to as the ‘Father of Federation’, and Arthur Woodward, a contemporary of Parkes, and director of the Bendigo School of Arts, was on record as early as 1899, two years before Federation, arguing the case for a national museum (Gardiner-Garden 1997 p.4).

Almost a century later, it could be argued that a national museum was overdue and understood to be so by subsequent Commonwealth Governments. Hence there seemed to be a kind of national museum fatigue at play. This malaise could be seen as being driven by a sense of inevitability which negated any sense of urgency. However, the centenary of Federation (2001) provided an appropriate catalyst for the political rhetoric to be put into action. The well documented history of the museum’s progress is most appropriately interpreted as an event driven process. This process was marked by political intervention usually by Governments, or opposition parties, formulating policies to take to an election. Accordingly, the raison d’être[18], type, scale and functional requirements of an anticipated museum changed over the course of the project’s history and with the changing of Commonwealth Governments and the feasibility reports they commissioned.

Indicative of this process was the 1975 study, which reported on the feasibility of a world leading facility in Canberra (Committee of Inquiry on Museums and National Collections 1975). The Committee report posited,

> In putting forward this recommendation, we may well be criticised on the grounds of extravagance and over-ambition. Our defence against such charges is that we have taken a long-term view of the museum’s development. Too many museum planners in other lands have encumbered their capital city with a museum site and building which now prevent innovative planning. The proposed museum must not be

[18] raison d’être, [French: reason for being], A purpose or reason accounting for or justifying the existence of a thing. Taken from the Oxford English Dictionary (Brown 1993).

> viewed as just another building which could equally be designed for a library or an art museum. We believe that, with the right approach, Australia could lead in museum planning (p.79).

Cited by Gardiner-Garden as a '*Key development in the history of the NMA*" (1997), the 1975 report represents the first significantly politically backed movement to house some of the disparate and scattered collections of Australian historical artefacts and memorabilia in a *low profile museum*. The next major event in the history of the NMA was the National Museum of Australia Act 1980 which relied on many of the recommendations of the 1975 report (Gardiner-Garden 1997). By 1996 the brief had evolved to require the NMA to not only house artefacts but also "[*R]esearch Australian history, develop and maintain a national collection of historical materials, and develop programs for exhibitions to inform more Australians*" (Peters *et al.* 2002 p.8). This requirement to inform the Australian museum-going public would prove the most contentious political/social element of the project. Subsequent to the 1996 report, the Commonwealth Government committed itself to deliver a national museum. In response to this report, the Commonwealth Government developed a brief which required non-traditional exhibition spaces, including "*a great hall, three main exhibition spaces, a digital theatre, research facilities, outdoor exhibitions and landscaping*" (Figure 9, p.18) (Auditor-General 2000 p.31). In the end it had "*6500 square meters of permanent exhibition space and 1500 square meters of temporary exhibition space*" (Jones 1999 p.10).

> In August 1994, the Centenary of Federation Advisory Committee, called on the Council of Australian Governments to consider, among other national infrastructure project, the National Museum proposed by the Government of the ACT and many community organisations (Gardiner-Garden 1997)

Having established a preliminary brief, the Commonwealth Government then conducted a two-stage competition to select a design. The first competition phase generated over one hundred entries (Peters *et al.* 2002 p.78) to what Michael Keniger[19] described as an *ideas* competition. The subsequent phase was a competition between five short listed joint ventures who attended a two day workshop to "*see what they could contribute to the team*" (Raggatt [interviewed by author] 2002), as Howard Raggatt recalls. This second phase required teams to be made up to develop the project. These teams included architects, project manager, service engineer, exhibition designers, etc. (see

[19] Michael Keniger, Deputy Vice Chancellor, Queensland University, a previous Queensland architect of the year, 1998 and the inaugural Queensland Government architect whose research has included the use of digital techniques in architecture. He sat on the Independent Quality Review Panel and Design Integrity Panel and assisted the competition panel.

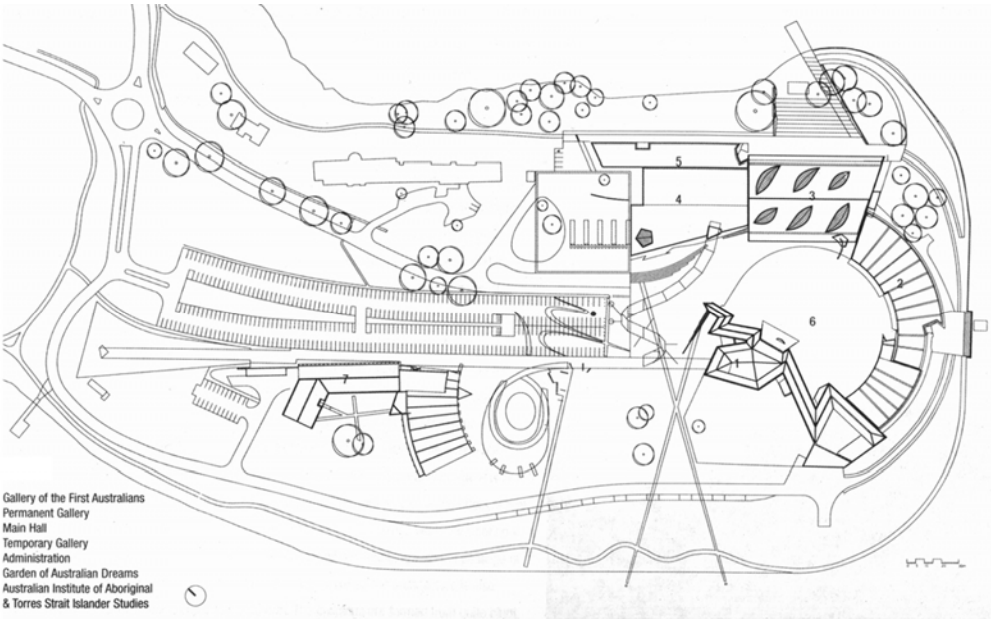

Figure 8 NMA, Annotated Site Plan.

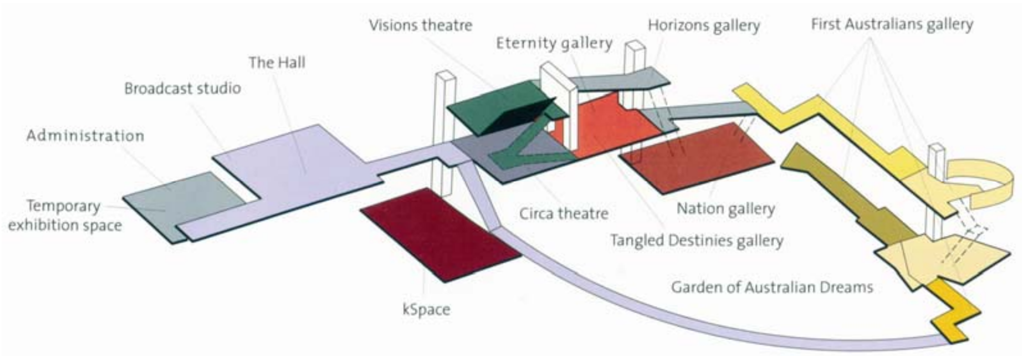

Figure 9 NMA, Graphical Representation of the Layout.

Table 6, p.186 for members of the Acton Peninsula Alliance) and were selected by the Commonwealth Government via its commissioning body, the Department of Communications, Information Technology, and the Arts (DCITA).

The design competition selection panel was advised by Keniger. Craddock Morton asserts the importance of Keniger's role when describing the process,

> The first cut was just to pick the design to get to the shortlist. After that they obviously had to develop them. I think that is certainly the case that Michael [Keniger], if we had somebody conservative

Figure 10 NMA, Acton Peninsula, Artist Impression, Planning Report.

> chairing the panel we would have ended up with a more conservative design and I suspect Michael took the panel along with him to some extent (Morton [interviewed by author] 2003).

Keniger's involvement was in part a response to a disagreement between the Royal Australian Institute of Architects (RAIA) and those responsible for commissioning the NMA (the DCITA).

> The institute had dis-endorsed the competition but in discussion with the client agency and the government had agreed to nominate two advisors, myself and another from Melbourne who advised on the competition probity (Keniger [interviewed by author] 2004).

The reason cited by Peters *et al.* (2002) for the rejection of the traditional RAIA competition criteria were as follows:

> The design competition was intended to determine a design team not a final design. It was important to the NMA and AIATSIS that Australians be the selectors of the design and the time frame was short – all of these contributing factors meant a different process (not RAIA's) needed to be developed to satisfy the circumstances (2002 p.9).

The RAIA's objections were also based on their consideration that "*It did not comply with the international union of architects (UIA) architectural competition* *guidelines*" (Auditor-General 2000 p.51). However a compromise was found. Ironically, the then manager for the DCITA, Dawn Casey, criticised for her role in the way the competition was originally set up, later received the Clem Cummings award for her contribution to the patronage of architecture, which she received from the ACT chapter of the RAIA (Casey [interviewed by author] 2003).

The reason cited in Peters *et al.* for the Commonwealth Government's non-adoption of the standard RAIA competition regime was the unsuitability of its system to the way the DCITA wanted to procure the project. This extra constraint was compounded by the inexperience of the Government staff and a tighter than usual budget, an observation made by the Commonwealth Auditor-General.

> The government recognised that the timeframe of a little over four years to complete construction was 'extremely tight'. Using a traditional tendering and construction approach, previous projects of this scale have taken six years to complete (2000 p.31).

The Commonwealth Government recognised it had required a shorter than usual timeframe. Due to these unusual constraints and having made a political decision, the Commonwealth Government adopted a procurement system selected by a specially commissioned task force (Table 9, p.193) which also formulated a functional brief for the proposed new facilities.

> The government concluded that the method of project alliancing was the most appropriate delivery strategy for this complex project and the one most likely to achieve the project objectives relating to time, cost and quality (Parliament of Australia 1998 p.32).

Once the final scheme had been selected, the task began of delivering this complex and ambitious project. The Commonwealth Government have a history of commissioning conservative architecture. Stephen Ashton characterises this approach as "J*ust incredibly conservative*" (Ashton [interviewed by author] 2003). An artist's impression (Figure 10, p.19) shows that the expectations of the planning committee were for a more traditional museum design. Whilst this image does not depict an actual competition entry, it does give an idea of what sort of architectural expression the committee was expecting. Despite the conservatism of the Commonwealth Government, the NMA was a departure from this perspective in several respects. In addition to the unusual conditions under which the project was commissioned, the form of the building was also unconventional. In addition, the time frame and budget were calculated and discounted by the Commonwealth Government, before any designs were formulated.

There was a contrast between the time and budget, and the status of the NMA as a national flagship project. Both were modest by international standards, a point not lost on those involved. The Independent Quality Panel's (described in Section 5.3) final report places the resources allocated to the NMA into some relevant contemporary context.

> By way of comparison, the Museum of New Zealand Te Papa in Wellington and the Melbourne Museum at Carlton Gardens took around eight and six years respectively. The budget was also relatively modest in comparison with NZ$280 million for Te Papa and AUD$288 million for the Melbourne Museum (Independent Quality Panel 2002 p.1).

ARM is an architectural practice experienced in working with governments, particularly the Victorian State Government. They were however, unaccustomed to how the Commonwealth Government worked. To paraphrase Ian McDougall, ARM was not well connected within Commonwealth politics and as this was their first Commonwealth Government project, their learning curve was steep. This view was supported by Ashton.

> That was the first time we worked on a Commonwealth government project and we knew nothing about the politics of Canberra or politics of the Commonwealth Government and we learnt a hell of a lot (Ashton [interviewed by author] 2003).

The Commonwealth Government's approach to the national and historic nature of the NMA generated a debate about the way Australians do, and should, see themselves and their countries history. Based on previous experience, the choice of ARM as the design architects for the NMA increased the likelihood that there would be some controversy regarding the architecture (as discussed in section 5.1.1).

Reconciling Australia's past with its present requires dealing with multiple versions or views of events, their relative importance and forming a narrative. When considering the NMA's relevance to the national identity, John McArthur[20] states "*We liked to think that the story of Australia is not one, but many tangled together. Not an authorised version but a puzzling confluence*" (2001 p.50). This ambiguity extends to the Commonwealth Government's approach to the resources it should commit to the NMA.

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[20] John McArthur is a senior lecturer in architecture at the University of Queensland, Australia.

The initial figures of the NMA were much lower than the final figure allocated. This discrepancy promoted the opposition upper house[21] representative for the ACT, Senator Kate Lundy, to make her view on this matter known.

> ACT Labor senator Kate Lundy suggested that the money the Government had committed could only build a 'glorified barn' (a realistic cost would be $150 million) (Canberra Times1996 p.3).

However, in 1993 the Labor party, then in Government, estimated $60 million as a total cost for a national museum with the Government committing only $26 million towards the joint public/private project (Gardiner-Garden 1997 p.4). The NMA budget was eventually fixed at $155.4 million from the Commonwealth Government, which included the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS). This part of the project received $3 million contributed by the ACT Government for a separate building co-located on the site. The funds were divided as shown in Table 1 (p.23).

As previously stated, the specific political beginnings of the NMA as a significant political exercise by the major political parties began in 1996 during the lead up to that year's Federal election[22].

> At the beginning of 1996, with a Federal election on the horizon, both the Labor Government and the Coalition Opposition sought to clarify their position on the contentious issue of the National Museum (Gardiner-Garden 1997 p.7).

The Commonwealth Government commissioned a series of projects for the centenary of Federation around this time. In keeping with the intent to provide a national museum before the Centenary of Federation, they commissioned a report on the feasibility and functionality of a national museum.

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[21] The Australian parliament is divided into two *houses*. The lower house or House of Representatives are directly elected using the Westminster system of one representative for a given population in a geographic area or *seat*. The upper house or Senate is a review chamber populated by a fixed number of state and territory based representatives or senators. This system was agreed to by the various independent colonies considering a *state house* or *house of review*, as part of the negotiation of a Federal system of national government.

[22] Australian Federal (Commonwealth) elections are held every 3 years (before a maximum term expires). The exact time before the required date is at the discretion of the Prime Minister. Recent Australian Federal elections have been held between 2 ½ and 3 years on average.

Budget Element	Budget ($m)
Museum Building	60.0
Museum Furniture and Fitout	6.0
Museum Exhibitions	49.9
Institute Building	12.4
Institute Furniture and Fitout	1.7
Institute Artworks and Exhibitions	0.2
External Works	14.7
Off Site Works	0.5
Relocation	0.4
Defects Liability Period	0.1
Quality Pool	3.0
Consultants, Contingency etc….	6.5
(Total)	**$155.4**

Table 1 Budget allocations for the NMA Project[23] .

> In early December 1996 the Advisory Committee on New Facilities for the National Museum of Australia and the Australian Institute of Aboriginal and Torres Strait Islander Studies handed its completed report to the Federal Minister for Communication and the Arts (Gardiner-Garden 1997 p.9).

Following this report (Advisory Committee on the New Facilities for the National Museum of Australia 1996) a decision was made to fund preparatory work for the NMA project when "*the Prime Minister accepted the Advisory Committee's recommendation [1996] to establish the new facilities on Acton Peninsula in Canberra*" (Auditor-General 2000 p.29). Subsequent to this,

> The Prime Minister Mr Howard announced that the Federal Government would provide $750,000 immediately so that design work could begin for the Museum of Australia on Acton Peninsula (Gardiner-Garden 1997 p.10).

Shortly after this an announcement was given,

> In February 1997, the Minister for Communications, the Information Technology and the Arts established the Construction Coordination Committee (CCC) to promote a cooperative and integrated approach

[23] Raw data taken from Peters *et al.* (2002).

> to the development of the new facilities on the Acton Peninsula (Auditor-General 2000 p.29).

This event driven chronology can be seen as indicative of projects with a reliance on governments for resources. It is a feature of political life that by influencing the public perception of an outcome of a project, the credit for a success can be claimed or the blame for a failure redirected and resources allocated on this basis. Consequently, the role of governments in flagship projects could be seen as adding extra layers of complexity for the delivery team to negotiate. Political concerns are traditionally centred in part around how the public and the mass media may perceive or present the outcomes. Hence relationships between the Government and those who provide them with the publicly scrutinised infrastructure are under constant review for a possible political triumph or to put distance between a potential political embarrassment and an elected representative.

However, there were no significant events or recollections to support the notion that the Commonwealth Government was concerned with the aesthetics of the design or the choice of architects. The main concern for them was the possibility of a cost blow out or a time over-run. For the Government, the complex geometric design was less of an issue than the flagship status the NMA had attached to it. When considering the most pressing issues from the Commonwealth Government's view of the NMA project Keniger contends "*It was less the complexity of the building than the fact that it was a national flagship*" (Keniger [interviewed by author] 2004),

This assertion is supported by Morton when he recalls, "*There was much more public concern that the hospital was being replaced with a museum*" (Morton [interviewed by author] 2003). There were issues of local political and public interest however. The demolition stage of the project was accompanied by tragedy when, a 12 year old child was killed by flying debris while watching the stage managed demolition of Canberra hospital (ABC 1997). The incident became the subject of a coroner's inquiry and an ACT Government inquiry[24]. The inquiries concluded that this traumatic event was the product of an incorrect demolition method being used which catapulted pieces of masonry over and into Lake Burley Griffin and the public who were watching the event from both boats and on the shore.

The Commonwealth Government did show some retrospective political interest in some very minor elements in the design of the NMA. The inclusion

[24] *See* http://www.courts.act.gov.au/magistrates/dec/bender/Conclusion.htm.

of the blue poles[25] can be seen as indicative of this political interest. Also the landscaping in the courtyard (GOAD) and the translation of the text on the Braille panels[26] which contained a politically sensitive message all attracted political interest. However, the main political concern at the NMA was how the exhibits would depict Australian's national story.

Political entities traditionally do not spend money on non-essential infrastructure, that is, museums, without either a perceived political advantage or a pre-emptive defence against a political attack. The political advantage in this case may have been as simple as keeping an election promise or, more cynically, not giving a political opponent an opportunity to highlight a promise broken. Gardiner-Garden (1997) maintains, when quoting from a speech given on behalf of the coalition government[27], that they will 'honour Labor's broken promise'. The newly elected Commonwealth Government had identified itself with this issue from this point on.

> The coalition will honour Labor's broken promise and establish a National Museum of Australia and that in the first year $1.5 million will be allocated to determine the best possible site, employ architects and establish an appropriate tendering process (Gardiner-Garden 1997 p.9).

The political influence of design is problematic when the ideas upon which the design is based are as abstracted as those that formed the NMA. Prime Minister John Howard did not seem to be cognisant of the ideas that formed the NMA when he opened it, as he remarked in his opening address on the 11 March 2001, "*In some respects it is very un-museum like*" (Howard 2001). Ironically this unfamiliar type of museum is in accordance with the early vision put forward by the Howard Government's advising panel when they suggested

[25] A previous Australian Labour Prime Minister, the Rt Hon, Gough Whitlam, championed the purchase of Jackson Pollock's artwork 'Blue Poles' by the National Gallery of Australia. This decision was at the time controversial and has hence linked the Blue Poles to Whitlam, who is still an outspoken critic of the incumbent Commonwealth Government. After some political interest, the poles included as a landscaping element of the courtyard (GOAD) were permitted, but were not to be painted blue, which they later were. *See* http://www.nga.gov.au/Pollock/index.cfm.

[26] The Right Honourable Mr John Howard Prime Minister of Australia (at the opening of the NMA) refused to admit responsibility for the Australian Government's historical treatment of its indigenous population. The 'SORRY' campaign was a high profile issue at the time of the museum opening. The Prime Minister's view of his personal responsibility became the main issue of contention. One of the original oversized Braille façade panels when translated spelt sorry. This panel was replaced when it was brought to the attention of the Government.

[27] The Coalition Government holds the majority of seats in the Australian parliament. This coalition is made up from the Liberal party of Australia and the National party of Australia with the Liberal party as the senior and controlling partner.

a departure from the previous museum types and advocated a "*Museum without walls*" (Mulvaney 1997).

The NMA was conceived by the design architects (ARM) as a narrative-based museum and it is this approach that provided the architects with a rich environment to generate their metaphoric forms. Whilst ARM's design was based upon a view of the Australian experience, it was expressed through a metaphoric response (described in section 3.2) which at times responds to what Gibson has termed a "*nugget of neuroses*" (Gibson 2001). The framers of the exhibits did not have the opportunity to abstract exhibition artefacts[28] to the same degree as the architects. The NMA budget reflected the prominence expected of the exhibitions by the Commonwealth Government which allowed a significant allocation for the framing of the exhibits; almost one third of the total budget ($49.9 million out of $155 million).

It could be argued that the intensity of the debate about the framing of the displays lessened the political and public debate about the architecture of the museum as Keniger points out.

> In terms of political intervention there was virtually none I know of in the building or the landscape design but there were more concerns as it became a reality as to the exhibits, what story was to be told. (Keniger [interviewed by author] 2004).

In addition to the Government's concern over the framing of the exhibits, they were also aware of the possibility of the project becoming a battleground for issues raised in the Cole Royal Commission, as Keniger asserts.

> I think as a project it was a complete recipe for disaster, it could have been used to press national issues by the unions, it could have been used as a source of embarrassment for the government, it had all the ingredients (Keniger [interviewed by author] 2004).

The social and political backdrop to the NMA project was and remains a focal point for competing views about Australia's history. These contentious views are still being played out in the mass media. The NMA project had and still creates highly charged debate about whether the purpose of a National Museum should be provocative or deferential to the nation's understanding of itself.

[28] The importance of a particular artefact is a matter for debate and as such is used to qualify the artefacts displayed as sufficiently important to be mandated by the museum for display, storage, sale and destruction.

Australia's post 1788[29] story is a complex and inter-connected narrative which has been seen from a variety of views. Hence the views expressed regarding the NMA could be seen as a bell weather for public sensibilities and the relative importance of exhibit items.

ARM's response to what they consider central to Australia's understanding of itself has certainly stimulated a lively and ongoing debate. Some see ARM's work as appropriate to the ambiguities of Australia's history, whilst others see it as trivialising it. The journalist and architect Peter Ward[30] characterises it as "*Theme Park Australia*" (2001 p.39).

When the museum opened in March 2001, some of the popular press reaction was very hostile to both the architecture and the choice and framing of exhibits. 'A Nation Trivialized' ran the headline of the Daily Telegraph, a major Sydney newspaper. Journalist Miranda Devine wrote that the underlying message of the museum "*is one of sneering ridicule for white Australia. It is as if all non-Aboriginal culture is a joke*" (2001 p.14). Journalist Jennifer Sexton[31] expresses the view (which was indicative of some Australian press reporters) that Australia's Anglo Celtic history has been considered deferential to indigenous history. Moreover, she sees the NMA as being part of a wider clash of ideologies played out through government funded institutions.

> The National Museum of Australia is jostling for space alongside the ABC at ground zero of the cultural wars – its exhibits accused of lacking enough Captain Cook and cricket bats, of being too sympathetic to the black-arm banded[32] and politically correct (Sexton 2003 p.27).

The most vocal and sustained of the NMA's critics is the prominent Australian historian Keith Windschuttle[33], who has maintained an aggressive campaign against the museum, mostly with regard to the choice and framing its exhibits. However he also believes that the architecture is unsuitable. His criticism is based on what he believes is an inappropriate architectural *style*. He sees the most appropriate style as monumental; a style which had dominated museum

[29] The year 1788 marked the arrival of the first fleet of British ships at Botany Bay, NSW and the establishment of the first permanent European presence in what would be known as Australia.

[30] Peter Ward is a Lecturer in Building at the University of Newcastle, Australia.

[31] Journalist Jennifer Sexton is a public commentator for the Australian newspaper 'The Age'.

[32] Black arm band is a term used to characterise historians who see Australia's post-1788 history as a series of shameful events perpetrated on indigenous Australians.

[33] Keith Windschuttle, is a former history lecturer in social policy at University New South Wales and a guest lecturer on history at several American universities and he sits on the board of the Australian Broadcasting Commission (ABC). He was given a Centenary award from the Prime Minister for 'Services to Australian society though history and writing.

design in Australia and overseas until the last few decades and would be in keeping with Canberra's existing buildings. Windschuttle believes the entire premise of the museum project was flawed in its entirety when he asserts

> The National Museum is a profound intellectual mistake as well as a great waste of public money. Indeed, the museum is already a museum piece itself – an expensive relic of postmodern theory. Apart from a few of the indigenous displays, it is not a real museum at all. It is a repository of nothing more than the intellectual poverty of the tertiary-educated middle class of the post Vietnam War era. It is not only one in the eye for the Howard government but also for the nation. (Windschuttle 2001 p.26).

He believes that the NMA represents a triumph of politically biased showmanship over scholarship when he characterises the NMA as framing Australia's history when he contends "*History has become both politicized and trivialized*" (Windschuttle 2001 p28). This view of the NMA's contribution to Australia's history is countered by commentators such as the author Robert Manne[34]. These publicly expressed and widely published polemic views prompted the inaugural director of the NMA, Dawn Casey, to contend

> The extreme views on both sides are unappealing and repetitive; the debate is in danger of becoming bogged down in simplistic opposition, with the National Museum of Australia being used as a battleground by both sides. (Casey 2003).

For some involved in this debate, these arguments are simply a convenient vehicle for some historians to endorse or discredit a particular view of Australian history and are in Casey's view, "*Generating more heat than light*" (Casey 2003 p.32). The architectural contribution to this debate was considered by most as secondary to the philosophical approach of the exhibition frames.

Public debate surrounding national projects have a well documented history that is not confined to Australia. French President François Mitterrand's (b1916-d1996, presidency 1981-1995) grand projects including the Pyramid extension, the Louvre, Paris, (1989) IM Pei; the Opéra de la Bastille, Paris, France (1994) Carlos Ott; and the Bibliothéque Nationale, Paris, (1995), Dominique Perrault (Figure 11 p.29) were all significantly politically influenced (Frampton 1980).

[34] Robert Manne is a professor of politics at La Trobe University, Melbourne, Australia. He regularly contributes essays and columns to the Melbourne Age and Sydney Morning Herald. He is the Chair of the Australian Book Review, a board member of The Brisbane Institute, and a member of the board of the Stolen Generations Taskforce in Victoria.

Figure 11 Bibliothéque Nationale, Paris, France.

Figure 12 Millennium Dome, Greenwich, London.

The political imperative in these projects adversely affected design decisions and choice of materials (Brand 1994). The most notable recent high profile politically influenced project was the Millennium dome[35] (Greenwich peninsula, London 2000 Richard Rogers Partnership, Figure 12, p.29). This project was a major topic of the tabloid newspaper editorials during the months of construction and its early operation. The British Government made many interventions into the project's design and choice of materials on political rather than architectural grounds.

In western democracies major outlays of tax payers' money are usually the subject of some debate, especially if the project is seen as having cultural overtones or implications. Unlike some areas of Government expenditure, museums that put forward a particular point of view, or are seen as only relevant to a small percentage of the population, should expect some level of public debate and some of that debate to be intense and vitriolic; Australia is not an exemption.

Australia also has a history of political intervention into high profile architectural projects; for example Jørn Utzon's Sydney Opera House (Figure 15 p.32) and Lab Studio architects' Federation Square project, Melbourne (Figure 13, p.31 and Figure 14, p.31). Philip Goad sees parallels between these projects which could be considered indicative of how changes in government intention impact on a cultural building progress. "*The connotations of political sabotage after a change of government are so obviously comparable to the saga surrounding the abortion of Jørn Utzon's design for the Sydney Opera House*" (2000 p.21). The Federation Square project is of particular interest to the understanding of political interest in Australian cultural projects because it was realised during the same period of time as the NMA project but was the subject of much public and political debate.

[35] *See* http://news.bbc.co.uk/1/hi/in_depth/uk/2000/millennium_dome/default.stm.

Figure 13 Federation Square, Atrium, Melbourne.

Figure 14 Federation Square, Façade, Melbourne.

Figure 15 Sydney Opera House, Bennelong Point, Sydney.

As previously stated, the vitriol of the debate over the role or interpretation of the museum's collection was more intense than that surrounding the architectural expression. One possible explanation is that because Canberra is not the most populous city in Australia and the site was not at the heart of that city, the country's attention was only drawn to it after its completion. Also, at the same time, the debate about the appropriateness of architectural form and prominence was being carried on elsewhere. A new apartment building on East Circular Quay, Sydney designed by Andrew Anderson, adjacent to the Sydney Opera House (Figure 16, p.33), and the Federation Square project, Melbourne, were both very prominent examples of architectural projects becoming politically influenced projects. In the case of Federation Square, many of the contentious issues between client, builder and architect were played out in the media. This, at times acrimonious, relationship was shown in the documentary film 'Inside the Square' (Balendra 2003) which chronicles the differing perspectives of the major stakeholders in the project and how the mass media was used as a tool for negotiations. A possible reason why the NMA did not degenerate into a public fight could be the procurement method used at the NMA. This system allowed for constructive debate amongst the partners (see section 5.2) rather than a damaging fight between partners played out in the media, and as such did not provide a story for the press or

Figure 16 East Circular Quay, Sydney.

opponents of the NMA to exploit. However, this thesis contends that the major factors that stopped the NMA becoming a *political football* were a lack of industrial action coupled with the modest budget the Government had allocated.

There is a view that any government-run national museum, should be as *value neutral* as is practicable. Giving a particular narrative of a nation's history is contrary to this view despite the label of "*A cultural history museum … dedicated to telling the national story*" (Usher 2001). However it is likely that, because the NMA cannot show all of its exhibits simultaneously due to the size of the exhibition space, there will always be debate about the relevant merits of what is displayed versus what is to be stored. Also the artefacts purchased, sold or destroyed by the museum required choices that will continually promote debate. Due to Australia's colonial past there are conflicting views of what constitute important events in Australia's history. A museum charged with representing Australian history would inevitably draw criticism from some quarters as to what type of building these artefacts *should* be housed in.

The political and social context necessarily impacted upon the NMA. Its form was generated by a particular view of the social, historical and political events that inform and form modern day Australia manufactured as a knot of destinies (described in 2.2). The Commonwealth Government have not imposed a view of what should, or how it should, be shown. They have allowed that debate to continue without an easily identifiable Government position. The competition process allowed ARM to engage with some of these uncomfortable, as well as whimsical, national issues in an atmosphere of freedom of speech through architectural expression but without the benefit of additional funding that Raggatt describes as providing the only architectural freedom.

2.2 Inspirations and Design

The following section provides an insight into the motivations and methods ARM used to generate the NMA. It deals with issues which were predominantly within their control.

The mixture of innovation and ingenuity supported by computer technologies in the hands of some contemporary architects has allowed generative or metaphor based design to be realised at an affordable price. This can be seen at the NMA project (Jones 1999; Reed 2002b). This hybrid use of the prevailing technology to suit a particular purpose is a recurring motif in the history of architecture. William Mitchell quotes examples of the work of Palladio (1508-1580) and his use of an elastic spline to create and document the dimensions of a column and Antonio Gaudi (1852-1926) and his use of cables hung with weights to give an inverted profile for use in vaulted ceilings (Mitchell in Raghed 2001).

The idea that drove ARM was a dissertation on Australia’s history and cultural identity. They abstracted cultural, social and historic themes that permeate the Australian psyche to generate what could be termed *form based ambiguity*. The subversion of cultural and historical themes is a device ARM has previously used successfully. Jencks characterises their previous endeavours of examining culture through architecture, “*ARM have been mining that vein for years*” (2001).

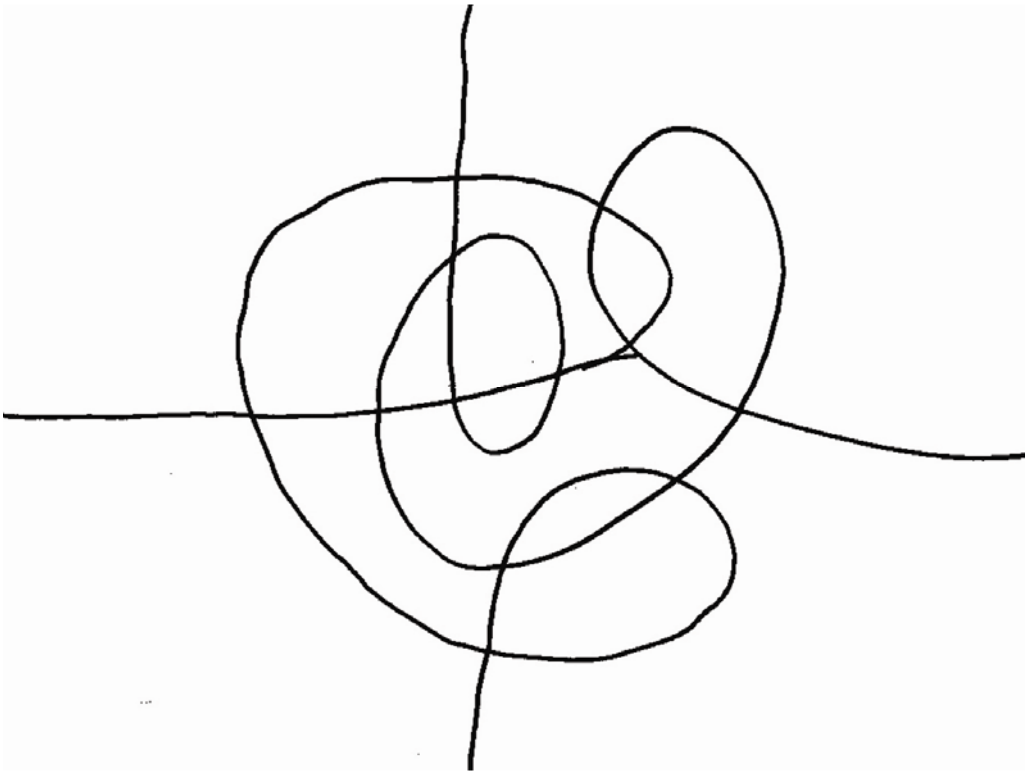

Figure 17 NMA, Early Sketch (the Wandering Line).

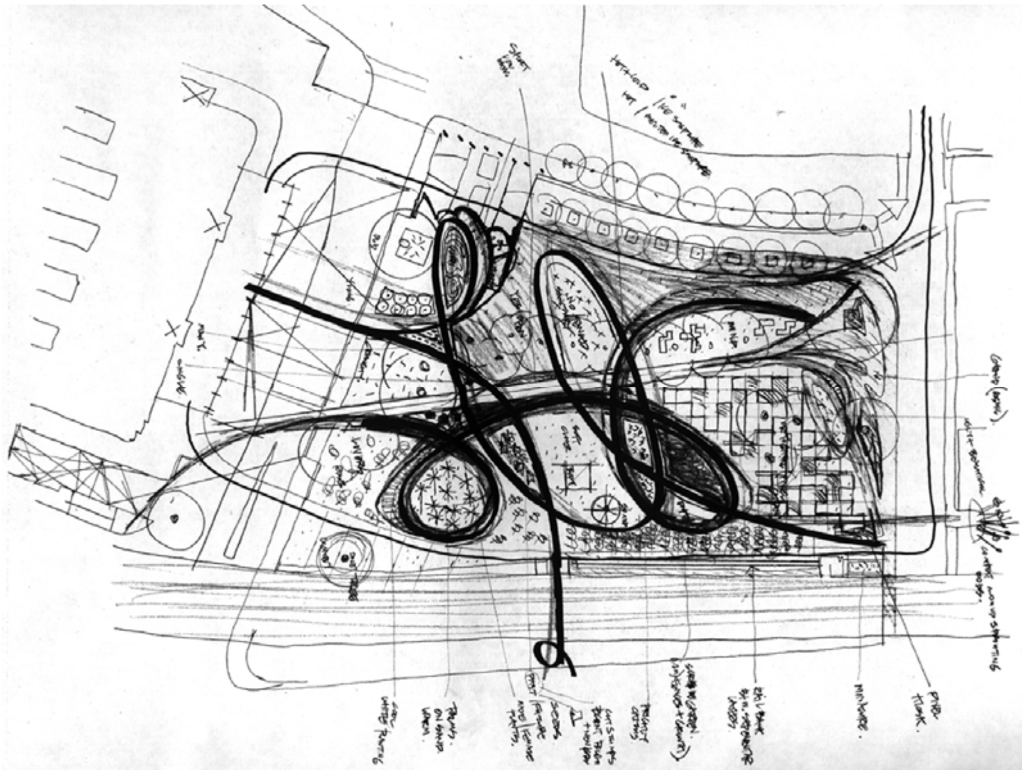

Figure 18 NMA, Planning Sketches.

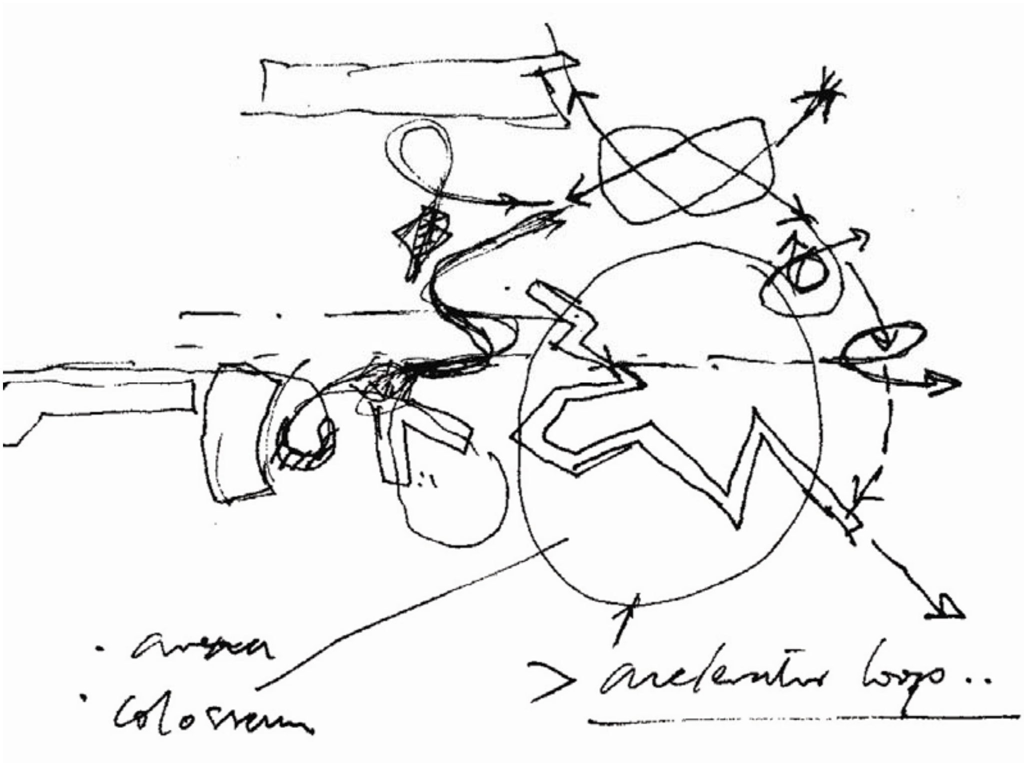

Figure 19 NMA, Wandering Line Sketches, path on Cutting Plane.

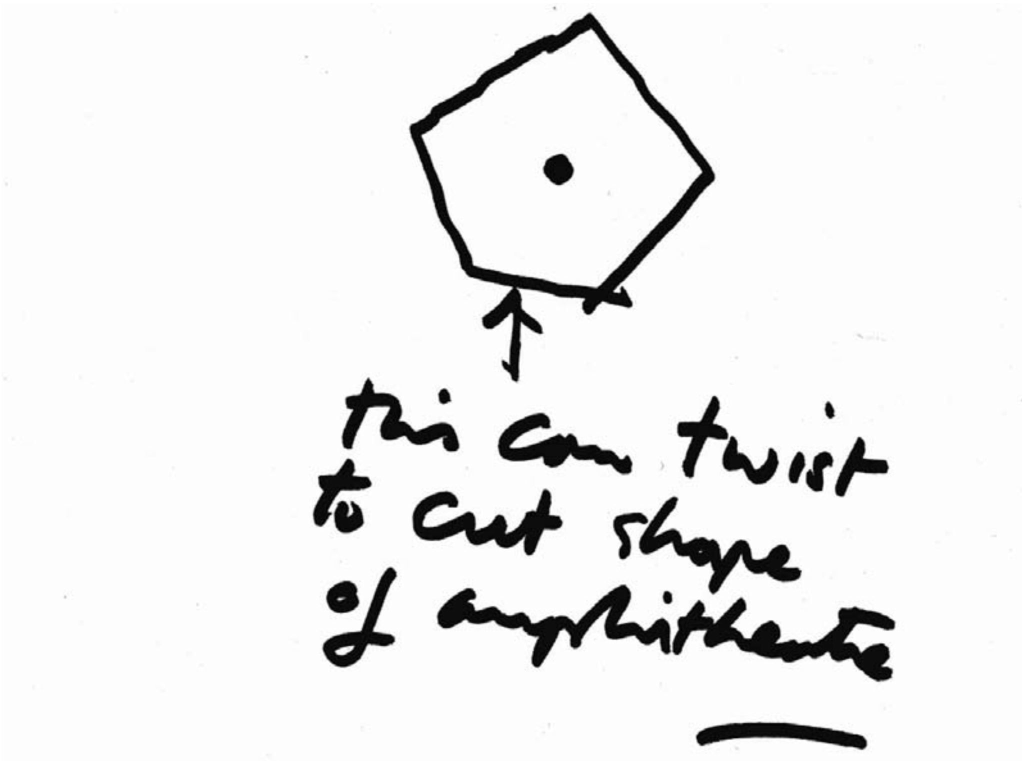

Figure 20 NMA, Early 3D Cutting Plane Sketch.

ARM approached the competition entry for the NMA project at many different levels including *an unfinished campus* and a knot of *tangled destinies*. Their use of ambiguity was evident in their competition entry materials which had the words "*this is not yet a design*" stencilled in bold red lettering across it (Reed 2002b).

The notion of the interweaving of many stories was connected by the concept of the wandering line (Figure 19, p.36 and Figure 17, Figure 18 p.35) (Reed 2002b). This wandering line would provide both a visual and physical continuity to the whole project. This wandering line would later prove a problematic element to construct and hence become an issue for debate amongst the various stakeholders about its importance to the design as designed versus a version modified for a lower cost of fabrication (see section 5.2.2).

As previously stated the architecture of the NMA was conceived as a commentary on Australian history; an unfinished project with all its uncertainties and contradictions. McArthur articulates ARM's treatment of these uncertainties when he contends:

> The architectural approach is close to the ideology of the museum. The NMA attempts to present Australia as an unfinished project and an unresolved concept - a nation in which an appropriate level of faith and affection balance a paucity of agreed beliefs and doctrine. One of the new genre of "social and cultural history" museums, the NMA is itself a problematic and uncertain enterprise. (Macarthur 2001 p.51).

ARM did approach the NMA with a definite view of what a public building should be. Raggatt summarises ARM's approach to their public building and what he believes all public architecture should aspire to, when he reflects "*I think architecture really tries to have an agenda that's a fair bit bigger than good design, I think it's about some kind of cultural synergy, some kind of public statement of aspirations of a society*" (ABC 2000). This view of architecture as a cultural or social activity is shared by Ashton when he states "*Our culture is a work in progress*'' ([interviewed by author] 2003). This view is supported by Reed when she asserts that "*Howard Raggatt sees architecture as a canvas for political action*" (2002a p.13). She sees the museum's built form as deliberately provocative.

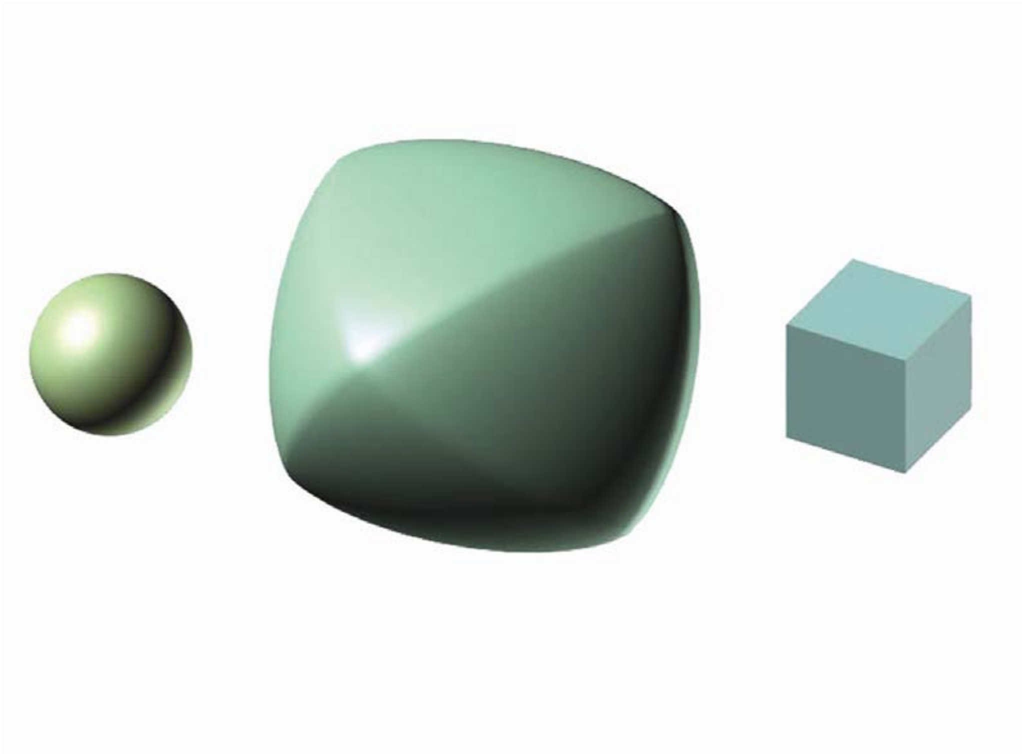

Figure 21 Super Ellipse[36] (ARM's Federation Square Competition Entry).

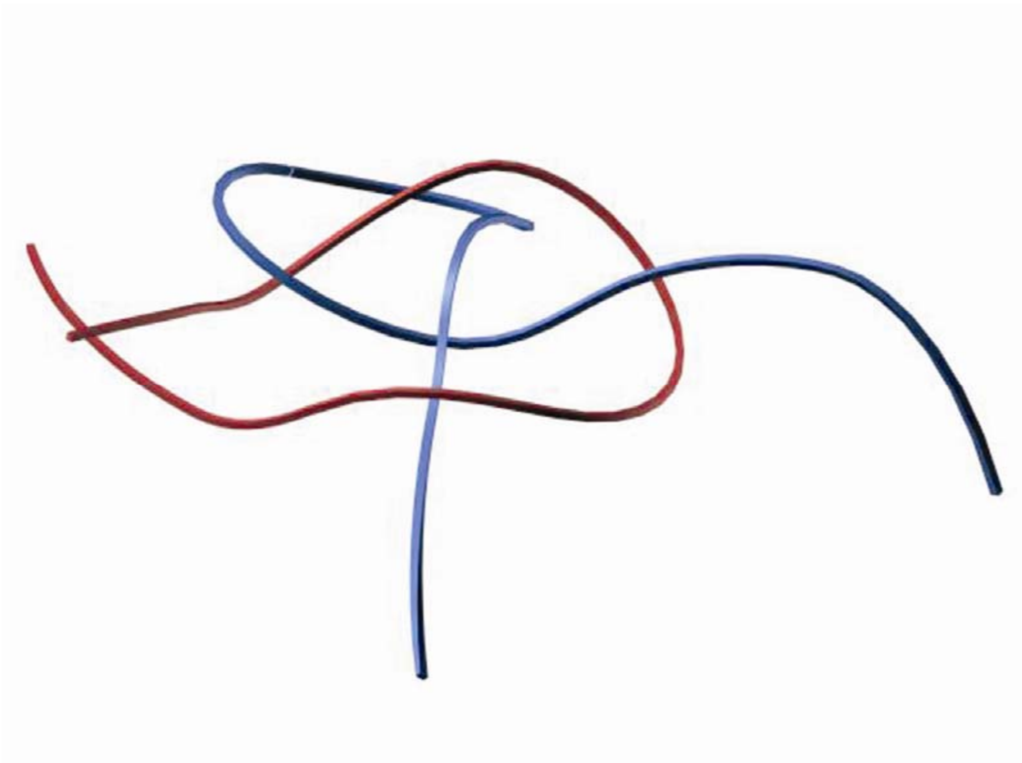

Figure 22 Boolean Knot, NMA.

[36] A super ellipse (or Lamé curve) is the geometric figure defined as a product of a cube and a sphere.

ARM was, by *their* definition of architecture, predisposed to intentionally subvert or question the traditions of museum architecture. This approach has led to the NMA project being characterised as "*A master work of subversion, ambiguity and fiction"* (Perlman 2001 p.91). These qualities posed by Perlman are also a reason for some of the criticism of the design as previously outlined (Section 2.1).

ARM used a strong symbolic metaphor to generate the form of the NMA. It is a visually complex manifestation of the architect's dialogue with the ambiguities of Australian identity (Raggatt 2002). As previously mentioned the metaphor was developed from the notion of tangled destinies, using the intertwining of Australian Aboriginal and Australian non-Aboriginal stories to generate a metaphorical knot as outlined in (Gibson 2001; Reed 2002b; Garbutt 2003). This knot was generated by a sequence of Boolean operations using computer aided solid modelling techniques (Figure 21, Figure 22, p.38, Figure 25, p.42). The Boolean sequence shown was developed for ARM's unsuccessful Federation Square competition entry[37]. Figure 26 (p.42) shows the Boolean sequence subtracted from a form generated from a box based on Stirling and Wilfords No. 1 Poultry Place (1985-98), London (Figure 27, Figure 28, p.43), an existing post modern form in preference to the mathematically design super-ellipse was used for the form of their Federation Square entry. Macarthur describes the NMA as "*A little lesson in architectural history, an opinion about a present architectural controversy and an essay in the complexities of the idea of originality in form making*" (2001 p.56).

Their work at the NMA project revisited the notion of axial connection which was a prominent factor of the Griffin plan (Figure 5, p.12). Ashton stated in an interview with journalist Deborah Jones that they were "*Revisiting some of Walter Burley Griffin's ideas for Canberra*" (Jones 1999 p.10). This idiosyncratic approach led to the superimposition of the lost axis (as ARM termed it), connecting Canberra to Uluru (Ayers Rock)[38]. ARM conceived this extra axis (Figure 23, p.40), as an acknowledgement to the connection with the previously unrepresented importance of Aboriginal Australia (Ashton 2002). Figure 24 (p.40) shows the end of the wandering line aligned along the lost axis, as it features in the landscape design.

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[37] ARM developed a competition entry for the Federation Square project. This project was commissioned for the Centenary of Federation and as such shared many issues with the NMA.

[38] Uluru is an enormous eroded sedimentary rock situated 335 km south-west of Alice Springs in the Northern Territory. Uluru (Ayers Rock) has significance to the local Aboriginal people, and has become emblematic of Aboriginal Australia's connection to Australia's remote natural landscape.

Figure 23 Canberra's Lost Axis (Plan).

Figure 24 NMA, the end of The Lost Axis.

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ARM recorded their metaphorical influences and inspirations by electronically storing images, i.e. images of Aboriginal dot paintings, land forms and scans of hand written notes and sketches, (Figure 19, and Figure 20, p.36). This regime tells a story of the issues ARM consider relevant. The scan of hand written notes also left a detailed record of their reflections and reactions to those images and a narrative of the design development.

ARM's view of the geographically non-specific nature of the NMA's design is reinforced by the similar form generated for the Federation Square project, a Victorian Government project commissioned for the Centenary of Federation and designed by Lab Architects.

The NMA is made up of a number of aesthetically separate but physically connected architectural *pavilions* (Figure 8, p.18). The horseshoe plan encloses a courtyard known as the Garden of Australian Dreams (GOAD). The circulation patterns are designed to take the visitor on the long journey through these spaces.

These pavilions which make up the NMA incorporate some architecture *elements of precedence* from Utzon (glazing panels of the Sydney Opera House), Libeskind (plan of the Jewish museum, Berlin), and Stirling (No 1 Poultry Place, London), previously mentioned, amongst others. ARM has a reputation for image inspired work, like the Kronberg Clinic Melbourne. This building used an image of the Vanna Venturi house, Chestnut Hill, Philadelphia, Pennsylvania 1962 (Robert Venturi) to generate a façade by moving the image whilst photocopier was scanning it and using polychromatic brickwork to construct the distorted pixels (ABC 2000).

ARM's inspirations and quotations needed to be transformed into form. The NMA was realised using many technologies to generate the design information. ARM's highly metaphoric design inspiration spawned an equally complex set of forms. They used a tool that could continuously remodel their inspirations and the iterations of those inspirations.

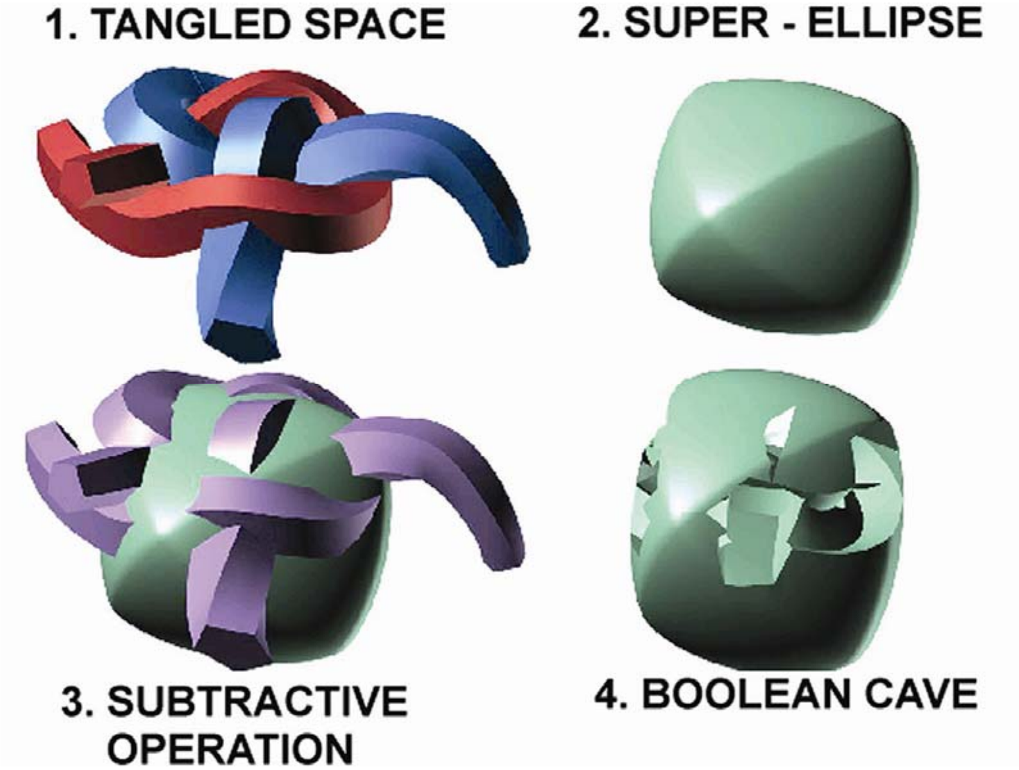

Figure 25 Boolean Sequence (ARM's Federation Square Competition Entry).

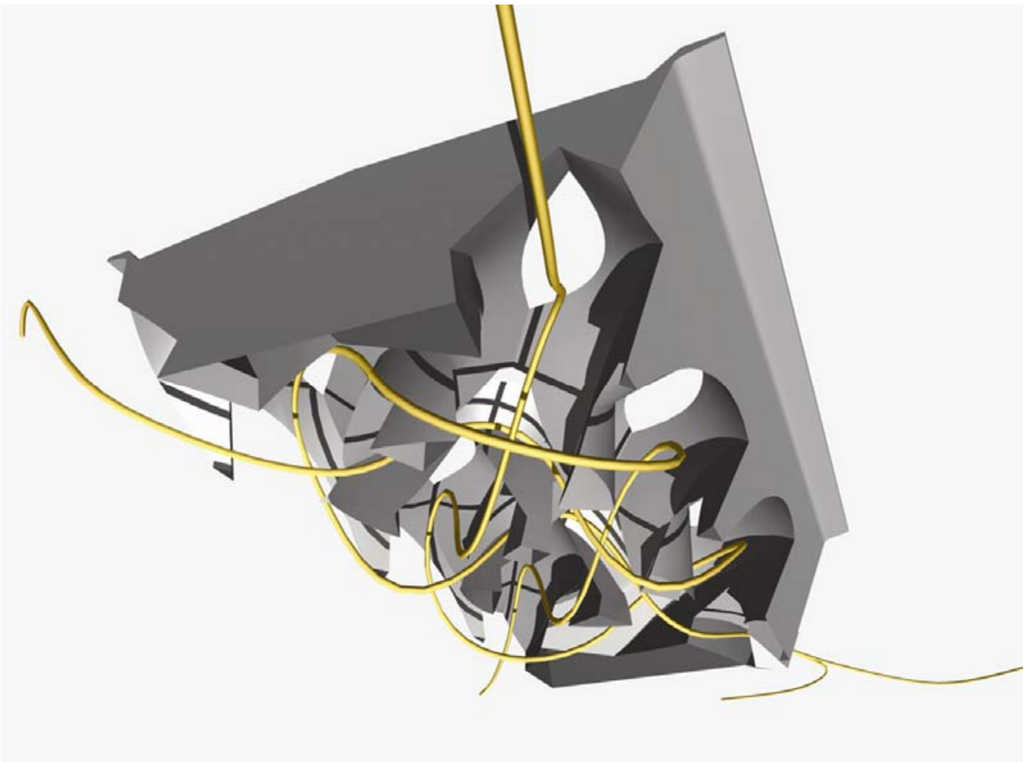

Figure 26 NMA, Solid Modelling Study (Main Hall).

Figure 27 No.1 Poultry Place, London.

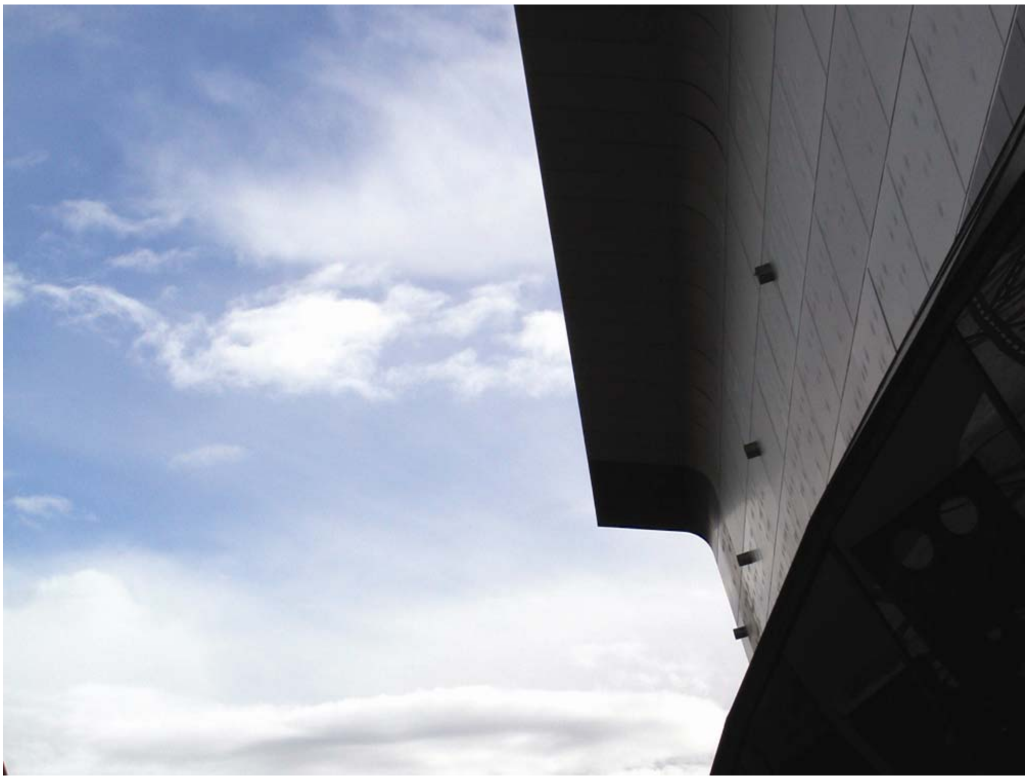

Figure 28 NMA, Parapet, Main Hall.

The software used for this purpose was 3D MAX, an animation software package[39]. 3D Max was well suited to the generation, manipulation and visualisation of complex forms due to the predominantly visual purpose it was used for (still photo-realistic pictures). ARM's view was that a standard architectural CAD package would have proved too time consuming to use to generate and edit such complex geometric forms (Shiel 2002). Traditional architectural CAD packages are designed to aid the speedy production of design and documentation. Hence they are geared toward traditional architectural elements and geometries, and not the geometries of the NMA.

3D Max (a solid modelling CAD package) was used to generate a series of Boolean operations which subsequently defined a set of 3D control surfaces. The virtual knot (the subtracted element) was formed by extruding a polygon (Figure 20 p.36) along a non-uniform rational b-spline (NURB[40]) defined 3D path. This operation was completed by a software package new to ARM as their existing software (AutoCAD v.13) did not allow extrusion along a 3D NURBS defined path (Shiel 2002). Once the 3D path was defined (Figure 19, p.36), a 2D form was needed to extrude along it to give it a distinct thickness of profile. This progression can be seen in Figure 22 (p.38).

A range of options was considered to form the cross section of the rope that made up the knot. A triangle was thought not to give enough space when subtracted, a square was considered too classical, and any polygon with six or more sides may have given the impression of an imperfect circle. The circle itself was also considered too classical for this purpose (Raggatt [interviewed by author] 2002). The outcome of these deliberations was that the pentagon was selected (see Figure 20, p.36) as the 2D cutting profile for the whole project. The 2D profile also rotates as it winds its way around the project. This can be seen not only in the Main Hall but also in the other voids that the rope forms (Figure 35, p.49) whilst winding its way through the various building elements.

[39] *See* http://www.3dmax.com/.

[40] A NURB is a Non-Uniform, Rational, B-spline which is a technique for using polynomials to describe smooth curves or surfaces. See Rogers, D., F (2001). Introduction to NURBS: With Historical Perspective. San Diego, USA, Academic Press. And Farin, G. (1990). Curves and Surfaces for Computer Aided Geometric Design: A Practical Guide. 2nd, Boston, Academic Press Inc.

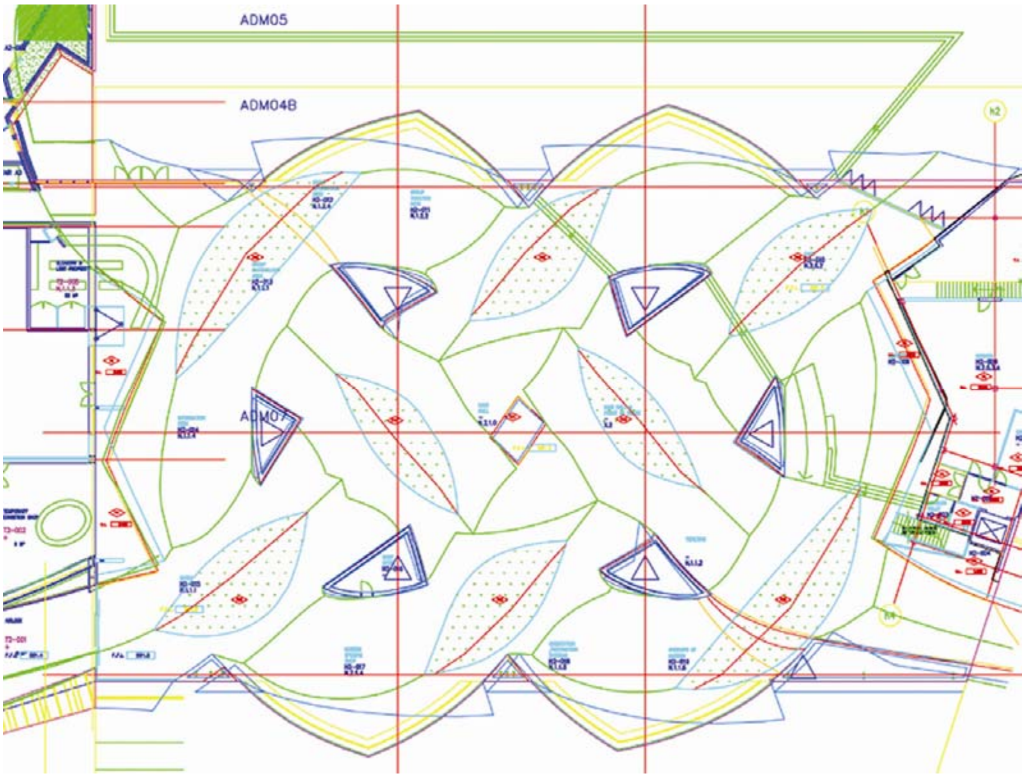

Figure 29 NMA, Hall Plan.

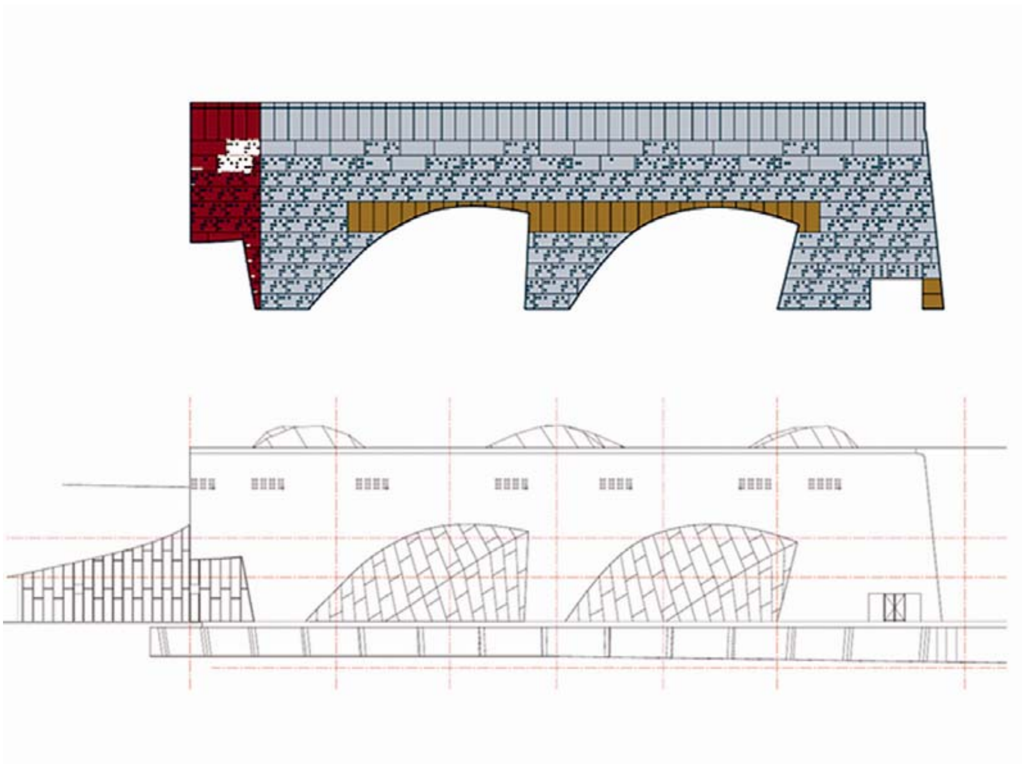

Figure 30 NMA, Unfolded Façades.

Figure 31 Diagrammatic Plan of the Jewish Museum, Berlin.

The complex forms the NMA's data stream were initiated and developed in a 3D Max virtual solid model. However, due to technical limitations in the interoperability of the output format of 3D Max, the information was transferred to RHINO[41] (Shiel [interviewed by author] 2002). The change to RHINO was to support the familiarity and format requirements of the structural engineers for the NMA, Ove Arup & Partners (McDougall [interviewed by author] 2003).

Several design development tasks were carried out whilst the model was in this form, i.e. solar penetration, shadow analysis etc (Ashton [interviewed by author] 2003). Many *what if* variations to the virtual model were generated (Figure 33, Figure 34, p.48). The *final* model was then analysed using a third party program[42] to extract or unfold façade information from the 3D models and convert it into a 2D representation (Figure 29, Figure 30 p.45, Figure 32, p.47) for the cladding contractor[43].

[41] RHINO is a structural engineering specific software program. *See* http://www.rhino3d.com/.

[42] A software package used to calculate folding patterns for industry purposes (name withheld at ARM's request).

[43] G James was the Integrated Glass and Aluminium Manufacturer and the Contractor who fabricated the facades for the NMA.

Figure 32 NMA Superimposed Calligraphy Panel, unfolded and folded.

2D working drawings were generated for the NMA from drawing files which were manually generated from horizontal slices taken through the solid model to determine the plan (Figure 29, p.45). However, this generation required the manual tracing of the outlines of horizontal sections via 2D AutoCAD as a drafting tool rather than a 3D design tool.

The construction methods of the NMA did not depart from traditional construction techniques, such as prime and secondary steel frames with external cladding panels and internal plastered lining. The way in which those existing techniques were employed to deliver the NMA were highly individual and unique.

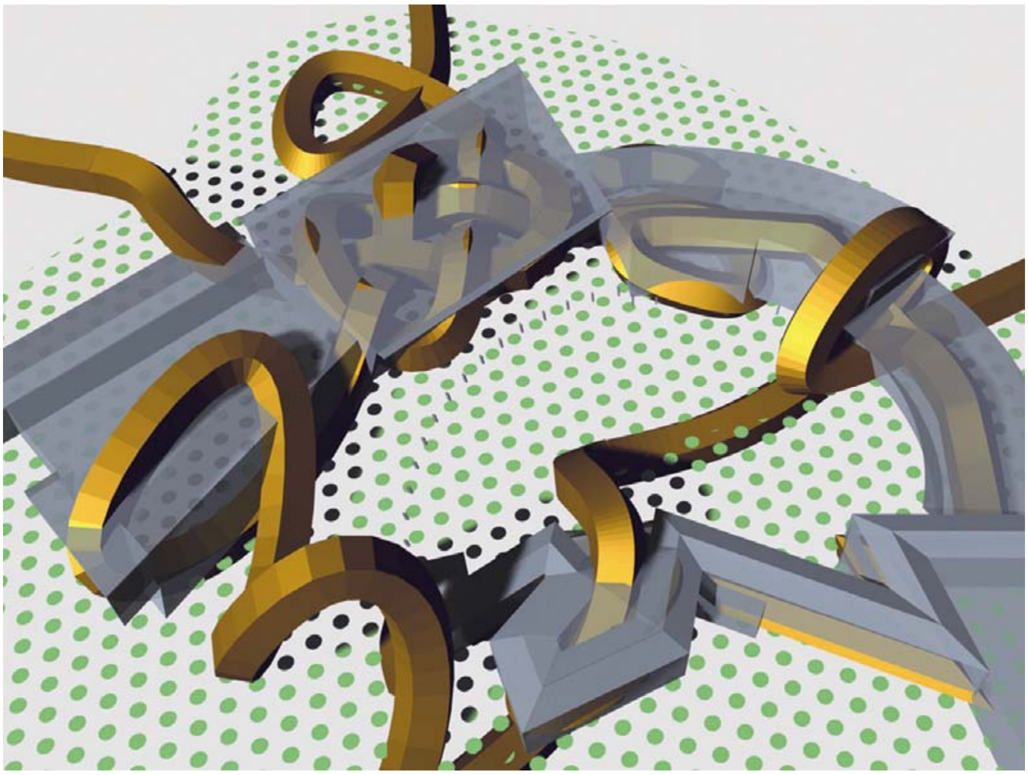

Figure 33 NMA, Final Solid Modelling Form Study.

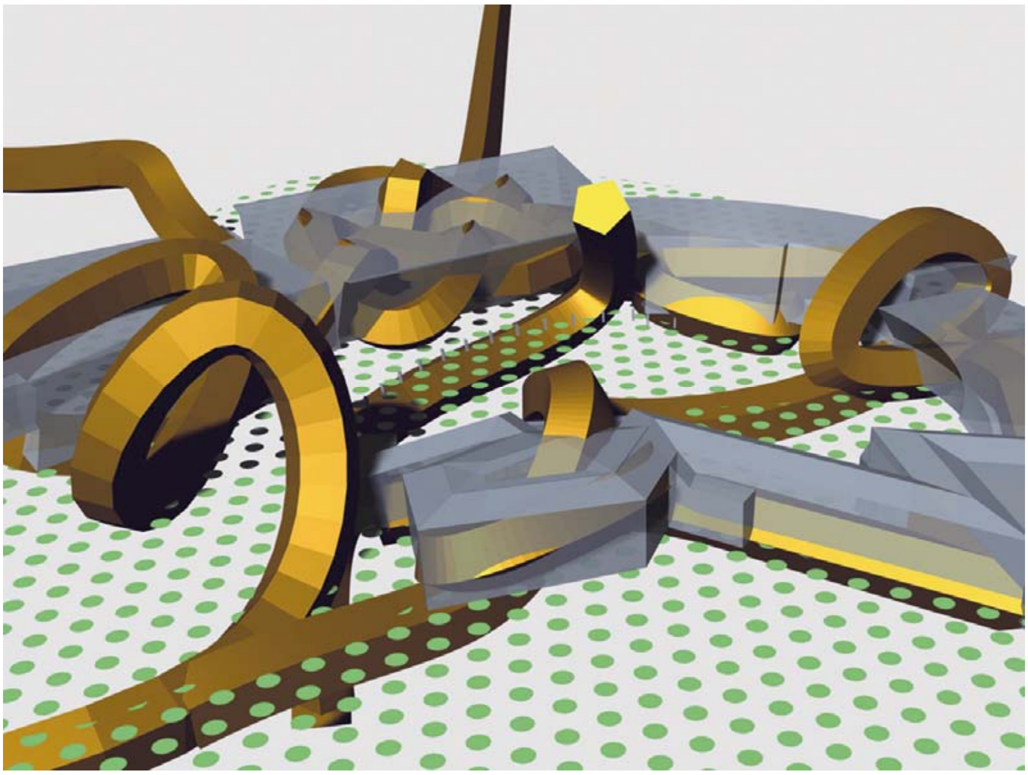

Figure 34 NMA, Final Solid Modelling Form Study.

Figure 35 NMA, Skylight, Main Hall.

ARM used multiple existing cultural references to generate new forms. This use of reference can be seen at the NMA in the forms taken from Daniel Libeskind's extension to the Jewish museum in Berlin (1998-2001) used (in plan) to generate the gallery of first Australians (Figure 31, p.46). Also, the glazing system used at the NMA for the voids left by the Boolean substraction in the Main Hall (Figure 36 p.50) were a reference to the glazing system of the Sydney Opera House (1957-73) (Figure 37 p.50). The parapet's profile of Stirling and Wilfords, No 1 Poultry Place was used for the Parapet profile of the Main Hall. Other references can be seen in early works such as the restoration of the St Kilda Town Hall in Melbourne which was destroyed in a fire. ARM referenced a ceiling design from Philip Johnson's Kneses Tifereth Israel Synagogue, Port Chester New York, (1956) and exterior details taken from Alvar Aalto's Finlandia Hall (1967-71), Helsinki.

ARM saw the NMA's design as part of the story of the museum project, not simply a shell to house exhibits, but a built statement of Australia's fragmented view of its history. It was a highly idiosyncratic response to a complex subject

Figure 36 NMA, Glazing Detail.

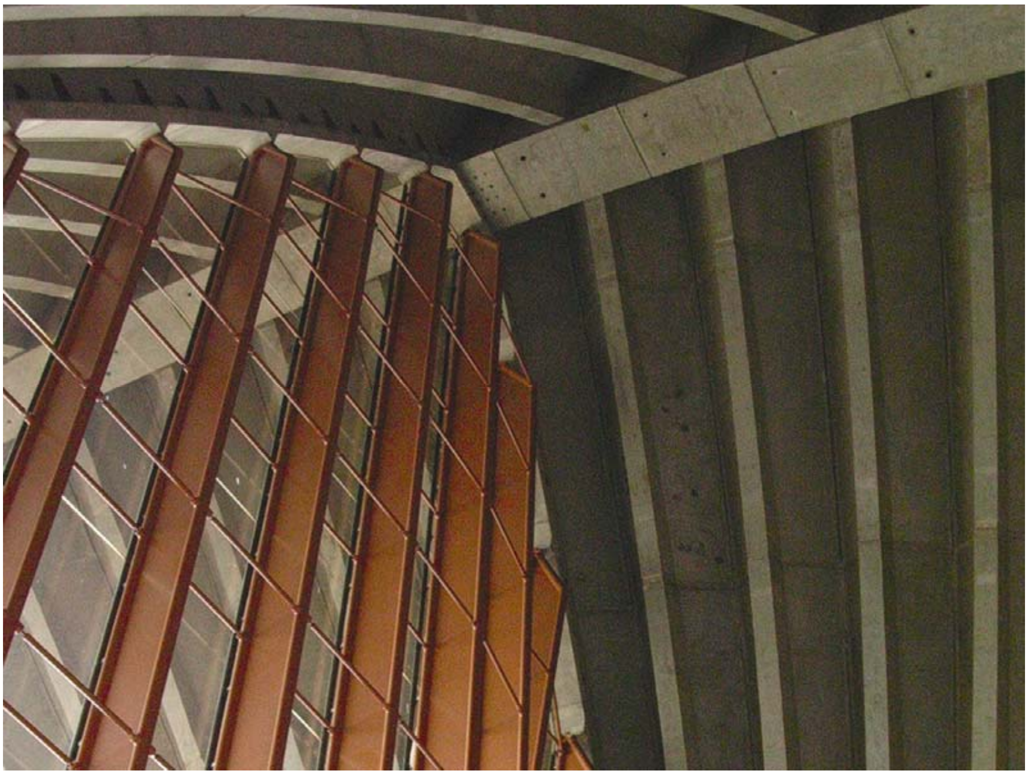

Figure 37 Sydney Opera House, Glazing Detail.

on how the project met all of its contractual obligations and also, as Dawn Casey pointed out, satisfied the functions required.

ARM succeeded in delivering a highly idiosyncratic work of architecture which was considered by the inaugural director of the museum as completely fulfilling its functional brief. When asked whether the architects had fulfilled the functional brief Casey replied,

> **DC** There was a large number of people at that time who had that view and internally the staff were concerned that the architecture would detract from the content, would make it complicated. There was that view. What people now think, and in some spaces it is a little awkward (Casey [interviewed by author] 2003).
>
> **JPS** In your opinion, the original brief, the functional brief given to ARM, has that essentially been fulfilled notwithstanding you would always want more space.
>
> **DC** Absolutely, John.
>
> **JPS** There is no question there.
>
> **DC** There is no question, (Casey [interviewed by author] 2003).

In short, ARM successfully balanced their predisposition towards cultural reference, both metaphorically and literally, and the complex functional requirements of a museum promoted a debate about the appropriateness of architectural form in museum projects.

2.3 The Guggenheim Museum Bilbao

This section deals with the context and design of the Guggenheim Museum Bilbao (GMB), a project which changed the way museum architecture was considered in both aesthetic and construction terms. The impact of Frank O. Gehry and Associates (FOG&A's) work in Bilbao has been felt throughout the international museum fraternity, including the NMA. Casey, the inaugural director of the NMA, observes "*I think Bilbao has certainly changed the way museums are considered*" (Casey [interviewed by author] 2003).

This multi-paradigm creating project is located in the provincial Spanish city of Bilbao, not previously known as a centre of culture. The city of Bilbao is located in the North East corner of Spain and is an area with a fierce local identity and in what is colloquially known as the 'European Aerospace Valley'. The city has a population of approximately 354,000 and was, previous to the

GMB, known primarily for its industrial output. The Basque region, of which Bilbao is the centre, was assimilated into Franco's Spain[44], as was Catalonia in 1937. Hence the Basque regional government[45] saw their collaboration with a major international art foundation as indicative of their status as more than simply a region of Spain, and a way to reassert their ethnic identity on the world stage (VanBruggen 1999).

The GMB is synonymous with Frank Gehry. There is a high level of association between the building and the architect. Gehry is now a superstar architect, a Pritzker prize winner (1989) (Thorne and Amery 1999) and the GMB is known as an iconic work of architecture that put the city Bilbao on the architectural map (Stephens 1999). His status has entered popular culture. Gehry is one of several high profile personalities chosen by computer manufacturers Apple to advertise their products under the slogan *think different*, the others being the jazz musician and composer Miles Davis and opera singer Maria Callis, both considered as icons of their chosen profession (Elliot 1998). He has also made a guest appearance on the popular animated television series *The Simpsons*. The GMB has also been used as an icon, including featuring in the opening scenes of the 1999 James Bond film 'The World Is Not Enough'. Previous to the GMB, Gehry has been characterised as "*an industrial ad-hocist and the father of the botched joint*" (Jencks in Papadakis *et al.* 1992 p.110). This reputation as a subverter of form has been replaced with a widely held belief that he is, since the success of the GMB, a virtuoso of affordable complex architecture, and arguably the most influential architect of his generation. The commission for the GMB however was serendipitous for Gehry. The incoming director of the Guggenheim Foundation, Thomas Krens, was philosophically pre-disposed to radically challenge the notion of what a museum could be, and this innovative approach from Krens coupled with the Bilbao-Metropol-30, strategically elevated Gehry and the GMB's profile to world wide attention.

> The "Bilbao Metropoli-30" Association was created to coordinate the synergetic action of all the involved institutions: City Hall, Basque Country and Spanish Governments, financial institutions, transport companies, airport and port, etc (Sanchez *et al.* 1999 p.694).

Metropolitan Bilbao is comprised of 44 municipalities centred around the Nervion River. These municipalities were aided by industry and the national

[44] General Francisco Franco (b1892-d1975) (Presidency 1936-75) enforced a national identity to all of Spain in the wake of the Spanish Civil War 1936-9, which was seen by the Basques and the Catalans as subjugating their regional identities.

[45] In 1978 the Spanish Government formed an autonomous Basque region with responsibility for education, health care, policing and taxation.

and European governments to effect a change in the city's international profile.

> The association "Bilbao Metropoli-30" was created to develop and coordinate the actions of the private sectors and the public administrations of the City (Bilbao), Province (Bizkaia), Region (Basque Country), Country (Spain) and European Union (Sanchez *et al.* 1999 p.694).

The NMA and the GMB share many similarities in context, however they were designed using very different techniques and inspirations. Gehry's inspirations for the GMB were based on the topography of the City of Bilbao and his fascination for the geometries of fish. The NMA project became a contentious intellectual and cultural project with a political dimension; the GMB also had a political dimension. However, this political dimension was not based on national history but on the aspirations of the Basque region. Unlike the NMA's metaphor-based form, the form of the GMB did not reflect, or hope to capture, a national Zeitgeist[46]. The GMB did not need to deal with cultural issues of national identity or historical truths in the same fashion. An international museum of modern art such as the GMB has few (if any) overtones of national identity; however there were undercurrents of politics surrounding the project. These undercurrents were largely generated by the regional Basque government which had made a conscious decision to actively improve the quality of Bilbao's built environment (Sanchez *et al.* 1999 p.695).

The Bilbao authorities also commissioned Foster Associates to design the metro system (Figure 48 p.64) and Santiago Calatrava to design the Campo Volantin footbridge (1990-97) (Figure 45, p.62) as part of the city's renewal.

The GMB project was the first one in a series of contemporary international satellites of the Guggenheim Foundation's New York art gallery program, along with galleries in Las Vegas and Berlin.

> The choice of Bilbao as the venue for one of the Guggenheim European centres is best understood in the context of the initiatives implemented by the Basque authorities as a contribution to the process of revitalising the Basque Country's recession-plagued economic structure (www.guggenheim-bilbao.es.ingles/home *Guggenheim Bilbao* 2001).

[46] Zeitgeist from the German "Geist = the spirit, Zeit = of the time". The expression means the intellectual and cultural climate of a given era.

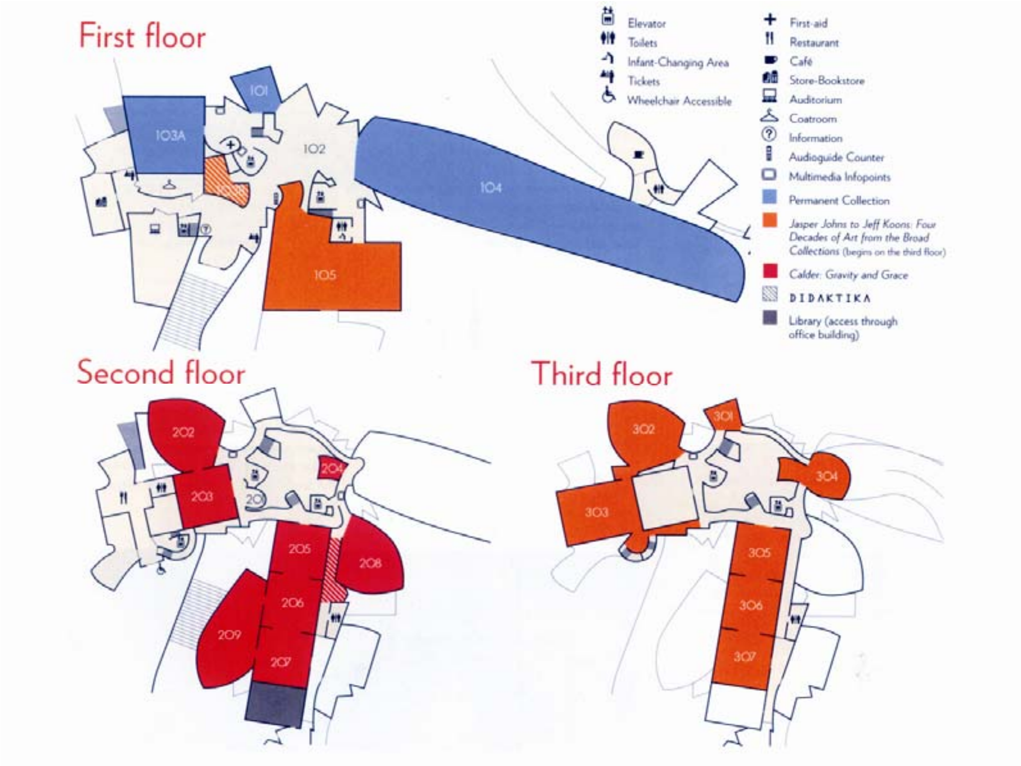

Figure 38 GMB Layout.

Hence the Basque government became a willing partner in the Guggenheim Foundation's desire to take modern art to a wider public, and consequently invested political capital in the success of the project.

The city of Bilbao greatly benefited from their willingness to embrace a museum in an attempt to put their city on the international cultural map (Sanchez *et al.* 1999; Stephens 1999; VanBruggen 1999).

There were concerns that ETA[47], the Basque Separatist Movement, would use the opening ceremony to draw attention to their political agenda, but this did not eventuate.

The Guggenheim foundation has a long and well documented history of commissioning high profile flagship works of architecture, usually with extremely idiosyncratic aesthetics as seen at the Solomon R Museum in New York City by Frank Lloyd Wright (1943-56) (Figure 40, p.56). The design that

[47] ETA (Euskadi ta Askatasuna), "Basque Fatherland and Liberty" when translated into the Basque language; a terrorist group demanding a fully independent Basque state.

Figure 39 GMB, CATIA Wire Frame.

Gehry[48] proposed was as innovative as Wright's original had been in its day. By comparison the Australian Commonwealth Government simply required a functional museum building to be delivered on time and on budget.

The majority of commentary on the GMB has been positive in both architectural and social terms. However, Joseba Zulaika[49] believed that the GMB has been too uncritically accepted. He has suggested that due to the aesthetic success of the GMB, the ethics of building a museum in a depressed industrial area has been overlooked.

> There's something odd about architectural criticism that isn't interested in the viewpoints of the very subjects who paid for and will live with the building. But why raise messy questions of context or function when the art is so sublime? That is how most American media have treated Frank Gehry's masterpiece, the Guggenheim Museum Bilbao (Zulaika 1997 p.60).

[48] The term Gehry has been used if an idea or design decision can be attributed to him personally, whereas FOG&A is used if the individual cannot be identified, or it is a collective action. Gehry Partners is the current practice's name. It was changed after the GMB had been completed.

[49] Joseba Zulaika is a professor and director of the Centre for Basque Studies, Bilbao.

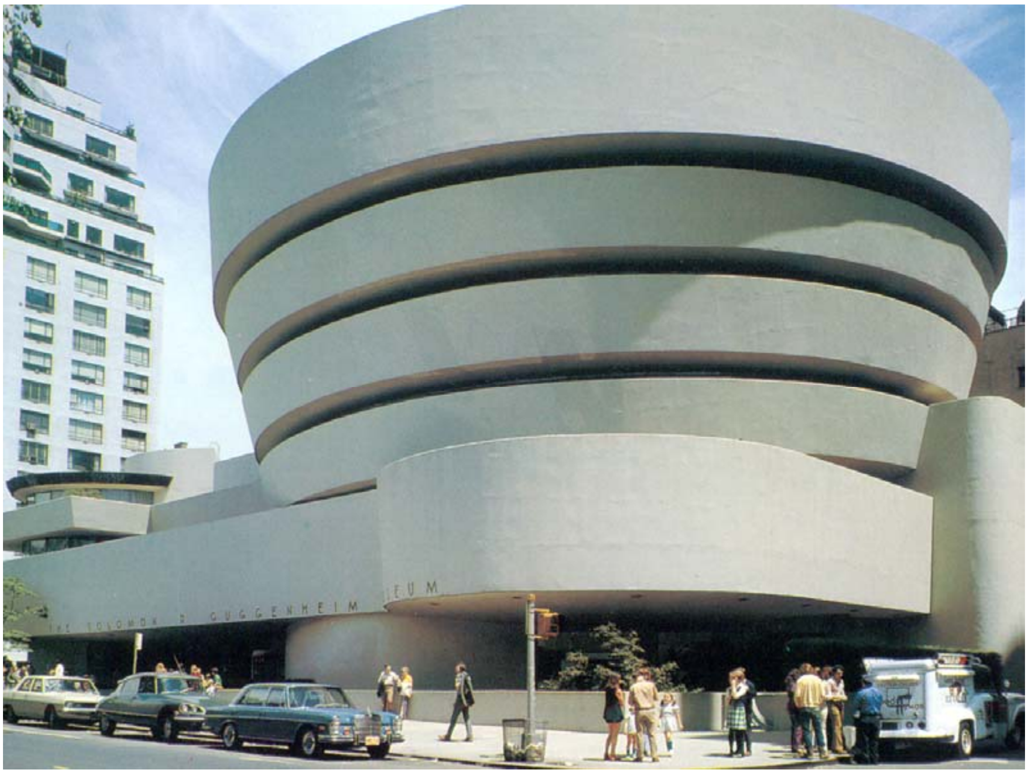

Figure 40 Solomon R Guggenheim Museum, New York.

The lasting and most commonly held view about the impact of the GMB is positive from both the architectural community and the business world, This strategy of commissioning a world class work of architecture in a provincial city was so successful that the ‘Economist Magazine’ featured an article praising the foresight of the city’s government. It details the positive economic effects the GMB has had on Bilbao.

> The story of Bilbao, once a mouldering industrial port in Spain’s Basque country, is popular with politicians because it suggests that investing in art (pleasing one lot of voters) can revive a city economically (pleasing others). Opened in 1997, the Guggenheim Foundation’s art gallery, designed by Frank Gehry boasted 5.2 million visitors by 2002. A report by KPMG, a consultancy, reckoned that the visitors spent Euro776million in the region in that period securing 4,100 jobs and generating Euro 118million in tax revenues, more than repaying the subsidies involved ('Exhibitionists; Museums' 2003).

Outside the architectural community, the GMB it is best known for its complex and unorthodox form (Palmeri 2003). Within the architectural profession, the GMB is of interest in part due to its use of a non-architectural CAD package for its complex form (LeCuyer 1995; Stein 1997).

> When Tomas Krens became director of the Guggenheim in the late 1980s, he declared the art museum in crisis, both as institution and

Figure 41 American Centre, Paris.

> building type. It was an eighteenth-century idea "the encyclopaedia" thrust into a nineteenth-century building type "the modified palace" (Krens in Lewis 1999 p.52).

He continues,

> The modern museum required a new concept as well as a new form. The solution lay in a profoundly twentieth-century institution: the corporate franchise. Krens envisioned a worldwide network of affiliated branch museums so that the Guggenheim might circulate the vast reservoir of art languishing in storage. Projects were launched in Salzburg and in Massachusetts, but ran into delays, making the Bilbao building the first test case of his concept (1999 p.52).

Krens commissioned an international design competition in the early 1990s, of which Gehry's design was ultimately chosen, and by early 1993 he had completed and presented his design.

> Gehry presented his model for the Museum building in February 1993, and the foundation stone was laid on October 23 of that year. In October 1994 work began on the structure …………The Museum opened its doors to the general public for the first time on October 19th 1997. Less than one year later the Basque Museum has already received more than 1,300,000 visitors (www.guggenheim-bilbao.es.ingles/home *Guggenheim Bilbao* 2001).

Figure 42 GMB, Site Context.

Figure 43 GMB, Site Context.

Figure 44 GMB Site Context, View to West.

However, before the final site and design was settled upon there were some outstanding issues to be addressed. The Basque Government and the Provincial Council of Bizkaia favoured converting a former Bilbao wine warehouse called the Alhōndiga. As it was not a new building it offered little scope for Gehry's vision (VanBruggen 1999). It was Gehry's influence, coupled with that of Krens, that persuaded the Basque administration and the Guggenheim Foundation to use a vacant site on the industrial waterfront (Figure 40 p.56, Figure 42, Figure 43 p.58, Figure 44 p.59, Figure 47, p.63 and Figure 48 p.64). Gehry's annotations on a map of Bilbao (Figure 46, p.63) showed his reasoning for persuading the Bilbao Municipalities to make the site available to the Guggenheim Foundation. The use of this site allowed a dialogue with the river, the road bridge and the scale of the harsh existing waterfront form. This industrial city with its imposing infrastructure inspired Gehry, as he recalls:

> I enjoy the complexity of a big project, trying to organise it. It's different from one room, but I think the one-room idea gave me the beginning of a way to break down the scale of big things. Scale is a struggle. How do you make a big monolithic building that humane? I try to fit into the city. In Bilbao I took on the bridge, the river, the road, and then tried to make a building that was scaled to the nineteenth century city (Gehry in Friedman 1999 p.178).

The geographic considerations and the functional requirements were the main generators of design. The bridge and the long (or boat) gallery were the most notable examples of the interplay between function and topography. The boat gallery was designed to utilise the restricted vertical height under the bridge, hence using this constrained area of the site to fulfil part of the functional brief. Using a strong symbolic metaphor to generate forms, Gehry has said the most engaging aspect of design was dealing with the topography of the site.

The building form was also informed by a hierarchy of contemporary and historical artists. The type of space of these galleries was shaped by the artists whose work would be displayed (Figure 38, p.54).

> Gehry created two types of exhibition galleries. For "dead artists" he fashioned traditional galleries, rectangular with vertical walls, while contemporary artists were assigned irregular, free-form galleries, since as "living artists, ... they can fight back" (Lewis 1999 p.53).

The highly articulated and complex geometric forms of the proposed museum needed to be realised. The GMB was born physically and became a state of the art virtually driven project. The NMA was born virtual and became an example of both a hybrid virtual and physical processes. CATIA's (Computer Aided Three Dimensional Interactive Application) ability to handle non-Euclidean geometries allowed FOG&A's work to fulfil a functional brief whilst delivering a highly sculptural work of architecture. The complexities of the GMB framing can be seen in a small view of the complex wire frame model (Figure 39, p.55). Due to the complex geometries of Gehry's work, a system able to manipulate polynomial equations was used. At that time, the only designers using such systems were the aerospace industry (Novitski 1992). A major technical reason for the aviation industry's use of CATIA is its ability to document polynomially expressed forms. This is also a major reason for FOG&A's choice of CATIA. Glymph's indication of a potential problem in traditional CAD programs which used Cartesian geometry to define their form highlights a recurring theme.

> Glymph maintains that what sets CATIA apart from other systems is its use of polynomial equations, so that instead of simply locating points in space as other systems do, CATIA is also capable of defining any surface as an equation, which means that if you query the computer for any point on that surface, it knows it (Steele 2001 p.129).

Since mid 2004 Gehry Technologies[50] (GT) have been carrying on business as a CATIA developer (Gehry Technologies 2004) providing a CATIA module known as Digitproject[51]. Previous to this, Maverick solutions, an American software retailer, advertised Gehry related products as their main service, not architectural services such was the level of interest from the architectural profession, in FOG&A's use of digital tools. This move by Gehry Partners into software development can be seen as an acknowledgement of what FOG&A consider to be an emerging area of architectural endeavour as it spans a construction project from design to numerically controlled on-site production.

The fundamental construction techniques for the GMB were a simple steel framed structure with titanium cladding panels for the gallery areas and a more conventional limestone façade for the administration areas. The flexibility of the titanium panels allows the curvilinear form to remain watertight. As Giovannini states "*Gehry built the Guggenheim the way Gustav Eiffel constructed the Statue of Liberty, cladding its complex skeletal frame with a contoured skin*" (Giovannini 2000 p.126). The NMA used similar techniques to clad its complex façades, however the complexity of the GMB's façades are far in excess of those of the NMA.

FOG&A previous works of architecture produced the complex geometries that would become FOG&A's trademark, including the Vitra Design Museum, Weil am Rhein (Figure 49, p.64) and the America Centre, Paris Figure 41 (p.57). However, the geometries of these buildings were necessarily more rudimentary as FOG&A had not yet made the connection between the non-Euclidean geometries they wanted to use and CATIA's ability to deliver them. The clunk in the spiral staircase of the Vitra Design Museum, Weil-am-Rhein, Germany (1990) (Figure 49, p.64), marked the beginning of Gehry's journey from work based in descriptive geometry to his work at the Bilbao Guggenheim which was based on polynomial equations (LeCuyer 1995; Blackwood 2000).

This move from Cartesian geometry to non-Euclidean geometry was a major departure from CAD usage in architecture.

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[50] Between the completion of the GMB and the launch of Gehry Technologies (GT), the business name of Frank O Gehry and Associates (FOG&A) was changed to Gehry Partners (GP).

[51] Digital Project is a software package developed by Gehry Technologies. It is designed to encompass all aspects of construction projects. Digital Project is designed to run in parallel with CATIA V5. *See* http://www.gehrytechnologies.com/.

Figure 45 GMB, Site Context.

The geographical (physical) context at the GMB and the metaphorical (non physical) context at the NMA were used by the architects to inform their designs.

The political background and ongoing political environment for both the NMA and the GMB is complex. They are both relatively trouble free when compared to the political and public vitriol which accompanied the Louvre extensions in Paris (Morshed 2003) and Millennium Dome, London (mentioned previously), which both dominated the public and political foreground for a significant amount of time. However they did both carry an amount of expectation with them.

The GMB did not have to grapple with the complex history of Bilbao or the choice of historical value laden artefacts and how to present them. It is simply seen as a great work of architecture which houses works of art, not as a cynical conspiratorial exercise in trivialising a nation's history as some saw the NMA. Whilst there was a political imperative to build the GMB there was no cultural baggage that came with the commission. Hence the political/social context of the NMA had a much greater bearing on that project. Both made use of computer technologies to underpin the forms they had designed and both made use of innovative procurement methods but in very different ways.

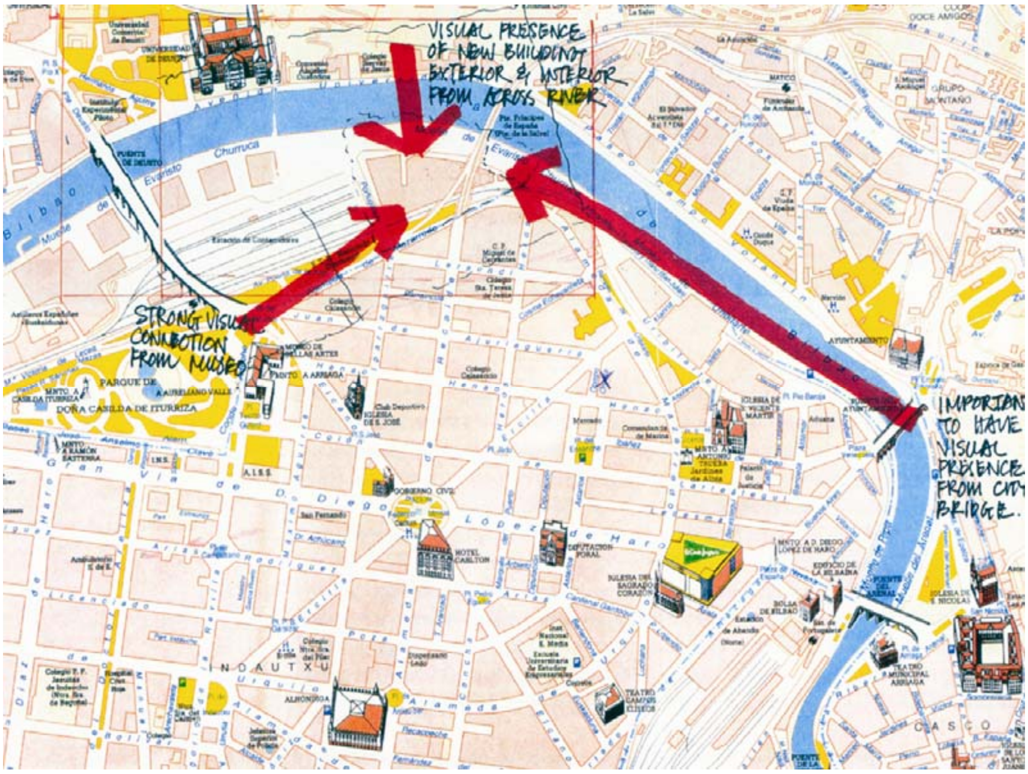

Figure 46 GMB, Gehry's Annotated Map of Bilbao.

Figure 47 GMB, View of Opposite River Bank.

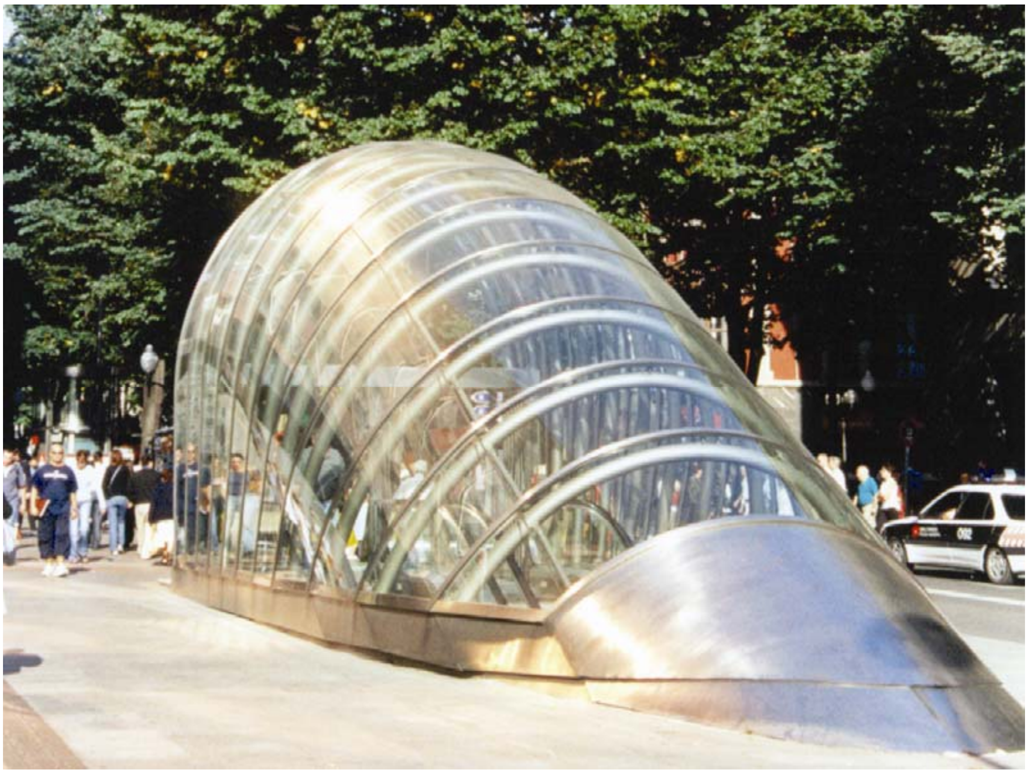

Figure 48 Metro Station Entry, Bilbao.

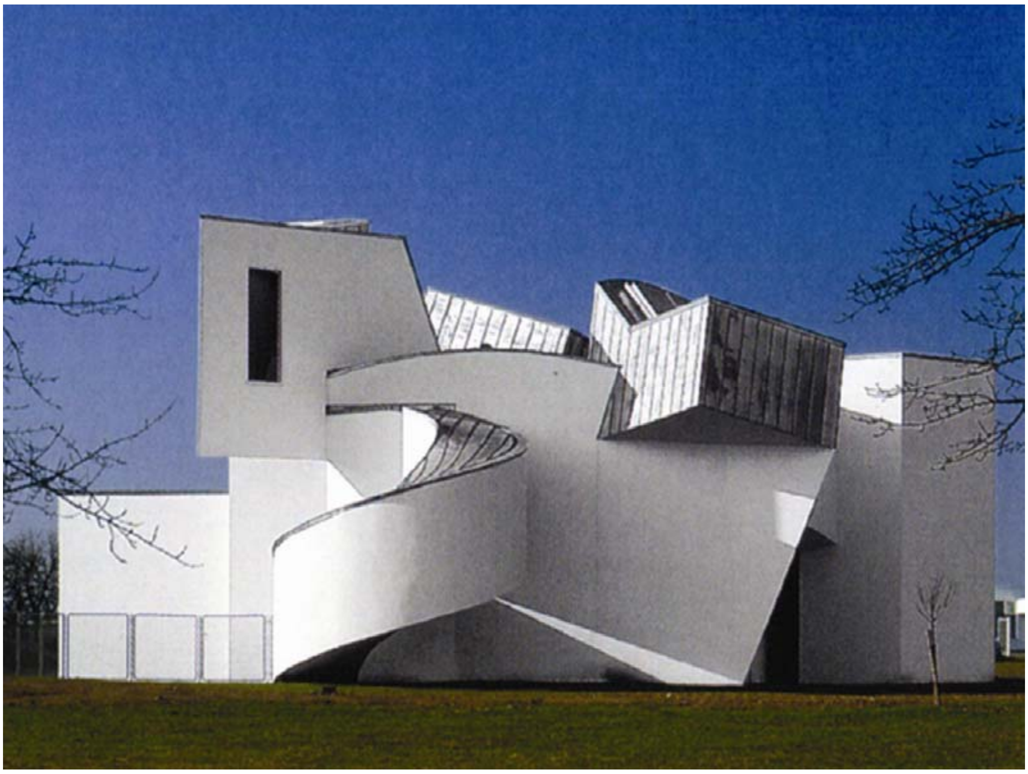

Figure 49 Vitra Design Museum, Weil am Rhein, Germany.

3 Literature Review

This chapter reviews the available literature relevant to computer technologies in architecture, non-traditional procurement methods and literature specific to the National Museum of Australia, the Guggenheim Museum Bilbao and their architects. It encompasses literature which increases the understanding of,

(a) the history and usage of Computer Aided Design (CAD) in architecture,

(b) computer technologies as they are used within architecture for total architecture[52], building information modelling[53] (BIM), form generation, and hybrid use,

(c) the use of non-traditional procurement methods in Australian architecture,

(d) computer technologies and non-traditional procurement methods and their influence on the changing role of the architect and,

(e) the process and effect of (a), (b), (c) and (d) on the NMA, the GMB and their architects.

This chapter is divided into the following four sections: 'Project Specific Literature', 'Computer Technologies', 'Non-Traditional Procurement Methods', and 'The Role of the Architect'. Within these sections, subsections have been provided to focus on germane nested themes. In addition to printed material, this review also includes films, television documentaries, and on-line material.

There is a body of literature on the NMA, the GMB and their architects Ashton Raggatt and McDougall (ARM) and Frank O. Gehry and Associates (FOG&A) respectively. Two subsections have therefore been included within 'project specific literature' in this review. Most of the generic (non-architectural) literature about the NMA is concerned with the social/political implications of the project as addressed in section 2.1 'Political Context' (p.11), whilst most of the architectural literature on the NMA is divided between the inspirations ARM used and the resulting forms, addressed in section 2.2 'Inspirations and Design' (p.34) and sections of Chapter 5 'Synergy at the National Museum of

[52] Total architecture could be described as a seamless flow of design information from form generation to finished product.

[53] Building Information Modelling (BIM) is a building design and documentation methodology characterised by the creation and use of coordinated, internally consistent computable information about a building project in design and construction.

Australia', (p.161). Also, relevant literature has been examined in Section 2.3 The Guggenheim Museum Bilbao, (p.51).
Both considered projects can, and have been, seen as milestones in the use of computing in architecture: the NMA due to its idiosyncratic approach and the GMB due to its seamlessness of process from design to delivery.

The majority of the contemporary literature relevant to this thesis focuses on computer aided design (CAD) for design and/or production. These articles are usually found in journals, edited compilation works or online databases of academic works. Most compiled works are based on conference papers by various authors such as Kolarevic (2003a) whilst most journal articles are based on milestone or landmark projects such as Macarthur (2001) for the NMA project and LeCuyer (1997) for the GMB project. There is also a body of literature produced by industry groups and software developers that detail the less philosophical and more generic functional aspects of CAD use such as 'The White Paper' by Autodesk (2003). Also literature on general purpose computing/Information Technology (IT) in procurement/communications has been published, usually by business groups or government supported construction forums or conferences edited by authors such as McIntyre (2005). However, less literature is available on the areas of commonality or interplay between computer technologies and procurement. The literature germane to computer technologies in architecture is centred on several overlapping themes. These themes have been considered as History and Usage of Computers in Architecture, Total Architecture, Building Information Models, Form Generation and Hybrid Use.

The sections that consider computer technologies cite some authors and works too extensive to be considered individually within this chapter. This literature either examines completed or published (unbuilt) projects or theorises about the future direction that computer technologies may provide for architecture.

Authors who have written extensively on the subject of computers in architecture and urban planning include William Mitchell[54] who has written both technical guides, such as 'Digital Design Media' with Malcolm McCullough (1995) and more philosophical works on the wider effect of the digital revolution such as 'E-Topia' (1999) and 'City of Bits' (2000). Authors such as

[54] William Mitchell is a Professor of Architecture and Media Arts and Sciences at Massachusetts Institute of Technology, and director of the Media Lab's Smart Cities research group and author. *See* http://web.media.mit.edu/~wjm/.

Richard Coyne[55] have taken a more philosophical approach to the impact of computers on architecture with published surveys 'Computers in Practice' (1999) and works on the impact of technology on the role of the architect- 'The Disembodied Architect (1999). Literature such as 'Being Digital' by Negroponte (1995) and 'The Digital Architect' by Sanders (1996) have also been influential in the study of the 'Digital Revolution' on architecture.

The majority of the literature concerning procurement methods is centred on non-traditional procurement and how to select an appropriate method, and its impact on the project constraints of time, money and quality. This literature is frequently published in journals such as 'Journal of Construction Procurement'[56] and is the subject of construction aligned conference proceedings.

There is a body of literature which touches upon technological implications for the role of the architect. There is significantly less literature however, on how different procurement methods impact on the same professional role.

In reviewing the available literature, the work William Mitchell presented in the fifth Wilkinson lecture, addressed two very similar threads of complexity and gave a comparison of the GMB and the Sydney Opera House (Figure 15, p.32) (Mitchell 2003), similar to the research in this thesis. However, due to the scope of his work he could not address these buildings in depth. The two major points made by William Mitchell which are relevant to this thesis are the conclusions regarding multiple forms of representation in 'In Praise of Paper' and how technology is allowing the realisation of complex architecture, in 'Constructing Complexity'; two key sections of the accompanying publication to his presentation (Mitchell 2003).

As a consequence of the volume of literature regarding computer technologies used in architecture or related fields, some areas not directly relevant to the research questions have not been included. The use of computer technologies for simulating hypothetical physical interaction, such as fire evacuation, thermal performance, lighting design, structural analysis etc were used perfunctorily on the NMA and GMB but they were not considered relevant to this thesis. These techniques traditionally use highly specialised software operated by specially trained personnel external to architectural

[55] Richard Coyne is Professor of Architectural Computing at the School of Arts, Culture and Environment (ACE), University of Edinburgh, UK.
[56] *See* http://www.journalofconstructionprocurement.com.

practices to generate data in a native format[57], only readable in tabulated form or by the same program that generated it. There were also innovations in the use of the internet for the sharing of data in digital form. As these uses were also not relevant to the research questions they have not been addressed directly in this chapter.

Due to the ubiquity of information technology (IT) as an increasingly utilised communication tool, the literature which deals with IT is substantially generic in nature. Hence the role and the impact of the World Wide Web, email, peer to peer file transfer, video conferencing and general purpose computing, have not been addressed in this review as these technologies are peripheral or irrelevant to the arguments of this thesis, whilst providing an undeniable background.

3.1 Project Specific Literature

3.1.1 ARM and the NMA

ARM's work features in a prominent portion of an episode of a series of television documentaries, one of three one hour documentary films made for Australian free-to-air television, 'In the Mind of the Architect' (ABC 2000). Whilst this documentary was filmed prior to the completion of the NMA project, it does show ARM's idiosyncratic approach to previous projects, especially the contentious Storey Hall project in Melbourne (Figure 50, Figure 51, p.69) and some generic views of their approach to architecture including their reasons for referencing others' works. This represents a comprehensive and personal account of ARM's architectural philosophy.

The NMA project was the product of an initiative by the Commonwealth Government which instigated many innovations new to architecture, and hence felt a responsibility to record contractual processes for posterity. Accordingly there were a number of detailed reports produced about the NMA project. These reports were mainly concerned with the construction of the project and how this was achieved, rather than the impact the combination of computer technologies and procurement had on that outcome.

[57] Native file format is a default file format used by specific software applications. The native file format is usually proprietary and these types of files are designed not to be transferred between applications.

Figure 50 Storey Hall, Swanston St Façade.

Figure 51 Storey Hall, Artefact Imprints (Swanston St Façade).

The most detailed report covering the NMA project is 'The Acton Final Report' (Peters *et al.* 2002), specifically commissioned as an external report by the Commonwealth Government. Due to the expectation that the NMA would create many firsts in Australian architecture the Australian Commonwealth Government commissioned a team of academics in a Cooperative Research Centre (CRC for Construction Innovation) linking Commonwealth Science Industrial Research Organisation (CSIRO), Royal Melbourne Institute of Technology (RMIT) and Queensland University of Technology (QUT) to review the success of the procurement process and its use. It used qualitative and quantitative methods including interviews with the workers on site, attendance at site meetings and a series of questionnaires.

The Peters *et al.* report is divided into four sections which are:

- Part A, Project Alliancing on Acton Peninsula Project,
- Part B, Information Technology Analysis for the Acton Peninsula Project,
- Part C, Dissemination to Industry and Government for the Acton Peninsula Project and
- Part D, Literature Review – Project Alliances and Information Technology Analysis Framework.

The report considers information technology and its effects on the communication strategy between the various levels of the alliance's hierarchical structure and how the IT affected the workforce. However, Peters *et al.* were restrictive in their scope which consequently meant they did not consider particular areas. Part D of the report, 'Literature Review', has been extensively drawn upon in Chapter 5, 'Synergy at the National Museum of Australia'. Part A has also been referenced in the same Chapter. Hence what follows in this subsection is an overview of the report.

The Report considered in depth two aspects of the NMA. The first was the exchange of information using Information Technology (IT) and the second the procurement method. However, it did not consider the wider context of the NMA, or computer techniques other than web based delivery systems, i.e. not the technology that generated the data that was posted on the web sites but only the use of the web site.

Due to the interaction between the procurement system and the use of Information Technology the research team made the decision not to address the procurement system and the information technology systems as separate entities but as components in a single study. The initial study design was to consider them in isolation, as the authors explain.

> Though this study was initially envisioned as having two distinct components, project alliancing and information technology - the researchers, informed by the construction delivery team, suggest that these two elements be considered as a unified project delivery environment encompassing the cooperative elements of alliancing with the collaborative IT environment of an advanced web based project communications interface (Peters *et al.* 2002 p.ii).

As the research team asserted "*It was the first project alliance so there was no established methodology for research and no comparative data*" (Peters *et al.* 2002 p.36). In comparing the use of IT in construction for internal rather than external communications with other organisations, Peters *et al.* focus on an area which they maintain has been insufficiently examined.

> The majority of research into IT in construction has focused on IT at the organisational level. Although this approach is valid for determining IT usage by an organisation, it offers only limited insight into IT use on a construction project as invariably, there will be many companies involved in the various aspects of the project (Peters *et al.* 2002 p.471).

Two internally produced reports were also published: 'Acton Peninsula Development: Final Report of the Design Integrity Panel' (DCITA 2002a), and 'Acton Peninsula Development: Final Report of the Independent Panel' (DCITA 2002b). These reports were published to promote and/or inform others about the workings of the two panels as they related to the NMA project. A report was also published by the Commonwealth Auditor General's department entitled 'Construction of the National Museum of Australia and Australian Institute of Aboriginal and Torres Strait Islander Studies' (Auditor-General 2000). This report covered "*The performance audit [which] was conducted in accordance with the ANAO*[58] *Auditing Standards"* (Auditor-General 2000 p.34) This report was commissioned to investigate the probity of the NMA project, and was published as part of the Commonwealth Government's policy of public accountability for major Commonwealth funded projects. This audit report was limited to compliance issues as follows:

> (a) the three major procurement activities – the appointment of the Architects, Building and Services Contractors and Museum Exhibition Designers (collectively known as the 'commercial alliance partners'): and

[58] **A**ustralian **N**ational **A**udit **O**ffice.

> (b) compliance issues arising from (a) that have on-going relevance to the project, the alliance and to procurement generally (Auditor-General 2000 p.33).

However "*The majority of the fieldwork was undertaken between April and October 1999*" (Auditor-General 2000 p.34) which was approximately two years before the Museum's official opening. The Auditor–General's report in contrast to Peters *et al.* (2002) did consider the NMA project in terms of its organisational structure, rather than the more elusive qualities of relationship building and its innovative use of technology. The Auditor-General's report foreshadows that the Government's primary interest was in traditional project performance indicators.

> DCITA's and the commercial alliance partners' performance on this project will be judged according to how well they perform in terms of the project's cost, timeliness and quality (Auditor-General 2000 p.102).

Despite the scope and breadth of these Commonwealth Government funded reports, they do not significantly situate the NMA in a wider context[59] or in terms of the architect's design intentions. However, the architectural expression of the NMA is considered in some literature.

Concurrent with the opening of the museum a large format text, 'National Museum of Australia: Tangled Destinies' (2002b) was published. This extensively illustrated collection of essays was compiled and edited by Dimity Reed[60]. Various personal views were articulated in this work around three themes, "Architecture, Landscape and Exhibition". The work featured contributions by prominent people either involved in the NMA project or by commentators on architectural affairs with an interest in Australian pubic buildings. This work includes essays from Howard Raggatt, Michael Keniger, Dawn Casey, Charles Jencks, Catherine Bull[61], Deyan Sudjic[62], Richard Weller[63] and Dimity Reed herself amongst others.

Reed in 'A Volatile History' (2002b) provides an introduction to the essays and a short history of the project, including her personal observations. She also

[59] The term wider context is used in this thesis to encompass the design intentions' social, political and historical influences and expectations for the studied projects.

[60] Dimity Reed is an academic, architect and professor of Urban Design at RMIT.

[61] Catherine Bull is Elisabeth Murdoch Professor of Landscape Architecture at the University of Melbourne where she is Deputy Dean of the Faculty of Architecture, Building and Planning.

[62] Deyan Sudjic is a visiting professor at the Royal College of Art, and architecture critic for the UK newspaper, the Observer.

[63] Richard Weller is the director of landscape architects Room 4.1.3, and is a senior lecturer at the School of Architecture and Fine Arts at the University of Western Australia.

looks at the procurement method, computer technologies and the underlying brief for the landscaping and exhibition design and a gives a description of some of the other authors.

Casey in 'Battleground of Ideas and Histories' (Casey in Reed 2002b) outlines some of the major difficulties between the NMA as built and what it could have been if traditionally procured. She gives a brief narrative of the 100 year history and outlines some of the challenges that the new "*non monumental*" (p.21) museum faces such as "*how can you tell …., an object's history on a 30 word label?*" (p.21). She makes the point that it was the product of a wider than usual work force and that in over 1.7 million hours worked there were "*no disputes, no lost time, no slow downs…on a project delivered without any extensions of time or budget*" (p.21).

Raggatt in 'Visible and Invisible Space' (Raggatt in Reed 2002b) gives a highly personal and philosophical view of the inspirations ARM used to inform the designs of the NMA. He also gives his views on ARM's extensive use of architectural reference. His highly cerebral essay is written in esoteric tone and is extensively illustrated. This is apparent when he describes the NMA in the following terms, "*a kind of platonic tangle like an ideal knot, like a new cloud, like a material epistemology, like that theory of everything, like a shadow, like a promise made visible*" (p.32). He also gives a description of the Boolean sequence used to form the internal spaces of the Main Hall.

Keniger in 'Intended to Provoke Curiosity' (Keniger in Reed 2002b) outlines the method of selecting a design from the competition process and how the design integrity panel were formed and their operations. He describes ARM's competition entry as "*a proclamation intended to provoke curiosity*" (p.51). He outlines the process the government used to reassure themselves of the capacity of those involved to deliver what would become a national flagship project. He discusses the benefits to the project of the adoption of the project alliance procurement system.

Jencks in 'Constructing National Identity' (Jencks in Reed 2002b) considers the role of the NMA as a case study in "*constructing national identity*" (p.58) an issue which he believes is "*a global problem to be agonised over*" (p.59). He puts the NMA in the context of previous Australian iconic buildings and analyses it with regard to international architectural theory popular at that time. He categorises the NMA's contribution to Australian architecture as providing Canberra with an iconic building as emblematic as the Opera House is for Sydney.

Michael Markham[64] in ‘5 Ways out of an Architecture’ (Markham in Reed 2002b) describes the context around the use of Libeskind’s Jewish museum and considers a range of other more generic subjects through the lens of the NMA project.

Perlman[65] in ‘Prescribed Meaning is not Strictly Necessary’ (Perlman in Reed 2002b) gives his personal views on the multitude of cultural factors and architectural influences that shaped the NMA. This is evidenced when he states “*[T]he culture that brought forth the Big Merino and the Big Prawn now present the Big Conundrum*” (p.90). He also gives a dissertation on how the Melbourne architectural community impacted upon ARM’s architectural sensibilities. His essay is the only one that provides a technical description of the way the design geometries were computer generated.

Jenner[66] in ‘The Place at 4am’ (Jenner in Reed 2002b) describes how the NMA used the notions of ARM’s perception of Semper’s contentions about the division of space through woven material. Hence he describes the importance of the weave or knot as an important architectural metaphor. He also raises issues of cultural self-awareness (p.107).

Sudjic in ‘Nuanced Response’ (Sudjic in Reed 2002b) looks at the NMA from an international perspective, but “[*I]t is packed with ideas and speculation about the nature of contemporary architecture in the very specific context of Australia*” (p.113). He gives a tour of the exhibits and how they relate to the Australian story.

Weller in ‘Mapping the Nation’ (Weller in Reed 2002b) gives a philosophical exposition of the connection between Australian culture and its landscape, including a narrative of the impact of colonial understanding of the Australian landscape and its inappropriate use by European settlement, when he asserts “*The design for the landscape and the architecture of the National Museum of Australia has been concerned to creatively embody shifting cultural constructions of landscape and identity*” (p.128). He considers the larger implications of ARM’s master planning design strategy of the wandering line for both landscape and architectural design.

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64 Michael Markham is co partner in FIELD Consultants. He was awarded the RAIA Victorian Architecture Medal in 2000.

65 Ian Perlman is a Sydney based architect and author.

66 Ross Jenner lectures architecture at the University of Auckland.

Rod Barnett[67] in ‘Field of Signs’ (Barnett in Reed 2002b) contests that the landscape design of the NMA is “*landscape as social history*” (p.141). He describes the Garden of Australian Dreams as an “*upset game of snakes and ladders*” (p.141) and as a “*semiological tour de force*” (p.141) using the superimposition of many physical and non-physical influences on a single groundplane.

Catherine Bull in ‘Hardly Polite’ (Bull in Reed 2002b) considers the landscape design of the NMA. In comparison to the other essays in ‘Tangled Destinies’ she looks at the landscape of the NMA and its connections to the wider landscape of Canberra. She also considers the interface between the Acton Peninsula and Lake Burley-Griffin and the landscape design elements that make up the National Museum that are found outside the Garden of Australian Dreams. In keeping with the more expansive consideration of the NMA’s landscape she also alludes to what the implications may have been by applying a similar landscape design philosophy to the other rejected sites for the NMA project.

Andrew Anway[68] and Scott Guerin[69] in ‘A Complicated Story’ (Anway and Guerin in Reed 2002b) explain how they developed the exhibition design and their interaction with ARM’s architectural intent. This led them to the conclusion that the interior and exhibition design should be considered independent of the architectural expression of the NMA when they describe the exhibits as “*[I]nserted within the architectural space rather than being a part*” (p.164). They go on to explain in great detail the rationality that drove the exhibit design decisions.

Leon Paroissien[70] in ‘Modelling a Museum for the 21st Century’ (Paroissien in Reed 2002b) gives a history of the themes used in the museum and their development through the deliberations which preceded the commissioning of the NMA. He puts the NMA in a wider context and assesses the influence of the evolving brief of the NMA compared to its international contemporaries. He also gives a philosophical exposition of how and why the museum-going

[67] Rod Barnett is a landscape architect and lectures at the landscape architecture program at UNITEC Institute of Technology in Auckland.

[68] Andrew Anway was director of the exhibition design team for the NMA and founder of Anway and Co.

[69] Scott Guerin was the lead designer of the exhibitions at the NMA project, for Anway & Co.

[70] Leon Parossien is the editor of Visual Arts and Culture: An International Journal of Contemporary Art. He was a member of the Design Integrity and Quality Panels for the construction of the NMA.

public are being educated and stimulated through the choice and approachability of both the exhibits and the architecture that house them.

The NMA was also featured in the 2001 Autumn edition of Architectural Review Australia with articles by Peter Kohane[71], Ian Perlman, Peter Droege[72], James Weirick[73], Catherine Bull and Valerie Austin[74].

Kohane, in his article 'Reconfiguring Canberra's Axes and Europe's Renowned Museums' (2001), discusses how ARM have used direct references from other buildings to create the NMA. He mainly considers the influences of Schinkel's Altes Museum, Berlin 1822-30 and its connections between internal and external spaces and how this has influenced the NMA. At a site planing level he explains how the many metaphoric lines have combined and interwoven to form a basis of a master plan for the Acton Peninsula.

Perlman contributed his article as part of a collection of artefacts to be contained in a time capsule to be examined in the Bicentennial of Federation. In his article 'Not a Themepark (National Museum)' (Perlman 2001), he places the NMA as a milestone of the century and how it may be seen by future generations. He continues by explaining the impact computers have had on architecture through the lens of the NMA's forms and how this aided ARM's highly cerebral design intentions.

Droege, in his article 'Australia's Hyper-Museum in Context' (2001), considers the deliberate ambiguities that the NMA project contains. He commends ARM for their mastery of what he terms "urban special effects" p63. He goes on to describe the interplay between the building and the landscape and its uneasy relationship with the Acton Peninsula's pre-existing forms. This theme of disjointedness, he maintains, is continued between the architecture and the exhibition design. He is also alone in raising the question of the environmental credentials of the NMA project. However he ultimately considers the NMA project as endearing in its brashness and confidence.

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[71] Peter Kohane is a Senior Lecturer in the Faculty of the Built Environment at the University of New South Wales, Australia.

[72] Peter Droege is the coordinator of the Urban Design Program in the Faculty of Architecture, University of Sydney, Australia.

[73] James Weirick is Professor of Landscape Architecture at the University of New South Wales, Australia.

[74] Valerie Austin is Graduate co-ordinator for Interior Design and Exhibition Design at the National School of Design, Swinburne University of Technology, Prahran, Australia.

Weirick, in his article 'Landscape and Politics: The Museum and its Site' (2001), sees the context of the NMA as primarily a politically influenced and compromised one. This compromise he believes has ultimately led him to the conclusion that the NMA has been mis-located. He sees this mis-location as symptomatic of the Government's ill-founded and ill-conceived interpretation of the Griffin plan. This theme of politics adversely affecting the NMA is extended when he asserts that the national parliament cost ten times that of the NMA. However, he does credit ARM with producing the best possible building for this poorly funded, badly situated, misguided attempt at a national museum in Canberra.

Bull, in her article 'Landscape. Museum. Garden' (2001), considers the site of the NMA whilst outlining the views that eventually coalesced into what she considers was the compromised siting of the NMA on the Acton Peninsula – a site she categorises as neither here nor there. However she does argue that that the existing natural landscape complements the NMA's design despite ARM's unsuccessful attempt to change some of the existing natural features of Acton Peninsula. She outlines what she considers to be the most evocative landscape elements and how they relate to one another and the various demographics they attract. She concludes on the optimistic prediction that wide sections of the museum-going public are forming enduring pleasurable memories of the NMA.

Austin, in her article 'Our Backyard' (2001), compares the NMA to traditional museum types in a detailed catalogue of contemporary paradigms of museum design. She also gives a view of how and why previous museum designs hoped to influence the viewer. She argues that the NMA has departed from the Australian tradition of museum administration by labelling the NMA a "*hyper-museum*" (p.66), borrowing that term from Umberto Eco. She further argues that the exhibition designers (Anway & Co) imported a particular view of exhibition framing that was "*naïve, narrow and insignificant*" (p.67), qualities she believes particularly unsuited for a museum to tell the Australian story.

Subsequent to the completion of the NMA, a number of journal articles were published describing the museum, its forms and design intentions by authors such as Macarthur in his article 'Australian Baroque' in Architecture Australia (2001). Macarthur boldly states the museum is "*garrulous, colourful and melodramatic, while being one of the few occasions for serious civil discourse in the medium of building in this country*" (2001 p.52). He describes the museum from many aspects. He argues that the building is "*formed from quite blunt, lumpish forms, which are then cut and deformed according to an* *abstract procedure*" (2001 p.52), a device which he asserts is appropriate to the ideology of the NMA as an unfinished or unresolved concept. He goes on to liken the geometry of the NMA to the Roman Baroque geometries which he characterises as "*always felt but never, finally, understood*" (2001 p.53). However, he does question whether the museum-going public will doubt the wisdom of the architects' choices, if not their determination and skill.

The international design journal 'Blueprint' featured an article titled 'Australian Rules' on the design of the NMA. This article was published in the same issue as the announcement of the NMA being awarded Blueprint's best public building worldwide for 2001 (Gibson 2001). The article covers the architects' design intents and the resulting forms, specifically written for an international readership considered to be unfamiliar with Australian history or the debate over Australian cultural identity.

Michael Garbutt[75] produces short documentary films covering significant Australian architecture. One of these features the NMA and explains ARM's design inspirations and includes a tour of the building and surrounding grounds (Garbutt 2003). He outlines his personal view of the museum's relationship to the museum-going public and how the many ambiguous architectural elements reinforce the overall concept of Australian culture as a complex proposition.

In Dec 2004 a special issue of the electronic journal Borderlands e-journal[76] was published addressing the controversy that still surrounds the NMA. The authors Kylie Message and Chris Healy, Stephen Foster and Greg McCarthy discuss different criticisms raised against the NMA.

Message[77] and Healy[78] in their essay 'A Symptomatic Museum: The New, the NMA and the Culture Wars' (2004) discuss the cultural politics surrounding the NMA since its completion. They argue that the NMA was designed to evoke emotion, which is what distinguishes it as a *new museum*.

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[75] Michael Garbutt is an architect, critic, artist and author. He presented a number of contemporary architectural postcards from around Australia for ABC television.

[76] *See* http://www.borderlandsejournal.adelaide.edu.au

[77] Kylie Message is a Research Fellow at The Centre for Cross-Cultural Studies, The Australian National University, Australia.

[78] Chris Healy is co-editor of Cultural Studies Review and director of the Cultural Studies Program at the University of Melbourne, Australia.

Foster[79] in his essay 'Yesterday and Tomorrow at the National Museum of Australia' (2004) examines the minimal resources available to the NMA for its exhibits and how this affects the NMA in meeting its charter to a greater degree than the political interference.

McCarthy[80] in his essay 'Postmodern Discontent and the National Museum of Australia' (2004) sees the NMA as a metaphor for the conflicting nature of contemporary Australian life and the inherent problems of advancing several agendas under single all-encompassing cultural institution which purports to be inclusive and representative. He outlines what he considers to be the most incongruous issues the museum faces in terms of its role,

> The political dilemma came when this dialogue became pluralist: wanting to include people's history, being postmodernist in its architecture and post-colonial in its indigenous sensibilities. All three influences challenged the agenda of the Howard government. Pluralism was a threat because it was associated with diversity and multiculturalism. Postmodernism was a threat because it challenged the government's claims of linear advancement under their neo-liberal agenda. Post-colonialism was a threat because it not only raised the whole character of settler history but also pointed to the on-going plight of the indigenous people as a result of their dispossession (2004).

The many contradictions and complexities that the NMA, either expressly or by implication, represents have necessarily led to a multitude of sometimes passionate interpretations of the NMA's role within Australian society.

3.1.2 FOG&A and the GMB

The high profile Gehry enjoys as an architect has inspired several retrospective texts and documentary films about his work. The film 'An Architecture of Joy' (Blackwood 2000) documents the story of Gehry's involvement at the DZ Bank Headquarters project in Berlin (2000) (see Figure 52 and Figure 53, p.81). This documentary also shows some of the computer technologies used on the GMB and features interviews with Gehry and members of his office covering the practice's chronology of computer use. It also deals with some of the advances made and lessons learnt on the GMB

[79] Stephen Foster is Professor of Museum Studies, Heritage and Collections at The Australian National University, Australia. He was previously General Manager, Content Development and Technology, at the National Museum of Australia.

[80] Greg McCarthy lectures politics at the University of Adelaide, Australia.

project. There are several substantial retrospective texts issued on Gehry's works (Gehry and Jencks 1995; Dal Co *et al.* 1998; Friedman 1999; Raghed 2001).

'Sketches of Frank Gehry', a film by Oscar winning director Sydney Pollack[81] was released at the Cannes Film Festival in May 2006. There are also many shorter interview segments contained in other documentaries regarding Gehry's architecture, for example 'Uncensored', a television interview for the Australian Broadcasting Commission (1999) in which he reflects on the path he has taken as an architect heavily informed by the plastic arts.

The literature surrounding FOG&A's use of computers is substantially centred about the perception of CATIA being the most important contributing factor in FOG&A's work. This has been endorsed by many authors (LeCuyer 1995; Abel 1996b; LeCuyer 1997) and it is widely accepted that the GMB represents a major milestone in the evolution of architectural technologies (Slessor 2000; Cachola Schmal 2001; Steele 2001). Many other authors have all extensively cited the GMB as a paradigm-creating work. However, it is difficult to qualify the GMB as a product of only one set of influences.

The literature on the GMB is mostly in the form of design orientated journal articles by authors such as Novitski (1992) and Stein (1997). There is a substantial text by VanBruggen (1999) devoted entirely to the GMB entitled 'Frank O Gehry Guggenheim Museum Bilbao'. All look at FOG&A's use of CATIA to facilitate his idiosyncratic architecture.

Investigations into the literature concerning the GMB show a large volume of opinion in praise of that work. This praise was mainly regarding the GMB as an exemplar of paradigm-changing architecture i.e. changing perceptions about what computers could achieve in architecture. Some published works addressed how FOG&A subsequently improved their use of computer technologies post the GMB project.

[81] Sydney Pollack won the award (Oscar) for Best Director from the Academy of Motion Picture, Arts and Sciences in 1985 for 'Out of Africa'.

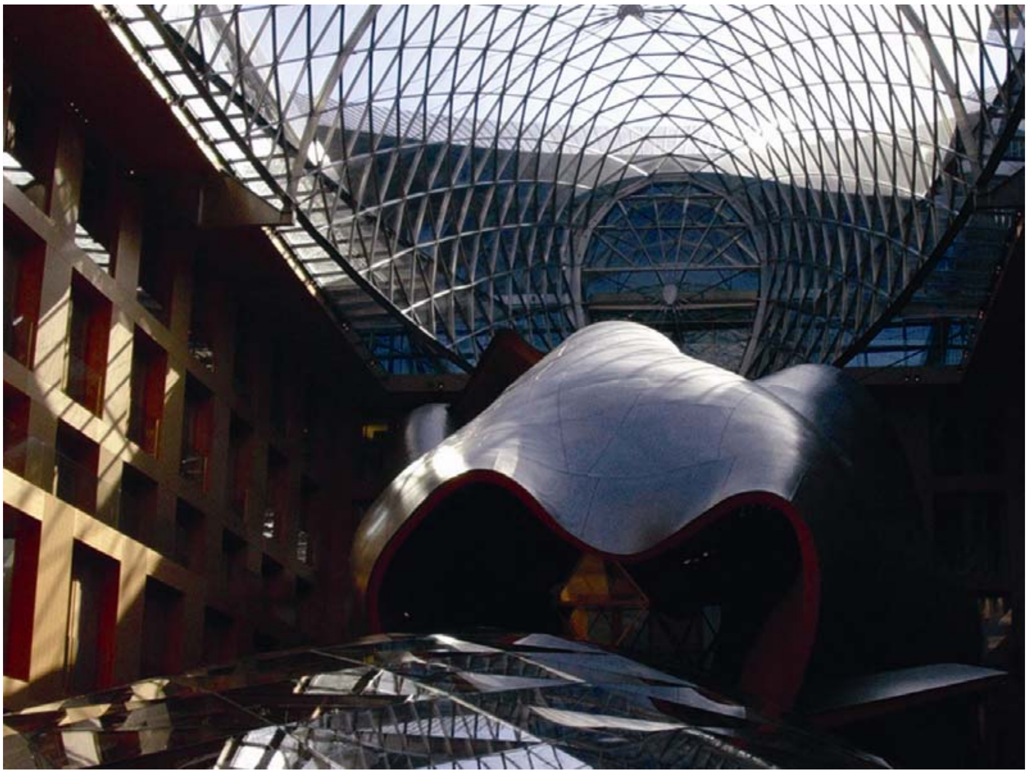

Figure 52 DZ Bank Headquarters courtyard, Berlin.

Figure 53 DZ Bank Headquarters, Berlin.

The GMB project inspired a range of literature which dealt with matters from the technological means of delivery such as 'Project Diary: Frank Gehry's Dream Project, The Guggenheim Museum Bilbao' (Stein 1997) which follows the project, to literature on the Bilbao effect[82] (Zulaika 1997; Stephens 1999).

FOG&A's vision of the future direction of architectural production as more than simply complex geometric form-making is supported by Cachola Schmal when he asserts,

> Even fully digital design planning, favoured by young architects, ultimately realises the potential of the computer for architecture only in part. True innovation in "digital architecture" can only be achieved through the operative coupling of CAD and CAM (2001 p.66).

Gehry's first use of CATIA was in 1989 for a large canopy inspired by the form of the fish commissioned for the Olympic village in Barcelona. This particular structure is of interest as it marked the first use of CATIA in architecture.

The best example of architect-driven advances in architectural computing is FOG&A's use of CATIA, - a use motivated by dissatisfaction with the geometries available to them at the time of an earlier project[83] - as Gehry explains to a previous client when describing the forms of the GMB.

> Remember your stairway in Vitra that I couldn't get it straight. That is what started all this. Its true because it really drove me crazy so we got, that is how we got into the computer and that is how this line [visual cue] is so perfect….It is absolutely true. Look it is just like my drawing. Now I can do those drawings and build it (Gehry in Blackwood 2000).

He goes on to describe the process of how the dissatisfaction of Vitra led to his practice's use of CATIA for subsequent projects.

> I had a stairway that had a curve-like shape and we drew it using descriptive geometry, but the builders couldn't do it. They didn't have a way in the field to make that so if you look at the stairway going up there is a little clunk like an aberration in the curve that never got resolved and it was that that perplexed me and aggravated me. I talked to the people in the office about how we were going to do shapes like that. I want to take my drawings and get that feeling of

[82] The *Bilbao effect* is the term coined by Stephens to describe the ability of an iconic building to regenerate the international image and increase the local pride of a city. This notion has become widely accepted to the point that a British cabinet minister, Tessa Jowell, describing areas in need of regeneration used the phrase "this is the new Bilbao" when describing that area's potential (*See* 'Exhibitionists; Museums' 2003).

[83] Vitra building, Weil am Rhein, the building Gehry cites as priming him to find new ways to document his work.

> the drawing into the building. So they went to the computer because they are all computer kids which I would never think to do, its so obvious but I am not that … so they started playing with the computer and getting computer people in and they found their way into the aircraft industry, and the system CATIA that Dassau was using, that software (Gehry in Blackwood 2000).

The GMB is traditionally treated in the literature as a milestone building with the underlying implications that there is no existing project with which it could be compared. The only literature comparing the context and the technology of the GMB to any other buildings by other architects which has been identified is 'Constructing Complexity' (Mitchell 2003) where the GMB is compared to the Sydney Opera House in a more generic sense. The practice itself adds to the literature through James Glymph from FOG&A contributing to conference proceedings edited by Kolarevic (2003a).

Most, if not all, of FOG&A's works post GMB are the subject of architectural reviews. These reviews usually consider how the complex geometries were realised and how Gehry conceived their forms. For example the DZ Bank building features in Giovannini's article 'Inner Beauty' (Giovannini 2001), and 'Disney Concert Hall' in Russell (2003).

'A Constructive Madness', a documentary film made by Jeffrey Kipnis[84] (2003), traced Gehry's progress throughout the Lewis house project (unbuilt). The Lewis house is a project which Gehry credits for allowing his practice to develop numerous technical advances. This film gives an insight into how FOG&A's work post Lewis house has been influenced by the technologies developed during that project. Gehry believes that the impact of the Lewis house on his architecture was profound when he asserts "*although it ended with nothing, it changed the world*" (Bates 2003).

3.2 Computer Technologies

This section reviews the relevant literature considering the impact of computer technologies on architecture. A historical perspective is given in the first subsection. This section has been consequently divided into 'Total Architecture', 'Building Information Modelling', 'Form Generation', 'and 'Hybrid Architecture'. Whilst these categorisations are not mutually exclusive, a delineation has nevertheless been made.

[84] Jeffrey Kipnis is the Curator of Architecture at the Wexner Center for the Arts at Ohio University, USA.

Whilst the use of Computer Aided Design (CAD) has been long advocated by experimental and academic architects, its use in the mainstream of architectural practice has been slower than other industry sectors (Australian Bureau of Statistics 2003). The technological advances made during the last two decades have been numerous, but the levels of engagement have differed. It is these differences in approach that create a divergence observed in the literature.

The role of computer technologies in architecture continues to be the subject of debate as to the most significant and substantial areas it affects and the nature of its influence. The idiosyncratic nature of computer usage, and the many and varied opinions available to architectural practice means there are significant differences in approaches and outcomes. There are very few obvious or discernable divisions between the ways computer technologies are used in architecture as cited in the literature that fit neatly into easily defined categories. Examples of successful computer usage in architecture have an elusive quality which makes them hard to qualify into a single category.

There is no identifiable definitive manifesto for digital architecture. It is now more than a decade since the first wave of digital projects and still there is no one seminal statement on the intents or general direction or consensus of how computer technologies are best used in architecture. James Steele[85] in his book 'Architecture and Computers: Action and Reaction in the Digital Revolution' asserted "*No manifestos have appeared to delineate a coherent vision of the drastic alterations to physical reality that are now underway*" (2001 p.8).

Historically, major changes in design and production techniques have been accompanied by a vigorous intellectual debate between identifiable collective positions. Ruskin, Morris and Carlyle[86] all participated in a debate that fundamentally influenced the subsequent direction of architecture in the post industrial revolution world. Due to the indisputable effects of the agricultural and industrial revolutions, a public debate could be maintained concerning the implications for not only the industries but also the ways of life they would

[85] James Steele is an Associate Professor School of Architecture at the University of Southern California, USA.

[86] John Ruskin, William Morris and Thomas Carlyle were seminal voices in the debate surrounding the industrial revolution which ultimately laid the foundation of the arts and crafts movement as a reaction against mass industrialisation.

affect. Due to the divergent and complex nature of the computer revolution[87] and the uncertainty of the opportunities and constraints afforded, the effects computer technologies will have are less obvious and hence more contentious. From these various viewpoints of the most appropriate uses of computer technologies emerged several paradigms of the computer use in architecture.

3.2.1 History and Usage of Computers in Architecture

Since Charles Babbage's[88] work in Victorian England, the evolution of computing had occurred as a discrete event driven process. The catalyst for such events was primarily an obvious or immediate requirement for the faster processing of raw data[89], most notably complex military calculations for plotting the trajectory of artillery shells. These needs drove investigations into new components from Babbage's' early mechanical arithmetic engines to electrical valves. The advances in materials physics allowed for a greater degree of innovation which prompted new uses for the new equipment. Activities such as the space program developed many innovations in materials physics and in the miniaturisation of electronic components (Ordway *et al.* 1972; Taylor 1974) from transistors, to integrated circuits, and in 1971 the microprocessor. The rate of change was driven and underpinned by many factors from the 'Cold War'[90] to advances in manufacturing technologies. The introduction of the microprocessor made available processing power at convenient physical scales. As is often cited, a personal computer (PC) which sits on a desk today would need an aircraft hangar full of valves to process an equivalent number of operations[91] before the advent of the microprocessor based computer.

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87 Computer revolution is a term used to place the phenomenon of computer use in the same social and economic categories as the agricultural and industrial revolutions.

88 Charles Babbage (b1791-d1871) is widely regarded as the first computer pioneer. *See* http://www.sciencemuseum.org.uk/on-line/babbage/index.asp.

89 Advances in computing are traditionally considered in terms of raw computational speed. Since the advent of the microprocessor, computational speed is largely a product of the amount of transistors that can be contained within a unit area. The most accepted measurement of the rate of miniaturisation was formulated by Gordon Moore (founder of Intel) in 1965. Moore's assertion, now known as Moore's law, states that the amount of transistors contained per unit area doubles every two years. Since this prediction, the rate of transistors per unit area has increased in line with Moore's law. *See* www.intel.com/silicon/moore.

90 The Cold War was the protracted geopolitical, ideological, and economic struggle that emerged after the Second World War between the Soviet Union and the United States. It took the form of an arms race, economic warfare and trade embargos, propaganda and espionage. It lasted until the fall of communism in 1989.

91 Computer operations are measured in millions of operations per second, (MIPS).

The first computer specifically designed for personal use was called Altair, and was offered for sale in 1974 by a company called Micro Instrumentation Telemetry Systems (MITS) and was available only by mail order in kit form. The first mass produced PC was made by the Tandy Corporation and introduced into the marketplace in 1977 (Montecino 2004). The growth of PCs from then on was extremely rapid with innovations by Apple Computers which introduced colour graphics, expanded memory and an internal disk drive system. With the introduction of IBM's first PC in 1981, personal computing moved from the mainly academic or hobbyist forum, to become a general purpose business machine and hence began to inspire programmers to consider a range of applications including CAD systems for this new universal machine[92]. The first experience of architectural practices with PCs was usually as a general purpose machine as Antony Radford's study suggests (1988). This view is still held, as Yehuda Kalay[93] states, that the "*IBM PC gained a place in most architectural offices as a general purpose business machine*" (2004 p.69).

The features that make personal computers accessible have traditionally centred on improvements in graphical user interfaces (GUI)[94] and the functionality / user friendliness of peripherals, such as pointing devices, larger displays and printers etc. In 1983 the Apple 'Lisa', the precursor of the Apple Macintosh, was the first consumer computer with a GUI. The introduction of a windows[95] environment in 1995 perhaps marked the end of direct or less arbitrated access to the disk operating system[96] for the standard IBM PC. Prior to the Microsoft Windows 95 operating system, computer users were required to have a more in-depth knowledge of the inner workings of the computer. This innovation could be seen as the most significant step towards making personal computers available to the general public, as opposed to those who were previously inclined to keep pace with technology. These innovations simplified the view of the internal operations of the computer to a degree that the user is unaware of the components and their interactions.

92 A Universal machine is a device which can interpret multiple sets of instructions to produce the required outcomes.
93 Yehuda Kalay is a Professor of Architecture at Berkeley University and author of texts on architectural computing.
94 Graphical User Interface (GUI) is the way in which the user can see their actions and the effects of those actions on a screen or video display unit (VDU).
95 Microsoft Windows is based in an Apple Macintosh GUI environment and a Unix X window interface and disk operating system.
96 Disk Operating System (DOS) commonly refers to the family of closely related operating systems which dominated the IBM PC compatible market between 1981 and 1995.

These advances that increased the processing speed are not as obvious to the user as the innovations of the mouse or the colour screen was.

Before the widespread use of computers in business, some architects were pioneering the use of computers for specific or custom usage such as CAD. The birth or the first generation of CAD machines is most often cited as Ivan Sutherland's sketchpad system. This system was the product of Sutherland's 1963 Massachusetts Institute of Technology (MIT) PhD work which used a customised IBM TX2-2 computer system built for the United State's Air Force (Kalay 2004 p.70). The limited user friendliness of computers in the mid 1960s was challenged by Sutherland. His system had no hard disk so therefore had no need for an operating system and ran on assembly code; an operation which requires a detailed and comprehensive understanding of how computers interpret input to give a worthwhile output. As a predominantly visual machine (for its day), it had a 7 inch (17.5cm) screen comprising of a 1024x1024 pixel[97] cathode ray tube display with a light pen. This machine had superior visual interface and input devices compared to standard computers of its time.

Sketchpad helped change the way people interact with computers. Sutherland's system is considered to be the ancestor of modern computer-aided design (CAD) systems as well as representing a major breakthrough in the development of computer graphics in general (Kalay 2004). Sutherland demonstrated that computer graphics could be utilized for both artistic and technical purposes in formulating an intuitive method of human-computer interaction. He predicted that computers could offer a glimpse of architectural possibilities previously considered unobtainable.

> A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland (Sutherland 2005).

The manner in which Sketchpad organised its geometric data was also pioneering in its use of objects[98] and instances[99]. This regime of *object oriented* programming became the most dominant way to portray and

[97] Personal computers used in contemporary architectural practices would use a 19" Liquid Crystal Display (LCD) screen, but would still have a similar pixel range shown on a monitor which renders a clear representation of those pixels.

[98] Objects are a series of database entries which make up a bounded and coherent object.

[99] Instances are the number of times and locations of an identical object within a drawing database.

document forms for virtual simulation[100] such as shadow analysis. Sketchpad also pioneered the master drawing which allowed global[101] changes affecting all other instances of that object within a drawing database. Sketchpad let the user to easily constrain selected geometrical properties within the drawing database with reference to other objects[102] (Sutherland 1980 p.56). These innovations were to influence the way CAD would evolve as Kalay asserts, "*later in corporate research labs, graphics-oriented software handled 'objects', not merely shapes*." (2004 p.71). Sutherland made this connection between physical objects and their virtual counterpart in 1967.

In 1967, four years after the Sketchpad system was built, Massachusetts Institute of Technology (MIT)'s architecture machine group was founded by Nicholas Negroponte[103]. This group developed architectural computing applications using an artificial intelligence approach. The architecture machine group approached computing devices with a view that they should be able to interpret the needs of the inhabitants and respond to those needs, without the intervention of an architect[104] (Kalay 2004 p.76). This project is still the subject of ongoing research. At the same time another system was also developed at MIT which was known as URBANS and was used for urban planning visualisation.

Contemporaneously in the United Kingdom software was developed for use on large scale public building projects taking advantage of modular coordination and industrialised building components. Some of the more significant developments were systems like OXSYS and HARNESS that were used in government projects for hospital design using prefabricated components (Kalay 2004). At that time software was specific to institutions or other developers and not developed for mass distribution or for third party development.

As computing hardware became more powerful there was a bifurcation[105] of directions in software. Kieran and Timberlake[106] argue that architecture has

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[100] Objects within the drawing database can contain additional information such as volume, mass and weight etc, so that a virtual environment could be simulated to assess how these objects would behave in the physical world.

[101] A global variable or parameter is one that is defined once and used throughout the program to reflect all instances of that object.

[102] Geometry could be generated with reference to an existing geometry such as parallel, perpendicular, or at an angle to.

[103] Nicholas Negroponte is co-founder and Chairman Emeritus of the MIT Media Laboratory, and author of 'Being Digital' (1995).

[104] What today has parallels with agent based computing.

[105] The term bifurcation refers specifically to the main body of one item splitting into two parts.

bifurcated into two separate worlds, that of art and commodity (2004 p.3) which could be seen as similar to the two separate paths CAD has taken in visualisation and production control. The recognition of divergence is categorised as an unfortunate event by Kieran and Timberlake (2004), particularly for architectural CAD systems compared to the production orientated approach.

> The architect remains content, apparently, to focus on the appearance of things, while the process engineer goes beyond appearance into the deepest substance of making to invert the historic, craft-based relations between cost and time (Kieran and Timberlake 2004 p.xi).

This view of the divergence is supported by Kalay, who contends the oversimplification of architectural CAD happened while the other disciplines – most notably the electronics industry – "*were making their own CAD software more intelligent*" (Kalay 2004 p.71). He continues,

> The development of computer-aided design in the 1970's took two different routes: a geometric modelling route, geared toward supporting the needs of mechanical engineering applications in the automotive and aerospace industries; and a building-specific route, geared toward supporting the needs of the construction industry (Kalay 2004 p. 67).

This division led to the automotive / aerospace developers placing a strong emphasis on functionality of intelligent objects[107] which can be seen in contemporary CAD programs such as CATIA. In contrast, most architectural practices have used high impact, photo-realistic 3D rendering for representation and have reverted to 2D vector drafting for documentation in place of BIM (described in Section 3.2.3, p.100). A smaller group of architectural practices wanted to extract data from their model and used their 3D data for functional operations.

As computer power evolved, opportunities for increasingly complex geometries were taken. Gyula Sebestyen[108] asserts that there is a correlation between complexity of form and computer power when considering the effect of computer technologies on architecture.

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[106] Stephen Kieran and James Timberlake founded Kieran Timberlake Associates in 1984. Both have written about the effect of manufacturing innovations on architecture whilst practising as architects in Philadelphia.

[107] An intelligent object is an entity in a 3D CAD file that has an attached list of attributes such as volume, area and can hold other user or 3rd party dependent data.

[108] Gyula Sebestyen is the former President and Secretary General of the CIB, "Conseil International du Bâtiment" (in English: International Council for Building) and author.

> Large scale engineering problems may require solutions to hundreds or thousands of linear and/or non-linear equations, which can only be undertaken by modern digital computers. The popularity of numerical methods has therefore progressed hand in hand with the increasing use of computers (Sebestyen 1998 p.79).

As previously stated in the introduction to this thesis, the Australian architectural profession has not adopted architectural computing with a coherent implementation strategy. There have been studies that considered the introduction of computers and CAD in Australian architectural practices, most notably by Antony Radford[109] (1988). This study, 'Computers in Australian Architectural Practice' was published by the Royal Australian Institute of Architects and used interviews with practitioners to record expectations of, and experiences with, CAD. This study concerns a number of architectural practices and was intended to represent a snapshot of many practices rather than an in-depth analysis of one practice in particular. In 1988 practices using CAD represented only a small percentage of architectural practices. However, there shines through a pioneering spirit, from those practices and individuals who were in the forefront of the introduction of computers to Australian architectural practice. As Radford's study concludes, most architectural practices in Australia adopted CAD for the three main reasons which were "*[T]he promise of higher productivity, a hoped-for benefit in marketing their services and because another firm with which the practice has traditionally compared itself has installed a system*" (1988 p.6).

The productivity issue is still the subject of debate but this issue has matured with the technology and is no longer about hypothetical advantages as it was in 1988. It is now about the most appropriate CAD system for the most efficient delivery of services. The marketability of services has also matured to a point of marketplace differentiation in services offered. Photo-realistic images, fly and walk through animations, and more sophisticated functional uses such as space syntax[110] and BIM (see Section 3.2.3, p.100) are offered as points of market differentiation. These advances allow the same unwillingness to allow a competitive advantage to exist today as they did in 1988. The major difference between 1988 and 2006 is that CAD is no longer an option, it is ubiquitous. The practices that are at the forefront today use technologies that, as in 1988, are available to all but are only used by a few; however some of the technical limitations are still seen to apply.

[109] Antony Radford is a Professor of Architecture at The University of Adelaide, and author of texts on the use of CAD and its implications for Australian architectural practice.

[110] Space syntax is a tool for the analysis of spatial configuration where significant aspects of human interaction with buildings and cities. *See* http://www.spacesyntax.org.

The usage of CAD in architecture still seems to divide practices that want to do the same work more productively than before from those who want to embrace innovation and push the boundaries of what is available.

> Overall, productivity gains from CAD systems are not the spectacular ratios often claimed and certainly do not extend to all kinds of work and drawings. Although productivity is frequently mentioned, the abilities to improve the quality of work and to do things which were previously beyond reach seem to be valued more highly (Radford 1988 p.10).

With these opportunities comes the realisation that computing is not a panacea. "*Computing is not easy. There are difficulties as well as opportunities*" (Radford 1988 p.10). One of these difficulties is the issue of interoperability which is still a major concern to the International Alliance on Interoperability[111] (IAI) who argue that there are no technical reasons why CAD data cannot be interchangeable. However, there are still problems transferring data from one package to another as Radford asserted in 1988.

> The problems of compatibility and the ability of different computer system products, both hardware and software, to communicate with each other is still far from satisfactory and a real difficulty in the industry (1988 p.10).

Despite the generally optimistic feel of Radford there was a cautionary note, even given the findings of the research.

> Computers, in some form, are simply the appropriate technology for the task, but this does not mean that exploitation of the technology is easy, that all uses of computers are good uses, or that the people in architects' offices are to any degree less important with computers than without them (Radford 1988 p.10).

Two practices that factored in Radford's survey were that of Sweetman, Godfrey and Ord, and Mitchell Walker Wright. Principals from those two practices, Ian Godfrey and John Mitchell[112], have continued to be engaged in the advanced application of computers in architecture. The use of CAD in Australia in this period was described by Godfrey.

> There wasn't much of a real uptake in Australia. And then, suddenly, CAD became easy and productive. I hope it is productive, the thing to

[111] IAI (International Alliance on Interoperability) is an international organisation devoted to standardising CAD elements to allow universal data formats. *See* http://www.iai.org.

[112] The opinions and observations of Ian Godfrey and John Mitchell can be further found in Chapter 5 Synergy at the National Museum of Australia, p.161.

> implement in architectural practice. Many people said basically, 'I think CAD is solved' (Godfrey [interviewed by author] 2003).

He goes on to say "*They just didn't realise it had gone up. It had got to a plateau. But it was just a plateau, it's a long way to go still*" (Godfrey [interviewed by author] 2003). Even in 2003 (the post GMB environment) Godfrey contends, "*Most people still use CAD systems as an electronic drawing board*" (Godfrey [interviewed by author] 2003).

Peter Cachola Schmal[113] summarises the advances that some architects have made in the same period.

> In just over a decade, the computer has become a ubiquitous tool in contemporary architectural production and, in doing so, has evolved through several stages, some concurrently: in the beginning (and to a large degree still today) it was first and foremost a more efficient drawing tool; next, it became a design tool in the sense of Deleuze's abstract machine (especially in the parameter-based design of Greg Lynn, Karl Chu, Marcos Novak, and others); and most recently it has also become a tool in building production itself (Cachola Schmal 2001 p.39).

The most notable advance in CAD-enabled building production is the advent of object oriented CAD which used 3D objects in place of 2D vector[114] representations. The evolution of computer software for architecture moved from object oriented CAD towards BIM in the early 1990s. These developments necessarily gave way to a difference in understanding of how design information could be perceived or understood. "*Drawings become a view into the database that describes the building itself*" (Autodesk 2002) which taken to its logical conclusion sees traditional paper based documentation as merely a printed by-product of the building information model arranged to suit the prevailing conventions.

The use of computers in architecture, as well as being qualified in terms of technical advances, can also be illustrated by examples of groundbreaking work. The GMB is, without doubt, a seminal example of the use of computers in architecture. It has had a similar impact that the computer analysis had to the ultimate success of the Sydney Opera House project (Mikami and Murai 2001). The future of computer technologies in the AEC sector is still dependent in part upon the collective aspirations of the individual architects

[113] Peter Cachola Schmal is an architect, critic and curator of the German Architecture Museum (DAM), Frankfurt, Germany.

[114] A vector is an element such as a line or arc with a start and end point, and shown as a line or arc on a VDU.

and practices and how they apply the technologies that are available to them. In this respect the future of computer technology is today, as Radford outlined in 1988, reliant on the people who use them. The varying levels of engagement and the available computer technologies have hence yielded a complex matrix of applicability. This figurative matrix maps the use and intent of some practices to conceive their architecture. In the extreme, architecture is conceived with reference to, generated by, documented by, controlled by, and even in part constructed by, the computer and/or computer controlled devices.

It is integral to the history of technological advances that innovations are typically framed in relation to the problems they seek to address. The motor vehicle was first defined by its exclusion of the horse rather than the inclusion of the engine (the horseless carriage). A reluctance to see architectural CAD as new, rather than a variation on what has preceded it, seems to be the prevailing ethos Marshall McLuhan considered in relation to media.

> Media guru Marshall McLuhan once noted that media take their initial content from the media they replace. The first motion pictures were filmed stage plays; the first television broadcasts were radio programs with pictures (Laiserin 2002 p.141).

The use of computer technologies in architectural practice has been a collection of discrete event-driven advances in processing power and software development and a series of computer aided architectural exemplars. The contemporary use of computer technologies in architecture could legitimately be seen as the culmination of the continual endeavour to employ structured mathematics to make possible increasingly complex designs e.g. the move from fixed point analysis to floating point analysis and its effect on mathematical levels of approximation[115]. In short, the rudimentary mathematics of the pyramid makers can be seen as the logical predecessors of the highly structured binary databases used by FOG&A to describe the GMB. An alternative paradigm has been offered by ARM's eclectic use of computer technologies at the NMA project. As architectural computing is linked to advances in computational power it could be reasonably expected that the complexity in design and construction of contemporary architecture would increase accordingly. However, the next generation of computer componentry could be based on organic (Spooner 2006) rather than silicon

[115] The term floating point is derived from the fact that there is no fixed number of digits before and after the decimal point; that is, the decimal point can float. There are also representations in which the number of digits before and after the decimal point is set, called fixed-point representations. In general, floating-point representations are slower and less accurate than fixed-point representations, but they can handle a larger range of numbers. *See* http://www.webopedia.com/TERM/F/floating_point_number.htm.

driven componentry as Bell Laboratories experimental bio-chip programme foreshadows.

3.2.2 Total Architecture

This subsection considers total architecture and includes a discussion on the related phenomenon of technology transfer. This notion that advances in computer technologies have facilitated a total approach to architecture has recently been argued strongly by several authors (Cachola Schmal 2001; Kolarevic 2001; Steele 2001; Kolarevic 2003b; Mitchell 2003). The total approach to architecture is normally considered referential to industries that have previously employed the types of coherent design and documentation to which total architecture aspires. As Wes Jones[116] asserts

> The use of computers is not limited to designing a form; it also functions as an operative interface in the constructional realisation of the form. In contrast to conventional design procedures, a spatial form is no longer designed separately in different plans (ground plan, elevation, and section), but directly as a virtual, three-dimensional model that is "constructed" on the computer. The 3D file that results from this process can subsequently be "spatially" plotted on a 3D output device such as a CNC-cutter, that is, it can be cut from a specific material (polyester, cellular foam, etc). In some cases – for example, ship – and model building – the resulting form is already the final product; in other cases it serves as a negative form or mould that is then cast in series in the appropriate material (used for interior finishing materials in automobile manufacture or in furniture production (Wes Jones in Cachola Schmal 2001 p.1).

This way to work is common in the aviation industry where virtual testing is done before any physical models or working drawings are generated. The importance of computer technologies in aviation is underpinned by the amount of capital invested; "*Boeing invested more than $1 billion (and insiders say much more) in CAD infrastructure for the design of the Boeing 777*" (Caltech 1997).

There is a body of work considering computer technologies in light of advances from other industries which could be applied to architecture. The concept of conceiving architecture as prefabricated chunks, as in the aviation/automotive/naval industries, has influenced contemporary

[116] Wes Jones is a principal of Jones, Partners: Architecture and visiting Professor in the schools of Architecture at Harvard, Princeton, and Southern California Institute of Architecture.

architectural discourse. The most notable text on the issue is Kieren and Timberlake (2004).

Some authors have seen the role of the computer and have put forward differing arguments about the most profound effect computers are likely to have on architecture. For example, Kieren and Timberlake argue that architects must not only forge new relationships but also embrace an understanding that their designs can become more complex due to the increased sophistication of the tools at their disposal.

This is indicative of a view that computational power equates directly to increasing complexity in engineering structures and the architectural form which they support. The symbiotic nature of philosophical intent and constructing architecture (Novitski 1994; Sebestyen 1998) suggests there is a parallel relationship between ideas and the data needed to make the ideas legible in construction terms. Therefore the speed that computers can use to generate data is most likely to play a role in the complexity of form and structure.

Computer technologies have also been seen as facilitating the coordination of complex geometries. John Zils, a lead engineer on the GMB project, asserts in a paper for the American Society of Civil Engineers that at the GMB the computer was the "*central player in coordinating design, fabrication and erection*" (Iyengar 1998p.108). Cocke also describes this innovation of project sequencing and coordination:

> If you look at the automotive or aerospace industry, they work with many, many subcontractors. They bring a lot of components together with extremely high precision. That has a parallel in the building industry. So if you forget the curves, and simply think about a centralised database for coordination, there are obvious advantages regardless of the nature of the architecture (Cocke 2000 p.54).

Annette LeCuyer shared this sentiment when considering CATIA's impact, "*The primary benefit of the program [CATIA] concerns improvements in the buildability of the projects*" (1995 p.89). LeCuyer continues this theme as the author of several notable articles about the GMB and its significance for the architecture profession in form generation and construction terms in addition to their landmark status.

Economies of scale using standardised elements were, in part, a justification for architects to use simple or repetitive geometries. Contemporary computer controlled fabrication machines made the savings offered by the economies of scale no longer as attractive as they once were. This is a point made by William Mitchell (Mitchell in Raghed 2001), where there is the promise of a departure from the economies of scale. As Jones asserts,

> The realisation that the production cost of an individual part can be reduced through increased quantities – which architects, and others, grew to appreciate through the introduction of conveyor belt production by Henry Ford in 1914 – resulted in the primacy of unified mass form in architecture, leaving ineradicable traces especially in the housing schemes and urban designs of Modernism. Architecture today could overthrow the iron law of serial production through the consistent application of CAD/CAM ……….What set these techniques apart is that a multitude of different forms can be produced in one and the same manufacturing process. To the computer-controlled cutter it makes little difference whether it is cutting out a cube or a hyperbolic form. And since the work process is fully automated the production cost is basically the same (Wes Jones in Cachola Schmal 2001 p.1).

This is a theme expanded upon by Kieran and Timberlake "*The single, most important change from Le Corbusier's vision has been the shift in fabrication from mass production to mass customisation*" (2004 p.111). The mass customisation benefits that are a product of advances in computer technologies can best be seen in architecture in FOG&A's work at the Neue Zollhof, 1994-9, Düsseldorf (Figure 54, Figure 55 p.97)

> The Neue Zollhof in Düsseldorf, created in collaboration with Buecker Maschlanka + Partner, is undoubtedly the most comprehensive project thus far which FOG&A has realised with regard to 'file-to-factory' processes (Cachola Schmal 2001 p.10).

Total architecture is sometimes portrayed within the literature as a panacea for the AEC sector. The exponents and champions of total architecture however have a more sophisticated understanding of the opportunities and constraints. Due to the lack of a cohesive definition of what constitutes total architecture, the literature dealing with product design (at a small scale) and aviation design (at a large scale) are often cited in literature pertaining to future directions of architecture occasionally with little regard as to the unique challenges faced by architecture. As Paolo Tombesi[117] asserts in his PhD thesis "*Segregation of design and construction knowledge is the norm*" (1997 p.124). However, the literature does in places address the potential for the greater possibility of inter-disciplinary involvement, particularly Kieran and Timberlake (2004).

[117] Paolo Tombesi, Associate Professor of architecture at the University of Melbourne and author of papers and articles on construction management and economics, and procurement.

Figure 54 Der Neue Zollhoff, Dusseldorf.

Figure 55 Laminated Object Manufacture Model, Der Neue Zollhoff.

The theme of technology transfer has been recounted in the literature, usually as a comparison with other industries. The efficiencies offered by exploiting the full potential of a sophisticated design package such as CATIA are best understood in reference to the systems they immediately preceded. Boeing's experience with the 777 jet liner design and construction gives a large scale controlled experiment (as can be expected) on the efficiency gains outlined by a California Institute of Technology research group when they assert.

> Comparing with extrapolations from earlier aircraft designs such as those for the 757 and 767, Boeing achieved
> Elimination of > 3000 assembly interfaces, without any physical prototyping
> 90% reduction in engineering change requests (6000 to 600)
> 50% reduction in cycle time for engineering change request
> 90% reduction in material rework
> 50x improvement in assembly tolerances for fuselage (Caltech 1997).

Architectural software is at the high end of the software market and is too complex to be produced by practicing architects; hence, production and support is likely to come from outside architecture. At the GMB the technology transfer came from the aerospace industry. Due to the GMB's use of high levels of off site fabrication constructed to very high tolerances this project has become associated with a paradigm of work which is considerably influenced by industries which use high levels of pre-fabrication. Consequently this generated literature concerned with process control of the architecture and its similarities to aerospace, naval and vehicular manufacture (Novitski 1992; LeCuyer 1997; Stein 1997; Giovannini 2000). This phenomenon has been cited by authors when considering FOG&A's work at the GMB. Indicative of these works was an essay in 'Digital Real' which advances the argument that the GMB was facilitated through technology transfer.

> The architect and his firm have had breathtaking success in pursuing a path between sculptural and digital architecture. The Guggenheim in Bilbao has revealed the potential of emotional architecture to the public, made possible through technology transfer with state-of-the-art software (Cachola Schmal 2001 p.23).

Whilst CATIA is traditionally solely credited with increasing efficiencies in design/fabrication industries, the implementation of such a complex and sophisticated design tool, it must also be tempered with an understanding of the underpinning organisational techniques.

> Designing airplanes has, ever since the Wright brothers, been a collaborative effort. The design of the Boeing 777 jetliner, however, took the idea of creative collaboration further by adopting new technologies and new organizational techniques. Among the most

> important of these were Design Build Teams, made up of engineers, technicians, accountants, and others (Creative Engineer 2006).

As FOG&A adopted an aviation software package they also employed several CATIA modellers from the aviation sector. FOG&A have been the most substantially featured architectural practice to integrate design, documentation and construction.

The industries most commonly cited as influencing the possible future of architecture all produce repetitive building elements for tightly bounded projects which benefit from the economies of scale[118] offered by refining repetitively manufactured component items. However, Sanders points out that this difference in industries which he believes should be taken into consideration in developing total software solution for architecture.

> The design community must first recognise the differences between the design and construction industry and manufacturing industries that create mass-produced products. As software developers borrow ideas from the latter industries, they also need to recognise what makes ours unique: how its economics are different, and how creating complex, one-of-a-kind products requires a broadly distributed, specialised work effort and method of decision making (Sanders 2004 p.4).

Kolarevic has commented about the disparity of CAD/CAM between other industries and architecture.

> While the CAD/CAM technological advances and the resulting change in design and production techniques had an enormous impact on other industries, there has yet to be a similarity in construction. The opportunities for the architecture, engineering and construction (AEC) industries are beckoning, and the benefits are already manifested in related fields (Kolarevic 2003a p10).

Martin Pawley[119] gives an overview of the problematic nature of Research and Development (R&D) in architecture when compared with other industries.

> A totally new Japanese car requires 1.7 million hours of research and development time from a blank sheet of paper to the first customer delivery. With an average production run of one million cars the design cost amortised across the production run comes in at only $425 per car, but each car has the benefit of 1.7 million hours of

[118] Economies of scale refers to the cost of reproducing identical elements hence economising on design time and costs incurred in prototyping and production costs, such as re-using design information, models, jigs etc to amortise the overall costs.

[119] Martin Pawley, architect, critic and architectural columnist for several British broadsheets, and editor of 'World Architecture'.

> design thought. By comparison, a new office building, costing $50 million with design consultancy fees running at 5% of cost, has the benefit of only 10,000 hours of design thought. The worst case of all is a three-bedroom architect designed family home, with fees running at 11% of cost. This will have only 1,750 hours of design thought. Under these conditions, it is ridiculous to talk about “smart buildings” (Pawley 1998 p.196).

This example compares very different industries, and shows the relative levels of research and development that industries can, and do afford. He also draws some insightful conclusions about the expected sophistication of the comparative end product. He goes on to say that architecture cannot compete on equal terms with other industries because the computer technologies used by architects are for one-off products, whereas the tools of the automotive industry, for example, are for mass production. Therefore, it should be argued that R&D in architecture should comprise a larger percentage of the amortised cost if it is to achieve comparable levels of sophistication with the automotive industry.

FOG&A have created a remarkably complex geometric work of architecture whose form was not generated by complex algorithms but was documented from Gehry’s original physical models. Due to the efficiencies offered to FOG&A by the support from allied CATIA-based industries, Gehry has categorically shown that using computer technologies without reliance on them to generate the form can still be considered an icon of the possibilities of computers designing architecture.

3.2.3 Building Information Models

In this subsection Building Information Modelling (Building Information Models are special cases of object oriented CAD) has been considered independently of total architecture, although due to the overlapping nature of BIM and CAD, there are some areas of commonality. The distinguishing feature of total architecture approach is the use of object oriented CAD to inform the same set of design information throughout the entire process. The literature available on Building Information Models is mostly related to the work of, or by members of, the International Alliance for Interoperability (IAI). The IAI mission statement is “*To develop a standard universal framework to enable and encourage information sharing and interoperability throughout all phases of the whole building life cycle*” (National Building of Information Sciences 2006).

A definition of building information modelling has been given by Autodesk as "*Information-centric software providing building information modelling in place of building graphic modelling*" (2002).

The only non-anecdotal literature on Building Information Models was commissioned by the United States Department of Commerce, Technology Administration in 2004, specifically to address financial losses which could have been ameliorated or eliminated by effective use of proper interoperability management. Gallaher *et al.* (2004) constitutes the most detailed and reliable literature on the cost implications of inadequate interoperability standards. Autodesk (developers of AutoCAD and Revit) advocate the use of Building Information Modelling as the most logical process to mitigate or eliminate interoperability losses. They advocate the most salient characteristics as:

> (1) They create and operate on digital databases for collaboration.
> (2) They manage change throughout those databases so that a change to any part of the database is coordinated in all other parts.
> (3) They capture and preserve information for reuse by additional industry-specific application (Autodesk 2002).

Graphisoft (developers of ArchiCAD), a leader in BIM, has also published similar 'White papers' on the benefit of the BIM approach. However, the successful use of BIMs is still seen as a way to work mastered by other data/design intensive industries which has not yet been embraced by the AEC sector. Architects must learn to complete their designs early to allow the reuse of information throughout the project. This line of thought relies heavily on the successful application of technologies in other industries and is articulated here by Autodesk in 'Information Modelling for the AEC sector'.

> Successful information technology solutions outside the building industry are based on one primary principle: Data is captured once, as close to its point of origin as possible, and stored in a way that it is always easily available (Autodesk 2002) .

Building information modelling as an architectural paradigm necessarily requires a reconsideration of how building information is stored and controlled. The notion that control over information is transforming architecture is closely related to the notion of a common or universal building database. This concept is advanced through the IAI. They have formulated a protocol for the definition of architectural elements in digital form known as Industry

Foundation Classes[120] (IFC). Industry Foundation Classes are a particular class of virtual elements identified by a drawing database. They have the added advantage of being non-proprietary and hence uncontrolled by commercial entities' involvement, and open to users and developers alike.

> "Because the specification is non-proprietary, the content, integrity, and reliability of the data can be independently verified. Moreover, at least in theory, end users have the ability, to exercise independent control over their data" (Bollinger 2006).

Due to the proprietary nature of commercially available CAD programs the IAI as part of its mission has, and will continue to, develop a format independent of proprietary systems but with the ability to extract coherent data from any supported proprietary CAD package for third party examination or manipulation.

> Industry Foundation Classes, IFCs, under development by IAI, are designed to provide a means of passing a complete, thorough, and accurate building data model from the computer application used by one participant to another with no loss of information. IFCs are data elements that represent the parts of buildings or elements of a process for a particular facility and contain the relevant information about those parts. Computer applications use IFCs to assemble a computer-readable model that constitutes an object-oriented database. This database may be shared among project participants and continue to grow as a project goes through design and construction and enters operation. The European Council for Civil Engineers estimates that the use of IFCs can reduce the risk factors for facility management contractors by up to 20 percent for new buildings and up to 50 percent for older structures (Gallaher *et al.* 2004 p.56).

The move to Building Information Modelling by the AEC sector has not been as complete as had been hoped. The reasons for this have been considered by the American Institute of Architects when they assert

> Some firms hesitated to change from electronic drafting to a model based process. This may be due to the software they were using as this certainly shapes and defines the process options. Also, there is the painful recollection of the transition from paper to 2D CAD without information standards to support them (Davis 2003).

This criticism is addressed by Sanders, when he considers why the Building Information Model paradigm has not yet become commonplace in 'Why

[120] IFCs are the only construction information standard recognised by the International Standards Organisation (ISO). IFCs are defined by the AEC **I**ndustry, they provide a **F**oundation for shared data Models, and they specify **C**lasses of elements in a common construction language.

Building Information Modelling isn't Working Yet' (2004). He makes some very pertinent points about the unique challenges that face the architecture industry, and how the aerospace and automotive industries are not a fair comparison. This is a counterpoint to Kieran and Timberlake (2004). He makes the point that there must be a commensurate system to support such an innovative use of computing in architecture.

One of CATIA's advantages over traditional architectural packages is its advanced functionality that facilitates a dynamic relationship with the design parameters. This ability to dynamically update the geometries and/or properties of form, provides opportunities and places constraints upon the designer. The designer can experiment with multiple designs with the knowledge that the designs would conform to preset design parameters and conditions. However, the design conditions need to be structured and codified early in the design process which may necessarily limit the design. This is a departure from the usual multi-phased design and document scenario.

Traditionally there were at least two separate and distinct phases in the production of architecture. These phases can broadly be characterised as design and documentation. FOG&A's use of CATIA from conception to completion of the GMB has consequently blurred or even removed some lines of demarcation. CATIA's most effective ability is to span all activities in the process from design to fabrication and generate the documentation largely as a product of the design intentions. The shift from distinct multiple phases to a single whole of project approach marks a major departure from the traditional design and then documentation approach. The lines of job description have now been reshaped to reflect the use of technologies that are not easily adapted to the traditional design then documentation regime. This flux requires situational appropriate approaches on how architecture can best be constructed in the digital age. Sanders has offered some insight into this predicament when he asserts there needs to be a new understanding between stakeholders of the project which is manifest in the arrangements for project procurement (2004).

Some of the world's largest and most innovative architectural practices such as Naramore, Bain, Brady and Johanson (NBBJ[121]) have already embraced

[121] NBBJ is a global architecture and design firm widely considered to be the largest in the world.

the paradigm of BIM as Lachmi Khemlani[122] has stated *"NBBJ has done 35 to 40 projects using BIM" (Khemlani 2006).* A fundamental benefit of BIM is that of multiple application of the model. A coherent BIM can be used for a variety of third party uses. One of the uses has been illustrated by the Singapore Government's program to use the data that constitute a BIM to automate the process of governmental regulations.

> *Solibri, Inc*., founded in Helsinki, Finland in 1999 use IFCs to produce software for building information model quality control and design process productivity. Solibri software automates model checking and analysis, adding valuable dimensions to BIM use. Solibri Model Checker uses an object-based "rule engine" to automate "design spell-checking" for a building model. It analyses models for integrity, quality, and physical security. It reveals potential flaws and weaknesses in the design, highlights clashing (inappropriately intersecting) components, and checks the model for compliance with building codes and with the organization's own best practices (Bollinger 2006 p.1).

Similarly a Singaporean non-government organisation adopted the IFC as their standard *"In Singapore, a $22.6 million Construction and Real Estate Network (CORENET) project was established to provide an integrated approvals system based on IFC" (Bollinger 2006 p.2).*

Whereas the Singaporean examples rely on commercial advantage to drive the use of BIMs, the Finnish Government have extended that philosophy to include the mandatory use of BIMs in government projects by 2011. They have formulated a policy whereby all government buildings constructed after 2011 need to be accompanied by a coherent Building Information Model (Fischer and Kam 2003). However, this requirement is beginning to be fulfilled and the report compiled by Martin Fischer[123] and Calvin Kam[124] details an already completed project which fulfils the Finnish government's aims.

The BIM and the IAI's IFCs are predominantly represented in the literature as not only the most advanced data standard but also the most likely to gain a widespread acceptance. *In November 2002, the IFC data specifications became an international standard: ISO/PAS 16793. Around the same time, ten*

[122] Lachmi Khemlani has a Ph.D. in Architecture from UC Berkeley, specializing in intelligent building modelling, and is the founder of Arcwiz (www.arcwiz.com), and is the founder and editor of AECbytes (www.aecbytes.com).

[123] Martin Fischer is the Director of CIFE since 2001 and an Associate Professor, Civil & Environmental Engineering and (by Courtesy) Computer Science Stanford University. He is a widely published author of 4D modelling tools in design and construction.

[124] Calvin Kam is an Assistant Professor at the School of Engineering in Stanford University and the Program Manager of the National 3D-4D-BIM Program with the Office of the Chief Architect for the United States General Services Administration.

software vendors applied for 16 IFC 2x applications to be certified as being IFC compliant" (Bollinger 2006 p.2)[125]*.*

3.2.4 Form Generation

In this subsection form generation is considered as a stand alone process; as the major exponents of computer generated form do not figure to any significant degree in the literature on total architecture or Building Information Modelling. There is, amongst some architects, a philosophical predisposition that drives or underpins not only their decision to use CAD but moreover how they may best employ it. In the early 1990s form generation was seen as a liberating force for architects who wanted to radically depart from Cartesian forms via this new powerful media. The output from investigations conducted into how computer technologies have influenced architecture can be seen most recently in Kolarevic (2003a), a collection of case studies where the central factors of influence are form generation and architectural computing for production.

An indicative text from 1994 outlining what computers can do for architectural form making 'Freedom from Form' (Novitski 1994) articulates a vision of how the forms of architecture may change to reflect the new opportunities for complex design made possible by the computer. This text is representative of a wide range of opinion on the impact of computer technologies on architecture and is cited in this review as representative of a certain point of view prevalent in the 1990s. Novitski, an architectural journalist interested in the use of technologies in architecture, was particularly influenced by the advances made in modelling complex geometries that would be impractical to consider commercially viable prior to the advent of affordable computer technologies. She continues her argument in reference to the types of new geometric forms previously too problematic to be manually resolved but which were beginning to be developed. She draws a conclusion about the connections between metaphorically (usually complex geometric) driven designs and the advances in computer power when she asserts more complex architecture to be realised "*if you want to represent a philosophy through geometrical relationships, you have to do it by computer*" (Novitski 1994 p.108). Philosophies can be shown through simple geometric relationships and complex metaphors which were previously too problematic are now

[125] Elizabeth Bollinger is a professor at the Gerald D. Hines College of Architecture, University of Houston, in Houston, Texas, USA.

buildable. In this work she cites the theoretical work of Peter Eisenman's project for the Max Reinhardt Haus cultural centre Berlin, an extremely complex but unrealised commercial project based on a folded möbius strip. The conclusion drawn in this text is that there are considerable advantages for complex form generation using computational power. She states that "*Sharing the technology with the building trades enables these irregular forms to be constructed at reasonable costs*" (Novitski 1994 p.107).

She extols the virtues of the computer's ability to directly interface with fabrication machines. "*This mathematically defined information will be translated directly into the milling machines without the error-prone process of intermediary paper drawings and human interpretations*" (Novitski 1994 p.111). This view is echoed by Cooke and Mayes (1996) two years later. Novitski also postulates that the increase of pioneering works of architecture that use computer technologies will increase the architect's understanding of design and construction. Then she asserts

> As computer technology improves, and as the architecture profession acquires a collective understanding about how to apply it to design and construction, examples such as these pioneering efforts will become more common (Novitski 1994 p.111).

Her assertions about the greater accessibility of complex geometries in architecture mark the beginning of a wider acceptance of computers in mainstream architecture. This view is reiterated and further qualified by Galofaro[126], who asserts that generating complex geometric forms is likely to be vastly time and resource intensive and hence unlikely to be undertaken without the aid of the computer (1999).

Previous to the work of Novitski and others, there were works of increasing complexity documented in Papadakis *et al.* (1992). The works featured in Papadakis *et al.* were more theoretical than practical as the computational power to adequately document works of this complexity were not yet available to architects. In this work, examples of the beginnings of works influenced by computer geometries were just becoming visible. This line of architectural inquiry was extended in such works as Zellner[127] (1999) which featured complex geometric structures predominantly realised in virtual space only. This type of architectural endeavour is celebrated by critics such as Charles Jencks as "*a kind of ultimate democratic method*" (Jencks in Abel 1996a)

[126] Luca Galofaro is author of several publications about the use of CAD; he lectures at University of Pennsylvania and was previously an associate of Eisenman Architects, New York.
[127] Peter Zellner is a Lecturer in Design at RMIT and an author and curator.

However, this phenomenon is cited by Abel[128] as an engagement with complex geometries for their own sake with little underpinning external rationality when he states:

> A distinguishing feature of much architecture in the 1990s has been a preoccupation with complexity for its own sake, most of all with its formal expressions. Rejecting both the reductionism of early Modernists and the eclecticism of Postmodernists – healthy reactions in themselves – many architects and students instead favour irregular and hard-to-fathom compositions based on mixed geometries (Abel 1996a p.48).

Abel's view runs contrary to one perspective of computer technologies as the herald for a new age of understanding inspired by technology. Abel has the view that "*Eisenman bases his approach on Derridan[129] literary theory and other non-architectural sources, on the assumption that they will offer critical insights into and a way out of outdated conventions*" (Abel 1996a p.60). Peter Eisenman, the experimental and academic architect, puts forward the following view in his essay 'Visions Unfolding' (Papadakis *et al.* 1992),

> During the 50 years since the Second World War, a paradigm shift has taken place that should have profoundly affected architecture: this was the shift from the mechanical paradigm to the electronic one (p.88).

Eisenman's views have been taken as indicative of a number of contemporary architects and academics who advocate technology as *parti[130].* These practitioners and theorists embrace the computer as the most appropriate way to generate new forms. The ability to produce these forms in a virtual environment exceeded the industry's capacity to fabricate / construct them at that time. However, within a decade the advances in fabrication control allowed similarly complex projects to be realised.

The works of Cachola Schmal (2001), Kolarevic (2001), and Migayrou[131] and Brayer[132] (2001) illustrate some of these geometrically complex projects that were successfully realised. The *ArchiLab*[133] and *Blobmeister[134]* tradition as

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[128] Chris Abel is an architectural theorist, critic and writer.
[129] Jacques Derrida (b1930–d2004) was the French deconstructionist philosopher whose work had an impact on continental philosophy and literary theory.
[130] Meaning a point of departure, a point at which the metaphor becomes a preliminary design
[131] Frederic Migayrou is chief curator of architecture and design at the Pompidou Centre in Paris.
[132] Marie-Ange Brayer is the director of the Centre for Regional Contemporary Art (FRAC) in Orleans, France.
[133] *See* http://www.archilab.org/.

featured in 'Digital Real' (Cachola Schmal 2001) allowed and encouraged architects to experiment with form as the primary generator for architecture. However, in the case of the NMA and the GMB, the primary generator was not the ability to make abstract shapes, it was the underlying understanding of context both physical and cultural, which provided the impetus for the strong, aesthetically complex, buildings to be realised.

> Blobmeisters use software the way modernists used structure: as a springboard for form …. These are visions of an architecture that reprise similar dreams in earlier periods (eg. In the late 1960s and early 1970s); the realisation has, however, only become possible today (Cachola Schmal 2001 p.1).

Architectural Movements which rely on a non-architectural philosophical underpinning are likely to leave a legacy of both successful and less successful buildings behind. "*The Blob*[135]*, the now ubiquitous, computer-calculated, infinitely variable architectural figure that has become the leitmotif*[136] *for a generation of digitally savvy architects*" (Cachola Schmal 2001 p.3).

Without any constraints form generation could degenerate into formless blobs. Therefore there needs to be a *parti* or starting point. One area of inspiration which has been used to inform highly complex geometric forms is the area of new science. As Lars Spuybroek[137] asserts "*if you don't have constraints you just freeze, there are just too many options*" (2006 p.45). To counter this paralysis caused by infinite possibilities, some architects have advocated a generative or rule-based approach to form generation.

As Kolarevic posits "*digital media is increasingly being used not as a representational tool for visualisation but as a generative tool for the derivation of form and its transformation*" (Kolarevic 2001 p.13). This radical direction is also advanced by architects such as Spuybroek, Karl Chu[138] and Toyo Ito[139], who all advocate letting the computer generate designs based on a set of user

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[134] The term Blobmeister is used to describe architects who use computer technologies as a metaphor to design. Blobmeister architects use computer software the same way modernists used structure for form.

[135] A Computer generated isomorphic polysurface, or Blob.

[136] A leitmotif (also spelled leitmotiv) is a recurring theme. A Leitmotif can help to bind a work together into a coherent whole.

[137] Lars Spuybroek is a principal of NOX Architecture and a professor at Delph University, Netherlands.

[138] Karl Chu is an architect and theoretician and is founder and principal of X Kavya research studio, California, USA.

[139] Toyo Ito is an honorary visiting professor at the University of North London and Columbia University as well as being a principal of Toyo Ito & Associates, Architects, Japan.

defined parameters. This work can be seen in Migayrou and Brayer (2001), and Steele (2001).

The intuitiveness of the designer and the ability to move from an idea to a data model plays a pivotal role in the production of architecture, as asserted by William Mitchell (2003). The interface (in both hardware and software terms) between the designer's mind and the data has become increasingly intuitive during the past decade. Consequently this has enabled the production of increasingly novel and intricate designs. One such interface is the illuminating clay system pioneered by Hiroshi Ishii. Mitchell describes Ishii's work at the MIT Media Laboratory.

> Hiroshi Ishii and his group at the MIT media laboratory, allows a designer to work directly with a clay model while retaining a real-time connection to computational capabilities. As the clay model takes shape under the designer's hands, a three dimensional laser scanner captures a corresponding digital model on the fly (Mitchell 2003 p.9).

This example given by William Mitchell of a real time artefact to file transfer technology represents the potential for an enormous shift in the way architects perceive and generate their designs. Currently this is the high watermark of the continuing endeavour to generate electronic data from a physical form. Prior to this work, a similar outcome could only be achieved in a much less seamless manner using the FARGO Arm (LeCuyer 1995).

Jencks''[140] 'Architecture of the Jumping Universe' (1997), describes how advances in technology drive a practical view of architecture informed by technology. Consequently this flux has also been the subject of more systematic studies of computer use. For example, Eisenman used a 2D form extruded along a path defined by a Möbius strip to form a complex geometric 3D form for the Max Reinhardt Haus, Berlin, Germany 1994 (unbuilt project) (Jodidio 1993; Novitski 1994; Galofaro 1999).

Jencks is involved in a debate regarding the next dominant architectural paradigm which he believes will be scientific, emanating from the interface between chaos and order (emergent theory) (Jencks 1997). Both Eisenman and Jencks believe in the potential of a yet unformulated 'second law of thermodynamics[141]' which, if proven, would change scientific theory profoundly

[140] Charles Jencks is an architectural theorist and historian and author.

[141] The second law of thermodynamics states energy spontaneously tends to flow only from being concentrated in one place to becoming diffused or dispersed, *See* http://www.secondlaw.com/two.html.

and thus inform architecture accordingly. For Jencks, complexity is inherently linked to *new science* (Jencks 1997).

> Illuminated by the computer, this new world view is paralleled by changes now occurring in architecture. Several key buildings show its promise -- those by Americans Frank Gehry, Peter Eisenman, and Daniel Libeskind. …..These architects, as well as those that flirted with Deconstruction -- Hadid, Moss, and Morphosis -- look set to take on the philosophy. In Australia, ARM (Ashton Raggatt MacDougall) has been mining the territory for many years and another group, LAB, is completing a seminal work of the new movement, Melbourne's Federation Square. Soon there will be enough buildings to see if all this is more than a fashion, or change of style, but it certainly is the latter.…….the goals of the new paradigm are wider than the science and politics that supports it, or the computer that allows it to be conceived and built economically (Jencks 2003 p.78).

The connection Jencks makes between the computer and complexity is sound at an abstract theoretical level. However, it is usually the practical connections that impact on built architecture.

The actual interface for form generation has also been the subject of some inquiry, especially as to the equipment used to achieve digitisation of a physical model. One example is LeCuyer[142] when she details the use of a high tolerance measurement tool used in medical industry imaging (1995). The most prominent of these measurement tools was the FAGO arm which was originally developed as the first step in a process which mapped the orthopaedics of a human body to enable a dimensionally accurate 3-dimensional artefact to be produced. This artefact in turn could be used by surgeons to practice difficult or unfamiliar procedures. This process has become widely known as reverse engineering (Kolarevic 2003a) and has been used by several academic institutions such as the Royal Melbourne Institute of Technology’s Spatial Information Architecture Laboratory (SIAL). In short, reverse engineering takes a non-computer generated artefact and produces a coherent 3D data model from it.

Asymptote, the architects of the Yokohama Port Terminal, Yokohama Japan (1995) (Foreign Office Architects 2000), are a practice identified with computers in architecture (Migayrou and Brayer 2001). They assert that with the advent of computer technologies in architecture there would be a corresponding move from the simple geometric forms of traditional architecture to the fluid and capricious forms made available by the

[142] Annette Le Cuyer is Associate Professor of Architecture at the University of Michigan, architect and author who has written extensively for architectural publications.

computer's ability to document complex works. This should open up alternative visions of what architecture can be.

> Architecture is entering an age of fluidity without the ontological anchor that geometrically defined space previously supplied; it must express and create new modalities, open up possible worlds (Migayrou and Brayer 2001 p.50).

When considering some of the more eclectic examples of architectural form making Jones asserts *"These projects cannot be judged as architecture but can be seen only as novelties"* (2001 p.1). He continues when considering the output of those projects, *"Those images, some day will be as collectible as lava lamps or pet rocks. And meanwhile, the Farnsworth house will still seem contemporary…One can only hope that architecture will resist such self-trivialisation and, having discovered the form of this new paradigm, will go on the discover its performance"* (2001 p.1).

At the most sophisticated level computer technologies have redefined the way architecture is conceived. The increase in computing power has allowed some architects to generate forms previously considered undocumentable, hence unbuildable within the current frame of reference. However there remains a challenge to use these powerful new tools in a mature and sophisticated and appropriate manner rather than to be seduced by the complex modelling tools now available at the expense of less visually evocative considerations. As Abel asserts "*One can renew architecture and make it a significant activity in contemporary life only if it is fully exposed to the complexities of human affairs*" (1996a p.63).

3.2.5 Hybrid Use

'Hybrid Use' considers the use of computer technologies in architecture in ways not envisaged by the software authors and/or hardware manufacturers. At a software authoring level, the computer is too complex a tool for non-experts to shape directly. The corollary is that architecture is far too personal and complex to be understood and/or coded by software authors. Hence, there is a gap or an overlap between the thresholds; an area that allows some leading edge practices to push those thresholds and in so doing create bold and innovative architecture which advances their understanding of new ways to work, sometimes as a by-product and sometimes as the stated aim and occasionally, as in this subsection, as a hybrid of the two.

> Good architects, graphic designers, and automobile stylists, like musicians and wine makers have finely tuned sensibilities in their domains of expertise. They are sensitive to nuances and subtleties that non-experts miss, and they can pick out emergent shapes and structures that are not obvious. Varied representations, that emphasise different aspects of an evolving design, and offer different opportunities for visual and tactile engagement, are thus crucial to sophisticated understanding and exploration. This is why designers commonly switch back and forth, during the course of a design process, among two dimensional and three dimensional representations, different abstractions (such as plan and section), different scales, hard-line and soft-line, and different media….. They open up opportunities to see the project in new ways, gain new insights, prompt decision making and add information to the representation (Mitchell 2003 p.10).

This statement by William Mitchell parallels the use of the computer technologies and physical models by ARM during the NMA project.

Literature concerning the hybrid use of computer technologies in architecture features ARM extensively as subverting the traditional form of architectural computing. This use of animation software has lead some to consider the NMA as an exemplar of 3D solid modelling, especially in terms of its skin as a major identifiable element in the architecture of the NMA (Keniger 2002; Allpress 2004).

Some CAD packages are designed for the complete suite of architectural services (such as REVIT and ArchiCAD) whilst others only address a particular area. However, whilst the use of CAD has been advocated by experimental and academic architects, its use in the mainstream of architectural practice has been slower than other industry sectors.

ARM's work does have international works of similarity with the work of the Californian architect Eric Owen Moss who features extensively in Steele as the lead practitioner of what he calls "*corrupting the media*"' (2001 p.82).

The selective use of software packages to satisfy the requirements of differing stages of the project reflects ARM's philosophy of using the most appropriate tool for each stage of the project. The use of software at the NMA could be considered, using Jencks and Silver definition, as *ad hoc*. Using this definition the Spirit of Adhocism would be the most appropriate epithet to describe ARM's approach to technology. Jencks and Silver contest that adhocism is a clarifying emotion which dispenses with the hindrances of hierarchy and specialisation. This drive to deal directly with the matter at hand has led ARM to use the most expedient devices (software) to produce the desired outcome

– a drive which they described as "*a purpose immediately fulfilled*" (Jencks and Kropf 1999 p.49).

Due to the pace of advances in computer technologies, any definitive statement or article on the state of computers in architecture has a reasonably short expectation of relevance for contemporary usage. This literature however does serve as an institutional record of the milestones and expectations surrounding architectural computing. It is only with the benefit of hindsight that some literature becomes an important period specific text and not a spurious and technically obsolete piece of literature which yields no significant insight. Due to the universal nature of the computer, the future direction is substantially the province of the software industry. Facilitated by the versatile nature of computer programming, the influence software exerts over the future usage of computers in architecture far outweighs any potential impact on advances in hardware technologies.

This diversity of uses underpins many overlapping applications. These applications become increasingly convergent as a distinction between different areas of usage i.e., form generation and total architecture, and progressively become considered as conglomerate rather than individual activities. The literature shows this eventual homogeneity of usage is being increasingly underpinned by advances in interoperability. Some commentators see the advent of a universal data exchange format as the AEC sector's most overdue innovation. Despite some literature being only concerned with reasonably narrow usages, there is a view that persists that computer technologies in architecture are essential for the profession to maintain its ability to generate increasingly complex works of architecture.

3.3 Non-Traditional Procurement Methods

This section considers the literature available regarding non-traditional procurement methods in architecture. This literature on procurement methods does not consider the role of computer technologies in underpinning procurement systems. The only substantial text is the journal article 'Why Building Information Models Aren't Working Yet?' by Sanders (2004) that considers both computer technologies and procurement in architecture. He asserts as one of its main arguments that the technology must be accompanied by an underpinning set of relationships which are in step with the technologies used. As Sanders asserts,

> The key prerequisite to achieving innovations, however, is not more digital technology. It is creating new partnerships between owners, designers, and builders; developing organisational cultures and educational programs that support them; and inventing new delivery processes to leverage them (Sanders 2004 p.56).

Whilst there are no significant studies on the role on computer technologies in procurement, general purpose computing such as information technology, is often quoted as a significant factor in aiding communications. Due to the slow uptake rate of computer technologies in architecture compared to other industries (PricewaterhouseCoopers 2003) the need for a change in procurement practice to mirror the technological environment has not been as necessary as other industries. This disparity, according to David Gann[143], is because the AEC sector relies more on tradition than innovation.

> It is something of a puzzle that innovation and technical change in the construction industry have received so little attention from economists and historians. No doubt, this is partly because construction was often regarded as a 'traditional' industry of very low research intensity and characterised by considerable conservatism and resistance to technical innovation. Such industries have been generally neglected by comparison with the more glamorous and research-intensive industries such as electronics, pharmaceuticals or aerospace (Gann 2000 p.xv).

Due to the disparity of scales of building work, from domestic extensions to major infrastructure, there is a commensurate disparity in the procurement systems and complexity of projects. Tony Sidwell[144] in his review of value alignment process for project delivery argues that historically the distinction between the design and construct approach and the construction management approach are the two major paradigms for building procurement, each particularly suited to a given scale and complexity of a project.

> D&C and construction management are generally applied to fundamentally different kinds of projects. Design and construct is mainly used for small and medium sized projects using well developed designs and technologies, while management construction and construction management tend to be used on large, complex, individually designed projects often using innovative technologies (Sidwell *et al.* 2003 p.18).

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[143] David Gann is the Head of Innovation and Entrepreneurship, Imperial College, London, holding the Chair in Technology and Innovation Management, and advisor to several government and industry organisations.

[144] Professor Tony Sidwell is a senior researcher at the Queensland University of Technology, Australia.

Also adding to the complexity of the myriad of available procurement systems is the problematic acquisition of accurate data on the productivity of the AEC sector, as Gann asserts.

> Output and employment, and therefore productivity in construction, are notoriously difficult to measure. Nevertheless, data suggest that construction has failed to keep pace with performance improvements realised in other sectors (Gann 2000 p.6).

This view is supported by Scott Munter[145],

> The building and construction industry forms a critical component of the Australian economy. It is made up of a number of specialist professions and trades largely operating as separate economic units. Perceptions about efficiency vary but hard research into better ways of doing things is sparse (Munter 2000 p.13).

These complexities are compounded by the economic impact of the AEC sector on the wider national economy. This financial significance of the AEC sector is outlined by a Price Waterhouse Coopers report generated for the Australian Construction Industry Forum 2002.

> The building and construction industry is one of the five largest sectors in the Australian economy. It contributed 5.5% of GDP ($30 billion) and employed 8% of the workforce in 1999-2000. Internationally, construction is a key component of many economies, contributing between 4% and 6.5% of GDP (subject to some unavoidable measuring differences) (PricewaterhouseCoopers 2003).

They continue, describing the subsequent impact the construction industry has on the wider workforce.

> The Australian construction industry has significant linkages with other sectors, so that its impacts on the economy extend well beyond the direct contribution of construction activities. The Australian Bureau of Statistics estimates that from an initial $1 million of extra output, a possible $2.9 million in output would be generated in the economy as a whole. This would create 9 jobs in the construction industry and 37 jobs in the economy as a whole (PricewaterhouseCoopers 2003).

The Commonwealth Government saw an opportunity to advance new ways to work and to research an industry sector not known for its innovation (Cole 2003) through the lens of the NMA project. However, the building industry spans such a wide range of skills that it is not an easy task to influence such disparate groups of people and their practices.

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[145] Scott Munter is the Australian Institute of Steel Construction State Manager NSW and ACT.

Most of the literature is concerned with large scale complex projects as these projects are sufficiently nuanced to allow a rigorous academic investigation of their performances and as the lessons learnt from these investigations could facilitate substantial financial savings in future projects.

Many authors have advanced the need for major changes in the way buildings are procured. The most published amongst these voices are Mohan Kumaraswamy[146] and Derek Walker[147] (co-author of the Acton Peninsula Report). At the time of the NMA project an exhaustive review of procurement methods was undertaken as a major element in the Acton Peninsula Final Report. As such, the overwhelming majority of literature pertaining to non-traditional procurement in Australia features in Peters *et al.* Hence the review contained in this thesis seeks to supplement rather than reproduce the extensive review contained in Peters *et al.* (2002). The findings summarise that the most relevant contributions to the AEC sector in Australia are that:

> [T]he use of independent Quality and Design Integrity Panels, use of Sub-Alliances and a Project Agreement that provided specific quality drivers to the site workforce represent clear industry advances. Key areas that have contributed to the success of the project alliance include the rigorous selection process, alliance facilitation, a no-blame culture, and targeted risk-reward mechanisms that drive behaviours focused on project performance (Peters *et al.* 2002 p.10).

Peters *et al.* advance the notion of relationship-based procurement as a valuable addition to the range of procurement alternatives. This view is held throughout the international procurement community. In the United Kingdom the Egan task Force report 'Rethinking Construction' (DETR 1998) commissioned by the UK government argues that the UK construction industry should improve the scope of relationship-based procurement, and strongly advocates an increased role for partnering particularly to improve supply chain performance.

The major centre of activity for the research into building economics in Australia is the Cooperative Research Centre (CRC) for Construction Innovation (CRCCI), located at the Queensland University of Technology. Their three main research thrusts are Business and Industry Development, Sustainable Built Assets and Delivery, and Management of Built Assets. The CRCCI is a cross industry government research centre which publishes

[146] Mohan Kumaraswamy lectures and conducts research in Construction Engineering and Management at the University of Hong Kong, China.

[147] Derek Walker is a Professor at the School of Property, Construction and Project Management RMIT University and co-author of the Acton Peninsula Report.

academic works pertaining to the three areas mentioned. They were also responsible, as the umbrella group, for the Acton Peninsula Final Report.

Tony Sidwell, project leader for many of the CRC publications, asserts in a literature review on the value alignment process[148] that the Egan report (Egan 1998) formulated a framework for the construction industry that should consider an industry-wide ethos of thinking differently rather than simply making incremental improvements to the existing system. He further asserts that the Egan report correctly identified several key areas of concern to the AEC sector. These areas are supply chain development, process and management skills, and the need to cultivate long term relationships (Sidwell *et al.* 2003 p.5). This notion of long term business relationships is also featured as a key recommendation of a report by The Australian Department Industry Science and Resources (1999). This report identifies major structural impediments which it argues the industry needs to transcend if it is to compete successfully. Sidwell draws two main conclusions from this report, which are the pre-occupation of the AEC sector with short term business cycles and the effect of a project by project culture rather than an ongoing relationship between parties as the two major obstacles to construction innovation (Sidwell *et al.* 2003 p.6).

The antithesis of this short term project-by-project ethos is the notion of animating a motivated team for an ongoing engagement with project partners facilitating enduring and productive relationships. These relationships underpinned by the use of clearly defined and agreed goals have been cited previous to the NMA project as the factors that most contribute to the success of a project. These factors were formulated as a result of a 1998 survey of 34 industry leading companies using notions of a shared vision or alignment in their project delivery strategies.

> The survey identified the project delivery issues which clients agree must contribute to successful project outcomes:
>
> - Clear project goals
> - Clear definition and understanding of the project scope,
> - Clear understanding and appropriate allocation of risks,
> - Agreed risk/reward arrangement,
> - Appropriately skilled project staff, and
> - Well-defined communications through all levels of the contracting parties with proper empowerment for decision making (ACA (Australian Constructors Association) 1999).

[148] Sidwell describes value alignment as the alignment of objectives or common or shared vision.

Walker *et al.* (2000) also asserts business systems within the industry need to be redefined and to move from a short-term project culture to one that is more strategic, long term and enduring.

> Revamped selection processes can set the scene for cultural re-engineering, since it makes sense to link performance requirements to selection criteria and thereby pre-condition selectees to align themselves to towards the envisaged working culture from the outset i.e., when they are competing for selection and therefore in their informative and selective phase (Kumaraswamy *et al.* 2002 p.7).

Kumaraswamy has authored many influential papers on alternate methods of procurement and the issues that they address. Whilst he considers the Hong Kong perspective on procurement methods, he argues that the conclusions are internationally relevant and '*illustrate these generic globally applicable concepts*" (Kumaraswamy *et al.* 2002 p.4). They outline the many voices that advocate "*this transformation must be driven from within the industry by strategic changes in procurement practices and procedures*" (Kumaraswamy *et al.* 2002). They argue that whilst their research was undertaken in Hong Kong, their underlying premise that there needs to be a fundamental cultural change in the construction industry is applicable worldwide.

The use of relationship-based procurement systems is becoming increasingly popular in large scale Australian infrastructure projects such as the Awoonga and Eildon Dams, the Wartook Reservoir and the Tugun Bypass amongst others (McIntyre 2005 p.27). However, as the Australian Construction Industry Conference 2005 illustrated, despite the acceptance of the fundamental premises of relationship-based procurement, no architectural projects have employed it since its application to the NMA project (McIntyre 2005). The NMA project was the first use of project alliancing in Australian architecture and was described by Sidwell as a "*radical departure from business as usual in both delivery and outcomes for building projects*" (Sidwell *et al.* 2003 p.19).

Sidwell argues that this innovative procurement system was highly appropriate for the NMA as it benefits from a series of attributes relevant to this project. These attributes were considered to benefit projects which have a high profile, tight timelines, limited budgets, using innovative technologies and preferably advancing technology transfer between parties. He goes on to categorise the alliance process as

> fostering innovation and encouraging flexibility as the alliance requires participants to move away from their fixed roles within the project and

> to deploy expertise where it can get the best results (Sidwell *et al.* 2003 p.19).

Non-traditional procurement methods have attracted academic and industry based analysis, the most relevant and comprehensive of these texts is a detailed report on the procurement/IT aspects of the NMA prepared during its construction (see Section 3.1.1 ARM and the NMA, p.68).

Peters *et al.* have argued that a belief in an established procurement system would be the most efficient way to procure a project is no longer a safe assumption for an increased likelihood of project success.

> The general consensus supports the view that non-traditional procurement facilitates greater construction management team involvement which, if the team responds favourably, increases chances of project success (Peters *et al.* 2002 p.356).

They highlight the persistence of a view that the traditional means of procurement usually contains an unseen agenda for future extra payments due to anomalies in the documentation.

> The competition ethic which served to drive a lowest initial cost based aspiration has been viewed as being discredited (DETR 1998, Latham 1994). These reports argue that the system of obtaining a low initial cost often disguises conflicts that almost always leads to claims for additional costs and a lack of cooperation of parties to meet or exceed project objectives (Peters *et al.* 2002 p.337).

They continue,

> The fundamental premise adopted is that "contracted parties must accept the conventional wisdom that risk should be assumed by the party within whose control the risk most lies. A major function of the BOT[149] arrangement is, therefore, to recognise and provide a mechanism for the assignment and management of those risks (Peters *et al.* 2002 p.339).

Whilst this assertion remains largely unchallenged within the literature it is one element in an equation; the other elements are the goodwill and trust of the parties involved. If properly harnessed, this element can deliver outstanding

[149] Build-Operate-Transfer (BOT) is a form of project financing, wherein a private entity receives a franchise from the public sector to finance, design, construct, and operate a facility for a specified period, after which ownership is transferred back to the public sector. During the time that the project proponent operates the facility, it is allowed to charge facility users appropriate tolls, fees, rentals, and charges stated in their contract to enable the project proponent to recover its investment, and operating and maintenance expenses in the project.

outcomes (in procurement terms) based on a flawed concept of bargaining through adversarial relationships.

> [S]ome projects using the traditional system were successful and others using procurement systems more conducive to success, remain unsuccessful. Part of the answer lies in the way trust, commitment and loyalty is harnessed (Peters *et al.* 2002 p.385).

Peters *et al.* continue by furthering this line of thought when citing a move within the business community to return to less strictly defined mutual agreements "*to re-create the 'handshake' or relationship orientated way of delivering projects*" (2002 p.338).

However these more informal agreements are not seen as a panacea for procurement. Moreover, they are seen as a device to encourage trust and genuine participation for the benefit of the project as Peters *et al.* attest:

> The procurement form is largely irrelevant and that the real issue is how the procurement option enhances or inhibits team members to maximise their constructive input to achieve project goals. While the traditional approach will be argued to generally inhibit positive interaction there are many factors that affect the impact of non-traditional procurement choices (2002 p.391).

Whilst the aims of these procurement systems include the harnessing of external knowledge, there are other systems which seek to address the same benefit. Tombesi, whose research interests include design specialisation at the Disney Concert Hall LA, describes FOG&A's "request for proposals" - a system which allows for the early involvement of builders and engineers but retains the ability to open tender due to an innovative design assist agreement (Figure 56, p.121). He describes that one possible alternative for a support system for the use of computer technologies in architecture is to harness the knowledge already existing in the allied industries and use them to inform productivity gains in architecture. In 'Involving the Industry' Tombesi lays out how FOG&A used Requests for Proposals (RfP) to compensate for a discrepancy between the complexity of forms and their ability to define how the complex elements could be fabricated (2002). However it should be noted that whilst FOG&A request proposals for alternate ways to achieve the design effects, there is no significant body of opinion that asserts that the authorship of the design does not remain with Gehry.

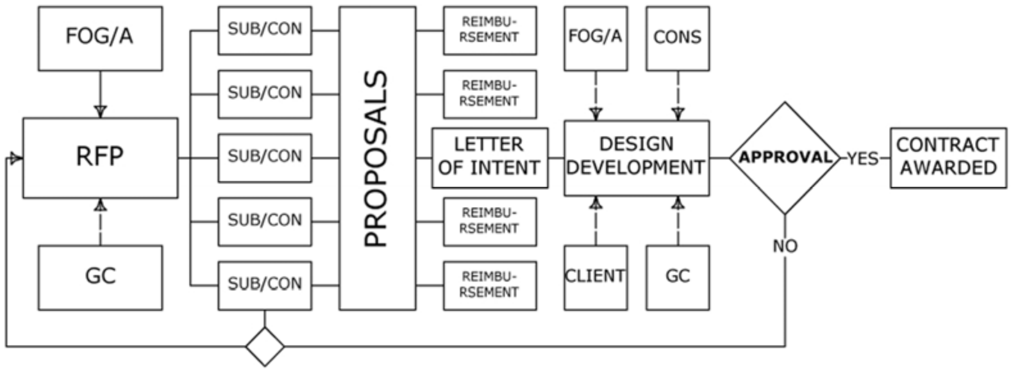

Figure 56 RFP, Flow Diagram (after Tombesi).

The concept of trust (or goodwill) between parties has been codified and consequently has been advanced as a possible rating system. The effect of such a trust rating, according to Ekström and Björnsson (2002) would allow commissioning parties an additional indicator which could be used in conjunction with the traditional tendering criteria of price and capacity to be used. Alternative methods for pre-qualifying have also been used. In 2001 the Hong Kong housing authority initiated a scheme whereby,

> [T]hey appointed six of their registered contractors to a 'premier league, based on better performance in recent projects. Contractors in the premier league would be eligible for more tendering opportunities than other contractors (Kumaraswamy *et al.* 2002 p.5)

Kumaraswamy *et al.* qualify the use of partnering as an encompassing cultural exercise as opposed to a strategically applied addition to traditional practices.

> [A]ttempts to really 'bolt on' collaborative efforts such as partnering to existing cultures on contracts have rarely succeeded, confirming the need for deeper cultural changes needed for achieving genuine win-win partnerships (Kumaraswamy *et al.* 2002 p.6)

Another approach to selection is pioneered by the Florida Department of Transportation which instituted a 'dollar value per day scored'. This system required tendering parties to divide their bids into two separate components, time and cost, which allowed a judgement based on the separate components (Herbsman 1995). These innovations in procurement have traditionally been the product of infrastructure rather than architectural projects.

Hence, the literature reflects a lack of interest in relationship-based procurement for architectural projects. However, it does reflect an ongoing debate as to the most appropriate method of procurement and a means to define them. Several articles have been published to this end, including Kashiwagi and Mayo (2001) which advocates the use of artificial intelligence to determine the most appropriate 'best value' method based on a set of project variables as detailed in a case study of improvements to school facilities in the US education system.

Al-Tabtabai (2002) argues that the most accurate and appropriate method for construction procurement can be determined by the application of what he terms 'Analytical Hierarchy Process' which allows project managers to make *pair-wise* comparisons to aid in the choice of the most appropriate procurement method.

There is a social factor in how the AEC sector in Australia is organised which has been the subject of a Royal Commission[150]. Whilst the Cole Royal Commission (Cole 2003) was mostly concerned with corruption and the entrenched interests of some, it highlighted that the building industry was also reluctant to embrace change in work practices. This view holds the building and construction industry as an industry mainly concerned with the repetitive application of known ways to work. As Peters *et al.* assert "*Clients continue to utilise traditional delivery systems which they acknowledge have shortcomings and that often lead to adversarial relationships and overruns in cost and time*" (2002 p.25). This assertion is supported by Kumaraswamy,

> Perhaps the biggest change in procurement approaches has come in the adoption of partnering relationships between all project stakeholders. The need to change the ground rules for production procurement as well as employing selection criteria that go beyond looking for the lowest bid has manifested itself in partnering, a now well recognised approach to improved project procurement and delivery based on teamworking value for money, trust, honesty and integrity – all traits commonly absent from traditional procurement (2002 p.11).

This reluctance to innovate is indicative of a world-wide phenomenon; however it has been suggested that Australia is slower than its international counterparts in embracing innovation.

> Australia in general is slower to innovate than a number of other leading countries including the United Kingdom, France, Spain, Germany and the United States. The building and construction industry globally is also slow to innovate. This research demonstrated

[150] The Cole Royal Commission (2003) was the first national review of the conduct and practices of the building engineering and construction sector in Australia. The findings demonstrated "an urgent need for structural and cultural reform" (Cole 2003 p.3).

> that the Australian building and construction industry is even slower to innovate. As a result, we believe that the Australian building and construction industry is well and truly lagging behind (PricewaterhouseCoopers 2003).

Most authors argue that the traditional procurement systems are now inappropriate. Many alternative systems have been used to address specific perceived shortcomings in the prevailing systems. Most agree that relationship-based approach to procurement is the most appropriate. Kumaraswamy asserts that non-traditional procurement systems provide "*a unique, if not golden opportunity to rethink the whole process of construction*" (Kumaraswamy *et al.* 2002 p.12).

Surprisingly since the well-publicised success of the project alliancing system used at the Acton Peninsula, a notion of alliance partnering has received less academic interest and hence is under-represented in the relevant literature. This is evidenced by the Australian Government's reluctance to recreate the Acton Peninsula alliance setup on subsequent and comparable projects. Whilst the literature on procurement systems is prolific, there is a marked deficiency in the interest shown in the type of alliance regime established at the NMA. Most of the literature is concerned with incremental improvements in traditional industry indicators of time, cost, and quality, and not on the cultural or structural reform of the AEC sector. The most feasible rationale for *business as usual* arrangements is the up side seems hopeful but the downside seems very real. Due to the complexities and the many variations that can exist within a procurement regime, the ability to quantify as many of the variables as possible is an attractive proposition. Conversely, the notion of wholesale cultural change appears as theory in the literature but due to the potential downsides is seldom reported in practice.

3.4 The Role of the Architect

This section deals with the literature which considers how computer technologies and non-traditional procurement methods impact on the role of the architect. Neither ARM nor FOG&A could be considered as producing architecture to reflect the digital revolution as this could simply define them as the makers of abstract shapes only possible in a virtual world. However, both could be seen as practices advancing an argument for a return to architect as a master builder. Both practices consider themselves as pragmatic in their approach to architecture but both are actively involved in the global debate surrounding the role of the architect. Both practices place more relevance on the application of technology to suit their needs than on advancing their profiles as technologically adept. As Steele asserts "*It is much more exciting and meaningful to participate in a revolution than to talk about it*" (Steele 2001 p.8).

In recent years some of the literature on computer technologies in architecture has documented the complex narrative of the fundamental shift in the way architects work. It has been noted by McCullough and Mitchell that any new (to architecture) software comes from people other than those who would use it:

> The result of this is an increasingly clear division of intellectual labour between the producers of software (collectors and encoders of architectural knowledge) and the users of software in execution of specific architectural projects (Mitchell and McCullough 1995 p.46).

Where there is a demarcation there is a need to categorise people or services. This phenomenon could be seen as redefining many traditional categorisations including that of the master builder. The idea of architect as the master builder is a recurring theme in the debate regarding the role of the architect as Kieren and Timberlake assert,

> Hundreds of years ago, all of architecture could be held in the intelligence of a single maker, the master builder. Part architect, part builder, part product and building engineer, and part materials scientist, the master builder integrated all the elements of architecture in a single mind, heart and hand (2004 p.xii).

Some like Kolarevic have considered how the skill set of architects have required a change in the role of the architect. He asserts how projects may influence the role by "*Providing unprecedented opportunities for the significant redefinition of the architect's role in the production of buildings*" (Kolarevic 2001 p.v). This theme is extended by Kolarevic,

> The currently separate professional realms of architecture, engineering, and construction can be integrated into a relatively seamless digital collaborative enterprise, in which architects could play a central role as information master builders, the twenty first century version of the architects medieval predecessors (2001 p.v).

He continues this line of thought when he states "*Architects have a chance to regain ground they've lost to contractors and other parties. We can overthrow traditional construction techniques, with profound consequences*" (Kolarevic in Snoonian 2002 p.1). This theme of the return of the Master Builder has been advocated by many including Glymph (Friedman 1999) and Snoonian (2002).

Glymph, a Gehry partner, asserts that the present generation of software which produces digital design information is "*necessary to re-establish the architect as a Master Builder*" (Glymph in Kolarevic 2003a), a view also held by Snoonian. "*Many technology enthusiasts believe that requiring architects and their collaborators to rely on digital design information is a necessary step toward re-establishing the architect as a master builder*" (Snoonian 2003 p.11). Technology could be seen as moving the architect towards the classical definition of the master builder. Lynn argues that Gehry's current way to work is already substantially contributing to this movement.

> I've heard Frank Gehry say that he wants to return to the ways of the master builder. He wants to be able to control my shop floor from his office. And this method of working together comes pretty darned close. The system we developed together allows more complex geometries to be developed at a more affordable price than ever before. It has permanently changed the way we do business (Greg Lynn in Kipnis 2003).

Cocke holds the belief that the return of the architect to the master builder is essential if the role of the architectural practice currently understood is to survive.

> The real issue here is whether we are going to start training architects to be builders again: to work with materials, to understand engineering. And whether we are going to be able to deal with the legal profession in terms of the appearance of risk; whether we are going to be able to deal with the standard practices that have developed over the last 40 or 50 years and be able to reverse them. If we don't, then I believe that the profession as we know it will cease to exist (Cocke 2000 p.55).

Whilst most authors have considered the re-emergence of the master builder as a product of technological advances, some like Kumaraswamy have considered the same outcome but from a project procurement perspective.

> The productive partnerships between architects and artisans, and the teamwork instilled by master builders, of previous centuries may remind us that what we seek may not really be a revolution but a 'cultural resurgence'. (Kumaraswamy *et al.* 2002)

With the increase in computer power and the commensurate ability to transform an esoteric notion into a complex geometric form, comes the attendant and problematic notion of authorship of designs. By extensively employing a metaphor based design via complex algorithms the architect cannot entirely envisage a given outcome. Hence their role within the design process becomes more an establisher of parameters and arbiter of outputs.

Steele describes one potential outcome of this interaction that "*The architect becomes a catalyser rather than a designer"* (Steele 2001 p.38). Whilst this is one potential scenario for the future role of a self-selected group of architects there is a counter-view.

This view stresses the importance of the process as increasingly becoming a more significant element in the realisation of architecture, "*The process engineer is the designer of methods*" (Kieran and Timberlake 2004 p.11) and as such is becoming integral to any future understanding of the practice of architecture. They further argue that architects have become preoccupied with the image and have missed the opportunity that other industries have taken up. As new technologies change the way buildings are designed, to take advantage of the benefits of prefabrication, so the construction traditions change to mirror this.

> Architecture built in a factory in sections that come together for the first time in the field requires new ways to control, manage, and distribute information about design and construction (Kieran and Timberlake 2004 p115).

They see the architectural community as holding an aversion to pursuing new ways to work as a matter of policy when they assert "*Architects must overcome an industry wide aversion to research and experimentation"* (2004 p.23). They continue "*Architects must forge general and project-based relations with those whom architecture has in the past avoided*" (2004 p.23). These assertions foreshadow what Kieran and Timberlake see as major changes to the role and skill set of the architect.

Architects and the wider AEC community were slower than their counterparts in other industries, such as manufacturing or aviation, to embrace the functionality offered by CAD and developed programs which were founded more on the visual and increasingly photorealistic output. Larson asserts architects seem to be more concerned with the visual impact of a design rather than its substance. The influence of computer technology on the role of certain high profile architects has also been described in less than flattering terms by Abel (1996a). He asserts that in certain cases architects have used what he considers to be architecturally unrelated methodologies to generate architectural forms and urban plan forms. He specifically cites the case of the deconstructionist technique of superimposition as used by Eisenman, Koolhaas[151] and Tschumi[152] which he considers to be an exercise in generating a mystique to replace some of the status that is lost to architecture in recent decades. He argues that the "*essentially exclusive nature of their designers' approach, which is as much determined by professional ideology and aesthetic prejudice as any logocentric practice's*" (Abel 1996a p.62). He continues by saying

> They point to a deep malaise in architecture. Unable to give up their elite status and prima donna ways, or to accept the loss of whatever influences their profession once exercised over urban form, these architects disguise their narrowing concerns by contriving sham images of complexity instead of genuine human development or dialogue (Abel 1996a p.62).

Kieran and Timberlake assert that the underlying structure of architecture is information management based which has implications for how architects perceive their role.

> All complex human endeavours, including architecture, require a regulating structure to organise the inherent chaos that underlies its making. Our regulatory structures today are information management tools, not the idealised mathematical constructs of classical architecture (2004 p.xii).

Total architecture offers a structure that requires the architect to understand a greater spectrum of disciplines than the compartmentalised architecture it replaces. Indicative of this emerging structure is the seemingly contradictory requirements of at once a greater and more detailed understanding of the process as in the issue of modular assembly. "*The irony of modular assembly is that it places a premium on a complete understanding of the whole as a prerequisite to strategies for fragmentation*" (Kieran and Timberlake 2004 p.65). These new pressures to understand a greater variety of issues is also accompanied with the client's expectation that due to advances in computer technologies the AEC sector should be able to work more efficiently.

> The new client mandate, the design and execution of architecture is increasingly subject to a new rule of economy. Architects find themselves having to increase quality and scope disproportionately to the execution cost and time consumed. Clients are demanding more for less (Kieran and Timberlake 2004 p.10).

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[151] Rem Koolhaas (b1944-), architect, and principal of the Office for Metropolitan Architecture (OMA), and Professor in Practice of Architecture and Urban Design at Harvard University's Graduate School of Design, USA.

[152] Bernard Tschumi (b1944), architect, and former Dean of Columbia University's Graduate School of Architecture, Planning and Preservation, USA.

The notion that as computerisation increases so does modularisation, is challenged by Jones-Evans. "*[C]omputerisation does not mean standardisation, rather, the opposite is clearly the case. In the big picture our increasingly globalised environment generates greater complexity, not less"* (2004 p.28).

The use of computer technologies allowed more alternative designs and alternatives within designs to be advanced and refined in a short time frame as Radford (1988) predicted and as Ian McDougall has stated "*It allows us a lot of 'what ifs'*" ([interviewed by author] 2003). These potential options and the ability to interrogate them are invaluable to a thought process which must consider many competing elements and formulating a strategy.

The most significant academic study to address the overlapping themes of technology, procurement and their effects on the architect is Min Ming Cheng's Masters Thesis titled 'Towards an Integrative Paradigm of Digitally Procured Architecture: A Case Study of Singapore's Construction 21 Initiative[153] and its Effects on Architectural Practice' (Cheng 2004). This thesis extensively used surveys and proforma interview questions to assess the influence of the Singapore Government's *Construction 21* initiative for digitally procured projects. The role of the architect is examined by Chen in terms of the rise of the professional class in Singapore:

> The rise of the professional class and evolution of the role architect as a person in charge of design and construction, and also how roles and knowledge domains of the architect and builder have shifted (Cheng 2004).

However the core of the thesis addresses Singapore's architectural traditions, its information technology policies and its effects on local architectural practices. It argues that Construction 21 does not adequately address the diversity in Singapore's building industry and differing procurement methods and IT needs are required to address this.

Architect's visions are a type of idiosyncratic collection of ideas about function, form and many intangible notions. Hence reducing that to data in the form of binary strings seems highly problematic. However, as 'Abstracting Craft' asserts the physical act of drawing uses hands to express intent through a pen (McCullough 1996). This notion that intent can be conveyed through a mechanical device can be attributed to an electronic device. It is the

[153] Construction 21 is an initiative by the Singapore Government to "be a World Class Builder in the Knowledge Age".

directness of the pen, the use of interfaces that makes the practiced hand able to convey intent (3D on a 2D surface). The interfaces between the architect and the data and the interfaces' ability to convert a subtle move of the hand to a form in virtual space has changed the way architects can transfer meaning of a form of contractually adequate data.

Glymph's assertion that advances in computer technologies will inevitably reinstate technically literate architects to the status of master builder necessarily has an air of inevitability which resonates with many who also believe in the power of the computer to fundamentally change the practice of architecture. It also makes a bold statement about how architects control the building industry. Glymph himself has said that architects are treated like children by most clients, as creative but out of touch with the realities of the construction industry (Friedman 1999). This example is indicative of a tendency to objectify only one of many factors that impact on the role of the architect.

Although Gehry has often called the computer a tool, he does use it in a way that suggests a dialogue, not just an electronic pencil as Lindsey perceives it. "*The drawing becomes not so much an act of communication, as a search for possible correspondences*" (2001 p.18). This dialogue that Gehry undertakes with computer technologies manifests itself at times through an almost adversarial process.

> … [F]or me it is that the image on the screen has no juice, there is no feeling. The computer has a way of taking all the feeling out of it. What that means is that you have got to hold it in your head and see it while you are looking at this terrible image on the screen. I find that holding that image in my head is excruciating, it is painful. You can hold it for three or four minutes. I liken it to putting your hand in the flame; you can hold it and go like this. I literally did that, I stayed on the screen until I couldn't stand it and I got up like a screaming idiot and ran and got myself a drink because it was horrible but I have to figure out how to overcome that excruciating pain of looking at that because it will be a lot quicker (Gehry in Blackwood 2000).

One of FOG&A's CATIA engineers, Rick Smith, describes the process FOG&A uses to take a hand sculpted artefact to a CATIA model and then back to a computer generated physical artefact.

> Frank will actually sculpt a physical model and then we will go and take his physical model and digitise it and build it in the computer. From that we build a physical model coming from the computer; we call that a verification model that verifies that we have captured

> Frank's design. So a lot of models that you see in this office come from the computer (Smith in Blackwood 2000).

A recurring theme of interviews with Gehry is, as he points out in 'An Architecture of Joy', the interplay between virtual and physical, which is essential in understanding the project.

> Frank will say he doesn't know about computers and he is not a user of computers but he designs without them and then uses them to build. I actually disagree with that because of all of my colleagues the person that knows the most about how to develop an architectural surface from a computer and construct them, it is Frank (Greg Lynn in Kipnis 2003 p.87).

The role of the architect cannot be reduced to a single overarching idea or Weltanschauung[154] as there are various ways of practicing architecture too numerous to adequately qualify. The options that are becoming available, especially those underpinned by advances in computer technologies, could underpin radically divergent directions for contemporary architectural practice. One possible alternative is expounded by Sanders,

> Without a strong client advocate, or an integrated approach to design and construction, BIM technologies remain difficult to leverage. It's challenging to confront the risks inherent in implementing new processes that seem to reward one party for costs and risks incurred by another. Indeed one might argue that it's easier and cheaper for our profession to continue to practice using our traditional methods (Sanders 2004 p.1).

He further advances this theory with the client's role in a possible future direction. "*As architects, we have a professional responsibility to learn how to package our services in collaboration with those who construct our designs*" (Sanders 2004 p.2).

One factor advancing technological innovation in architectural computing is the frustrations of the traditional or existing (Friedman 1999; Blackwood 2000) i.e. the reliance on descriptive geometries, in Gehry's case, the limitation in setting up a staircase at the Vitra International Manufacturing Facility and Design Museum, Weil am Rhein (Figure 49, p.64). This aesthetically, pragmatically driven direction also brought improvements to cost control and production. This journey has seen Gehry's work become less compromised as his control over the process has increased (Blackwood 2000), hence in his

[154] Weltanschauung is a German word meaning a "look onto the world". It implies a concept fundamental philosophy and epistemology and refers to a wide world perception. It refers to the framework through which an individual interprets the world and interacts in it.

opinion returning him to a more classical definition of the architect as master builder.

The importance of the client in the architect/client relationship is either underrepresented or subservient to the importance of the architect in the canon of architectural literature, yet the enlightened commissioners of architecture are pivotal to any successful project. The success of flagship projects has been particularly influenced by the client's actions. This view is supported by Larson in her comment about how clients contribute to architectural exemplars.

> Being a real architect depends on making architecture, and then depends on a crucial factor that no architect controls, unless he (or more rarely she) builds for himself. Clients – their wills, their tastes, their money – control commissions. Commissions are not only the livelihood for which architects must compete; they are what allow architectural exemplars to exist (Larson 1993 p.65).

Due to the many relationships and skills that architects must maintain and cultivate, any change to any number of these must necessarily impact to some degree on the role of the architect. However, as the third in a sequence of revolutions, the first two being agricultural and industrial, the present unfolding electronic revolution must change the conception of the architect as the controller of information to a significant degree. How architects deal with this seemingly irreversible movement at this crucial time will lay the foundations for whether architecture becomes pre-occupied with esoteric theories and the forms they generate reducing the role to essentially a generator of forms or a graphic designer of façades, or whether the opportunities presented by computer technologies would be sophisticatedly incorporated into the future role of the architect.

Rather than distancing the architect even further from the construction process, then, as some believe the abstract exercise of computing has the potential to do, Gehry believes it will finally earn the profession more respect from contractors and clients because of the accuracy in documentation, budgeting, bidding, and manufacturing, that makes it possible (Steele 2001 p.58).

> Form becomes more complex with the use of tools which allow better generation and understanding of the form imagined by architects and designers. There is no limitation upon architectural ideas with the use of the computer. The only limitation is how we can understand and use the tool. As Gehry said, "I just did not like the images of the

> computer, but as soon as I found a way to use it to build, then I connected (Osman 2001 p.340).

The hybrid use of computers in architecture can be seen at ARM's NMA. ARM selected appropriate technologies to suit the needs of the NMA project and their idiosyncratic way to work, and as such can be described as hybrid architecture. The total approach to architecture can be seen at the GMB. Both the NMA and the GMB used innovations in harnessing the complementary knowledge usually not available due to traditional non relationship-based procurement systems. There is a substantial body of literature that alludes to the re-emergence of the master builder or a re-definition of the role of the architect as a consequence of emerging technologies. There is also a substantial amount of literature that addresses the need for a more progressive procurement regime to abrogate the deleterious effects of the traditional procurement environment. The literature in both of these areas however, does not significantly overlap. Some literature which does consider the areas of commonality do so in a bounded and geographically specific manner such as Cheng (2004). No case studies have been identified which address the range of issues contained within the research questions of this thesis.

Kieren and Timberlake, Sanders, Peters *et al.*, have all alluded to the need for a range of complementary systems to facilitate the efficiencies offered by advances in computer technologies. The underlying proposition for cultural change found in the literature in broad terms supports the conclusions of this thesis.

4 Methodology

This chapter reviews the research methodology used in this thesis. It analyses the various methodologies available to determine the most appropriate to answer the research questions.

4.1 Theory

When undertaking research it is essential that an appropriate methodology is selected in accordance with a pre-defined set of criteria which are then consistently applied. This is to produce a worthwhile and reliable outcome and to justify the resources expended. The choice of a methodology is necessarily determined by the phenomenon it seeks to investigate, the access it needs to raw data, and the suitability of the researcher to it. Hence an investigation of the various methodologies to determine the most suitable is necessary.

In broad terms, research methodologies can be categorised as either quantitative or qualitative (Patton 2002). Quantitative methodologies seek the *facts*[155] or *causes* of phenomena. These methodological approaches traditionally return data which is expressed numerically and relies on standardized, structured data collection. These methodologies are best suited to research that has high percentages of data that can be analysed statistically from numerically ordered sets of raw data. They seek to eliminate bias in the collection of data by employing highly structured regimes, consistently applied. Consequently, devices such as surveys and closed-ended interviews are used to capture structured data which can then be manually, or (more usually) computer compiled and analysed.

Qualitative methodologies seek to understand a phenomenon without a pre-existing hypothetical statement or proposition (hypothesis) (Strauss and Corbin 1998). These methodologies are most appropriate to research which is premised on one, or a series of, research questions in preference to a strict, and necessarily limiting, hypothesis[156]. These research methodologies are

[155] A fact is something demonstrated to exist or known to have existed. Fact is a relative term, usually used in particular fields of science. The establishment of facts is used to qualify a variable or unknown into a known and reliable element.

[156] A hypothesis based study can be undertaken using qualitative methodologies.

most often applied in social studies e.g. anthropology[157] where there is insufficient numerical data to analyse or inadequate infrastructure to apply a quantitative research methodology. These methodologies are most appropriate when dealing with equivocal research topics which consequently allow a theory to emerge from the phenomenon itself in preference to testing a predetermined hypothesis. Qualitative methods have traditionally relied on data collection techniques such as observation, open-ended interviews, and document review. A concise comparison of quantitative and qualitative methodologies is offered by Robert Yin[158].

> A quantitative research methodology is appropriate where quantifiable measures of variables of interest are possible, where hypotheses can be formulated and tested, and inferences drawn from samples to populations. Qualitative methods, on the other hand, are appropriate when the phenomena under study are complex, are social in nature, and do not lend themselves to quantification (Yin 1994 p. 76).

Due to the scope of, and interplay between the research questions, a methodological perspective that allowed for a theme to emerge from the fieldwork was considered the most appropriate within the constraints of the study. Identification of which qualitative approach was best suited for the research questions posed in this thesis was required.

Both quantitative methodologies and qualitative methodologies have internal divisions which are applied for particular uses. Within qualitative methodologies there are a number of divisions or perspectives which are based upon different disciplinary roots. These perspectives seek to address different central questions, as listed by Patton (Table 2, p. 136).

Perspective	**Disciplinary Roots**	**Central Questions**
Ethnography	Anthropology	What is the culture of this group of people?

[157] Anthropology is the study of human beings as they socialise (Greek "Anthropos-" means "human", and "-logy" means "study of"). It is a discipline that aids in the understanding of similarities and differences between groups of humans to determine a culture.

[158] Robert Yin is the Principal Investigator for the COSMOS Corporation. He has a Ph.D. in brain and cognitive sciences (MIT), and is a visiting scholar at the US general accounting office and a committee member of the national academy of sciences (US).

Autoethnography	Literary Arts	How does my own experience of this culture connect with and offer insights about this culture, situation, event, and/or way of life?
Reality Testing: Positivist and Realist Approaches	Philosophy, Social Sciences and Evaluation	What's really going on in the real world? What can we establish with some degree of certainty? What are plausible explanations for verifiable patterns? How can we study a phenomenon so that our findings correspond, as much as possible, to the real world?
Constructionism / Constructivism	Sociology	How have the people in this setting constructed reality? What are their reported perceptions, "truths", explanations, beliefs, and world view? What are the consequences of their constructions for their behaviours and for those with whom they interact?
Phenomenology	Philosophy	What is the meaning, structure, and essences of the lived experience of this phenomenon for this person or group of people?
Heuristic Inquiry	Humanistic Psychology	What is my experience of this phenomenon and the essential experience of others who also experience this phenomenon intensely?
Ethno-Methodology	Sociology	How do people make sense of their everyday activities so as to behave in socially acceptable ways?
Symbolic Interaction	Social Psychology	What common set of symbols and understandings has emerged to give meaning to people's interactions?
Semiotics	Linguistics	How do signs (words, symbols) carry and convey meaning in particular contexts?

Hermeneutics	Linguistics, Philosophy, Literary Criticism, Theology	What are the conditions under which a human act took place or a product was produced that makes it possible to interpret its meanings?
Narratology / Narrative Analysis	Social Sciences (interpretive): Literary Criticism, Literary Non-Fiction	What does this narrative or story reveal about the person and the world from which it came? How can this narrative be interpreted to understand and illuminate the life and culture that created it?
Ecological Psychology	Ecology, Psychology	How do individuals attempt to accomplish their goals through specific behaviours in specific environments?
Systems Theory	Interdisciplinary	How and why does this system as a whole function as it does?
Chaos Theory: Nonlinear Dynamics	Theoretical Physics, Natural Sciences	What is the underlying order, if any, of disorderly phenomenon?
Grounded Theory	Social Sciences, Methodology	What theory emerges from systematic comparative analysis and is grounded in fieldwork so as to explain what has been and is observed?
Orientational: Feminist Inquiry, Critical Theory, Queer Theory	Ideologies: Political, Cultural and Economic	How is X's perspective manifest in this?

Table 2 Traditions in Qualitative Methodology (Patton 2002 p.132).

The methodology selected from qualitative perspectives needed to be appropriate to the rich set of opportunities available. Within this spectrum of alternative qualitative research perspectives, grounded theory offers the most appropriate method to answer the types of research questions posited by this thesis.

Grounded theory is an overarching research paradigm under which many research strategies can be employed, as clarified by Patton, "*Let me be clear.*

Grounded theory is a general method. It can be used on any data or combination of data" (2002 p.127).

The dynamic nature of research responsive methodologies (including grounded theory) is now becoming widely accepted as an established and reliable method by the research community, as Patton states.

> Many researchers today advocate a "paradigm of choices" that seeks methodological appropriateness as the primary criterion for judging methodological quality. This will allow for situational responsiveness that strict adherence to one paradigm or another will not (2002 p.30).

Grounded theory allows the research to be conducted in its natural setting and hence to be more responsive to lines of inquiry that reveal themselves as a study progresses. This strategy allows for insights, which are not apparent in a quantitative study which limited the lines of inquiry to a numeric value.

The treatment of data is also a fundamental difference between quantitative and qualitative methodologies, as Grant McCracken describes,

> The most striking difference between the methods is the way in which each tradition treats its analytic categories. The quantitative goal is to isolate and define categories as precisely as possible before the study is undertaken, and then to determine, again with great precision, the relationship between them. The qualitative goal, on the other hand, is often to isolate and define categories during the process of research. The qualitative investigator expects the nature and definition of analytic categories to change in the course of a project (1988 p.16).

The responsive nature of grounded theory facilitates open-ended investigations. Therefore a limiting device or strategy must accompany a grounded theory study. Hence, a study could be open-ended, in methodological terms, but constrained within the time and resources available. Within a qualitative framework a single project or case study is well suited to open-ended devices used by grounded theory.

Case study is a strategy or approach within a methodology which is appropriate to a real life situation with all the complex interactions and disparate types of evidence that are generated. Yin concisely describes the applicability of case studies to the following scenarios,

> a) investigates a contemporary phenomenon within its real-life context; when b) the boundaries between phenomenon and context are not evident; and in which c) multiple sources of evidence are used (1994 p.23).

Disparities in the types of data available required the identification of a strategy which allowed a meaningful interplay between the issues. Any particular single strategy would obscure either the wealth of published and broadcast material or conversely the rich insights revealed by those involved in the study. A building project provides a bounded vehicle for a grounded theory study. The National Museum of Australia (NMA) provides such an appropriate vehicle for an inquiry. The case study project provides a rich and complex set of interactions and events due to its innovations in both data exchange and non-traditional procurement system. Hence a way to use all the various types of data generated by the NMA project and the subsequent interviews was required.

Mixed method research is a strategy employed to include the widest relevant types of data into a study. A multi-method strategy was the most appropriate for the various types of data generated at the NMA. The strategies of mixed method are best described by Brewer and Hunter when they address the need for research methods to *exploit* the opportunities presented by more than one type of data.

> To exploit these opportunities, the myriad of research problems, we must develop more cosmopolitan research strategies. What is needed are approaches that systematically explore the new avenues of research that methodological diversity affords, multi-method research is one such approach (1989 p.13).

They continue by listing the benefits of a multi-method approach,

> A multi-method approach allows the researcher to:
> - Deal with the disparities in the types of data, i.e. primary interview data and secondary published data as well as artefact study, and to
> - Allow for an easier flow of theory building within the individual themes (Brewer and Hunter 1989 p.45).

The multi-method strategy was employed to gain insight from both published and personally obtained data. Although a multi-method strategy was employed for this research, the primary (and most relied upon) source of data was the open-ended interview, which offered expert insights to the NMA which could not have been achieved without an interactive source of data. A balance of contemporary and historical evidence was used. However, the contemporary component (interview) of the data outweighed the historical part. McCracken describes the interview as the main and most important device for directed interactive feedback.

> The interview is, in effect, the third source of information at the investigator's disposal. The literature review and the cultural review begin the search for categories and relationships. But, plainly, it is the interview itself that is the most important opportunity to pursue this search. It is also the most challenging. The respondent encounters salient data in the midst of a very crowded and complicated speech event. There is virtually no opportunity for unhurried identification or reflection. There is also the pressing knowledge that this opportunity will never come again and what the investigator does not capture in the moment will be lost forever (1988 p.38).

He also outlines opportunities only available from the unique perspective of the interviewee.

> The long interview is one of the most powerful methods in the qualitative armoury. For certain descriptive and analytic purposes, no instrument of inquiry is more revealing. The method can take us into the mental world of the individual, to glimpse the categories and logic by which he or she sees the world. It can also take us into the lifeworld of the individual, to see the content and pattern of daily experience (McCracken 1988 p.9).

As the researcher is the main instrument of investigation, the various traditions, strategies and tactics involved in qualitative methodologies acknowledge a potential for bias in a necessarily idiosyncratic process. Bias is the tendencies of the researcher towards an idea of concept without the required supporting evidence. As Yin suggests when considering the impact of biases, they should be "*a virtue to be nurtured not a prejudice that distorts*" (1994 p. 32). If this bias is acknowledged and understood, and an appropriate set of techniques are applied, it can provide an enhanced clarity of vision, as vision is necessarily idiosyncratic. This vision is central to grounded theory, as Strauss and Corbin (1998) discuss,

> [T]he importance of this methodology is that it provides a sense of vision, where it is that the analyst wants to go with the research. The techniques and procedures (method), on the other hand, furnish the needs for bringing that vision into reality (p.8).

As the outcomes of a case study will be unique to the setting and people involved in it, the repeatability of the methods is of central importance. It was therefore necessary that the conduct of the case study be in accordance with the strategic design to ensure the repeatability of the method is maintained. Hence it is vital that the collector, coder and analyser of the data is consistent with the application of the methodology.

For a myriad of reasons, research is undertaken by a researcher with a particular affinity with that methodology. The reason for this phenomenon pertains in varying amounts to experience, tradition, judgement, pride and perhaps apathy. Also there are potential consequences related to the biases acquired from previous experience, as outlined by Liebscher.

> [T]here is a strong tendency in all fields of social science for particular methods to be valued so highly by their users that they become ends in themselves to be defended against rival methods and nourished by selecting only research problems for which they are well-suited (1998 p. 669).

The recognition and understanding of bias can be considered a positive attribute, as grounded theory is in part premised on the notion that the interviewee gives their voice via grounded theory techniques. This voice can inform the categories/codes that the data is sorted into, which in turn informs the emerging theory. This premise of theory building from the issues raised utilises the interviewee's insights and hence relies on an objective recognition of the interviewee's voice from within the data.

> In qualitative research, objectivity does not mean controlling the variables. Rather, it means openness, a willingness to listen and to "give voice" to respondents, be they individuals or organisations. It means hearing what others have to say, seeing what they do and representing these as accurately as possible. It means having an understanding or recognising that researchers' understandings often are based on the values, culture, training and experiences that they bring to the research situations (Strauss and Corbin 1998 p.43).

In short, it relies on personal and professional insights as the primary means to generate data. This voice is best heard when there are open-ended questions, loosely directed. These directions should be legible to both the interviewee and interviewer, as Gillham describes.

> The use of 'open' questions doesn't mean that you have no control over the way the interviewee responds. Indeed, your (unobtrusive) control is essential if you are going to achieve your research aims, i.e. you need to 'steer' for the direction and also ensure that key points or topics are covered (2000 p.45).

The quasi-unstructured mode of the open-ended interview necessarily required a definite end point. When assessing where to conclude research interviews the following assertion by Strauss and Corbin (1998) provides the most consistent definition,

> Within the limits of available time and money that the researcher finds that no new data are being unearthed. Any new data would only add, in a minor way, to the many variations of major patterns (P.28).

The raw data (verbatim transcripts) that resulted from the interviews requires a systematic and reliable method or device to sort it into categories denoted by thematic codes. Coding is a device used to sort fragmented but interwoven concepts into an ordered set of categories.

The purpose of categorising and coding data is to allow built theories from themes embedded in the raw data which can be woven or reconstructed into a theory grounded in the fieldwork as Glaser states.

> The purpose of coding is to move from having a set of data to developing a theory. It is to get 'the analyst off the empirical level by fracturing the data, then conceptually grouping it into codes that then become the theory which explains what is happening in the data' (1978 p.55).

This initial coding of data can be seen as the '*fracturing of data into analytic pieces which can then be raised to conceptual level' (Glaser 1978 p.55)*. In developing categories and assigning codes, a qualitative analyst must initially address the challenge of convergence. The subtleties within the data must be identified and ordered by a coding device before deciding how the coded themes combine, and what narratives unfold. This is achieved by examining the data for recurring regularities. These regularities reveal patterns that can be sorted into relevant categories. These categories can then be judged by the criteria of internal and external homogeneity which develop conceptual codes. The identification of a conceptual code is the essential relationship between data and grounded theory. Glaser outlines the process, "in *developing a hypothetical relationships between conceptual codes which have been generated from the data, we "discover" a grounded theory"* '(1978 p.55).

Qualitative research relies upon the researcher to collect, code, and analyse data in a consistent and appropriate manner. An advantage of grounded theory is that "*it offers a framework, a set of coded procedures to help provide some standardisation and rigour*" (Patton 2002 p.127). Patton also contends that verbatim transcripts are "*Undigested complexities of reality*" (p.463), and "*Simplifying; making sense out of that complexity constitutes the challenge of content analysis"* (p.463). He further asserts that *"Developing some manageable classification or coding scheme is the first step of analysis*" (p.463) and will illuminate the theory.

The analysis of data relies on a process of comparative testing between available categories or specifically generated ones. This process of testing informs the categories/coding which is then used to build, not test, theories. As Patton asserts, "*Grounded theory is meant to build theory rather than test it. It strives to provide researchers with analytical tools for handling masses of raw data*" (2002 p.127).

The timing of the coding and the continuing collection of data is also an issue. Coding starts when data collection begins, and the analyst should not be delayed by data collection. This is necessary as the results of initial coding influence the collection of further data. The choice of coding method is reliant on many factors. These factors include the context specific knowledge of the coder and analyser of this data and the amount of raw data to be coded, as they both affect the choice of coding method. Due to the multi-thematic approach and the technical nature of some of the expected responses, a manual coding procedure was used. An alternative method is via computer aided coding eg. software packages like NUDIST[159]. These packages analyse strings of text for recurring themes (defined by the juxtaposition of ASCII[160] sequences). These software driven processes may not be able to distinguish a subtlety of meaning in a turn of phrase or the specific context or inflection given to a specific word. This assertion is supported by Joseph Wiesenbaum's[161] work in artificial intelligence in his text on 'Computer Power and Human Reason'. One of his major contentions to the study of artificial intelligence concerns the computer's inability to understand an evolving context. This, according, to Wiesenbaum and others (Dreyfus *et al.* 2000) should consequently limit computer processing to sorting information according to a known quantifiable and rigidly defined contexts. Also, if the amount of raw data (predominantly interview transcripts) is of a manageable size for the allocated time a manual system of coding provides a more contextualised and sensitive outcome.

[159] NUD*IST is a software system for qualitative data analysis. It is used for handling Non numerical Unstructured Data (now known as N6) by processes of Indexing Searching. *See* http://www.qsrinternational.com.

[160] ASCII codes (**A**merican **S**tandard **C**ode for **I**nformation **I**nterchange) are character sets used by computers to represent a letter, number or symbol in a character set or language. It could be argued that computer sorted codes are an abstract of an already abstracted idea.

[161] Joseph Wiesenbaum, formerly Professor of Computing at MIT and is considered a pioneer in the field of Artificial Intelligence.

4.2 Instrumental

This section details the application of the methodology discussed in the previous section of this chapter. It characterises the particular events and describes how the research was conducted.

The initial research question of this thesis, informed from the original literature review, was how the re-framing of the design/construction relationship was redefining the architect in the classical tradition of leading builder, or arkitektōn[162]. This is a proposition argued by many contemporary authors including Glymph (in Friedman 1999), Snoonian (2002), Mitchell (2003) and Kolarevic (2003a). This initial direction led to subsequent reflections on the nature of technology and architecture. These reflections set a direction guided by technology and procurement issues, which become the most prominent and repeated theme of the early research. The nature of the evolving and intersecting phenomena posed many subsequent questions prompted by the ongoing literature review process and the first interviews. The following represents the chronology of relevant questions prompted by the initial investigations.

As the literature review and early interviews progressed, the research questions coalesced in varying degrees to form questions about technology and its uses and the impact of various uses of procurement in architecture and their effect on the role of the architect. As these many variations shaped the lines of reasoning patterns began to occur. These patterns illuminate a multiplicity of external factors which impact upon both the NMA and the GMB. The social, political, financial and technological implications on architecture and especially the NMA led to the conclusion that the most important contribution that this thesis could make to this field of knowledge was an examination of the symbiosis of computer technology, non-traditional procurement methods, and its effects on the role of the architect. This rationale underpinned the research questions restated here,

1. What relationships were facilitated by the procurement method used at the National Museum of Australia?
2. What connections exist between procurement methods and the computer technologies that were used on that project?

[162] Architect from the Greek arkitectōn; arkhi – archi + tektōn – builder, leader builder or prime maker.

3. What lessons are to be drawn from this experience for contemporary architectural practice in Australia?

The blurring of the distinction between phenomenon and context, as it can be seen in the NMA project, makes the case study the most appropriate way to engage the research question. A building project is a necessarily bounded or single setting, as Huberman and Miles state, "*The case study is a research strategy which focuses on understanding the dynamics present within single settings*" (2002 p.8). The NMA project fulfilled the requirements for a bounded, completed, significant, accessible and recent project.

As previously stated, grounded theory research allows for (and if applied correctly requires) changes in focus during the course of the study. Hence a study is based upon a series of questions which are designed to tease out possible but unidentified issues or themes which suit the research questions and the researcher. The necessary characteristics of a grounded theorist are:

- The ability to step back and critically analyse situations
- The ability to recognise the tendency towards bias
- The ability to think abstractly
- The ability to be flexible and open to helpful criticism
- Sensitivity to the words and actions of the respondents
- A sense of absorption and devotion to the work process (Strauss and Corbin 1998 p7).

The nature of personal bias requires a personal statement to contextualise the way the methodology was chosen and applied. As someone who believes in Cartesian common sense[163] I have approached this study pragmatically but with an open mind to what would emerge from the data. I do not, or have not, during this research believed that matters involving human beings can be explained in absolute truths, binary logic, or simple mathematically represented forms. In short, the type of questions that interested me (the intersection of people and technologies) could not be adequately addressed by a quantitative study.

Before my interest in architecture, my chosen profession was as an electrical/electronic engineer. My tertiary education was in science and engineering rather than in the humanities. As such I was aware of my tendency to measure things and reduce data to discrete mathematical forms. My tendencies were towards a method that could quantify a phenomenon and distil its essences. In addition my dyslexia also inclined me towards a method

[163] Cartesian common sense can be read as common sense or a commonly held belief based on a shared experience.

that required less text based information. The most appropriate method for answering the question I was interested in required a significant amount of text-based material. However the chosen method of interviews conducted under grounded theory did not rely on a study based exclusively on secondary literature. Therefore the drive to find out how people and technology interact at the NMA outweighed my predisposition towards quantitative research.

The NMA project offered a case study which had the desired mix of technological innovation and rich context and interaction made possible by the nature of the procurement system. Having identified the NMA project, access needed to be negotiated to the data and the people that had shaped and used it. In negotiating access approaches were made to ARM after an initial e-mail contact was made by someone known to one of ARM's partners and the researcher. This led to ARM making a considered decision[164] to provide access to primary data and to the architects most closely involved in the NMA project. Their involvement was also invaluable in gaining the cooperation of others involved in the NMA project, who also generously made themselves available for interview.

ARM also allowed access to the computer network and archival data files. ARM allowed access to both physical (photocopies of paper documents) and data files (including CAD files) with minimal restriction[165]. As this data was in easily reproducible form the researcher could examine the data outside ARM's office. This allowed a more intimate and lengthy engagement with the archival data.

As discussed in the previous section, open ended interviews were the primary device used to collect data. A detailed list of the interviewees and their roles in the NMA project can be found in Table 3 (p.146). However, a researcher should be informed by the physical context of the case study. Hence a personal study of the architecture and other related artefacts was undertaken. Consequently visits were made to the GMB in September 2003 and the NMA in June 2002 and May 2003. Also visits were made to the interviewee's offices or places of work in June 2002, October 2002, January 2003, May 2003, June 2003 and July 2004 (Table 3, p.146).

[164] There was a request for ARM's involvement with the study was granted after a debate amongst ARM which concluded they would support the research by providing access to people and archive files.

[165] A form documenting the documents and files taken was required to be completed before ARM would release them.

First Name	Last Name	Company	Role	Location	Interview Date
Simon	Shiel	ARM	Project Architect	Melbourne	20-Jun-02
Ken	Bool	ARM	Project Architect	Melbourne	20-Jun-02
Howard	Raggatt	ARM	Design Architect	Melbourne	8-Oct-02
Stephen	Ashton	ARM	Senior Project Architect	Melbourne	30-Jan-03
Simon	Shiel	ARM	Project Architect	Melbourne	10-Oct-02
Ian	McDougall	ARM	ARM Partner	Melbourne	31-Jan-03
Ian	Godfrey	Go-Strategies	Former IAI Chairman (Australasia)	Melbourne	29-Jan-03
Craddock	Morton	DCITA	Client Representative / DCITA Manager	Canberra	22-May-03
Bruce	Henry	DCITA	Client Technical Manager	Canberra	22-May-03
Dawn	Casey	NMA	DCITA Manager / NMA Director	Canberra	22-May-03
Peter	Wright	Construction Control	Project Manager	Queanbeyan	23-May-03
John	Mitchell	Graphisoft	IAI Chairman (Australasia)	London	Oct-03
Michael	Keniger	University of Queensland	Panel Chair (Design Integrity / Independent Quality Panels)	Adelaide	11-July-04

Table 3 List of Interviewees.

As the interview was the primary technique used for data gathering, research into the most appropriate and effective conduct of an interview was undertaken. The most utilised texts in this area were 'The Research Interview' by Gillham (2000) and 'The Long Interview' by McCracken (1988), both of which provided valuable insights into the nuances in preparation for, and conduct of the interviews.

A code of ethics was formulated (which was based upon a template supplied by an experienced qualitative researcher). This code of ethics was then provided to all parties at the beginning of each interview. Appendix C is a duplicate of the Code of Ethics given to the interviewees. Due to the amount of personalised data required for the Code of Ethics, Appendix C shows the merge template including generic placeholders, shown as << >>, that referenced database entries used to personalise them. There were no variations in the text on the code of ethics except for the personal information (names, dates) of those who took part in this study. The code of ethics was supplied to allay any concerns the interviewee(s) may have had about access to the data.

As previously stated, the role of an interviewer requires a professional, and perceived to be professional, demeanour, which is integral to the reliability of the outcomes. As such, consideration was given to both personal appearance and behaviour. A professional approach was taken to attire and deportment. Also, an understanding of technical competencies and interpersonal relationships which were to develop during the interviews was considered.

Due to the time constraints of the interview a concise and complete summary of the research and its aims were stated. The interviewees were informed that the researcher/interviewer was a graduate student in architecture as well as being a graduate of architecture. This was done so that the interviewees could tailor their answers to a level of perceived mutual competency. This understanding of a shared frame of reference was established to facilitate a conversation between contemporaries. This had the effect of creating an atmosphere where the interviewee felt little or no need to dilute explanations of technical aspects of their answers, or to omit or explain theories of architecture *at large*[166], which may have used the interviewee's time in an unproductive or remedial manner.

[166] 'At large' denotes concepts or architectural precedence that are common to those with a formal architectural education and hence considered shared knowledge between the interviewer and interviewee.

The selection of interviewees was guided initially by the literature available on the design team. The major source for this was Peters *et al*. (2002). A secondary list was generated based on recommendations from interviewees. For example, the design architect for the NMA, Howard Raggatt, suggested speaking to Simon Shiel, one of the architects involved in the design development and much of the computer aided design elements of the project. Raggatt also suggested Ken Bool, the architect who had spent most time on site and was described in the literature as the project architect and a manager for ARM at the NMA. An additional list of technical experience was compiled to address some of the specific technical information furnished by ARM during the interviews. Whilst not directly involved in the NMA project, the current and previous chairmen of the IAI (Australasia) were interviewed. Both were also cited in Radford (1988) as pioneers of CAD use in Australia. This allowed an overview of best practice in architectural computing and some historical perspective on current and possible future computer usage within architecture. The interviews contained generic points common to all, in addition to a more detailed dialogue which allowed a better perspective on some issues with which the interviewees were more involved.

For example, Stephen Ashton, who was the only member of ARM to sit on the alliance board, was interviewed in part for his perspective of the pragmatics of the museum's construction and the new opportunities made available by the alliance structure. A valuable insight was gained from the differences between his judgements and recollections about the process, and those of the others on the design team.

During each interview, normally between the mid-point and the end, once the interviewee had a clearer understanding of the research direction the question was asked, "Who else do you recommend I speak to, and why, to further my understanding of the NMA project?" Contacts were made following specific answers to questions by the interviewer, about which other members of the alliance partners should be interviewed and why their insights may be relevant. This yielded a much greater understanding by the interviewer of the role of those who were most involved in the project and how important their contribution was considered.

A timetable was set, as far as practicable, for the interviews at specific intervals, far enough apart to allow a review of the interview transcripts for emerging codes to be identified before the next interview. This was undertaken so that any points that needed to be clarified could be noted and raised for further discussion as necessary.

The interviews were arranged to build upon emerging themes. The only potential interviewees who were not interviewed were the structural and service engineers. Several attempts were made to contact the specified engineers. Neither the structural nor mechanical/service engineer responded to attempts to arrange an interview with the named person or an alternate interviewee nominated by their companies[167]. The decision to continue without their input was made although every practicable attempt was made to verify they were the people recommended and the correct contact details used; it is possible that they simply never received the request or were unable or unwilling to be involved in this study. However, as no formal or informal correspondence or contact was made, there was no way to determine the reason why.

Each interview started with a series of identical questions that included the question "do you want to see the printed transcript or be sent a copy of the audio disk when they are available?" All declined, however in case this offer was seen by the interviewee as an additional work load to the interviewer, the final printed transcript was mailed personally to their business address with a cover letter (Appendix C).

The methodology used in gathering the primary data was described to the interviewees. The interviewees were informed that the interview would be open ended in nature. This was done specifically to indicate to the interviewees that there would be an opportunity to digress from the original questions if they felt they needed to qualify an answer or make a statement. This technique encouraged the interviewees to volunteer data / insights which would not have been acquired if the interviewee rigidly adhered to the question asked. The most insightful comments were made consequently by the interviewees when they considered the interview to be drawing to a close, as a consequence of the interviewee feeling comfortable and wishing to add their *voice* to the data in a manner the interview had not allowed to that point.

The interviews were most accurately characterised as conversations. This was stated in the introductory emails to the prospective interviewees and restated the initial strategies of the interview. A particular expression of concern was raised by ARM during the first interview as to the nature of the study, especially the use of the data by third parties. This concern was contextualised by a statement that previously information released to academic studies had been used by journalists. This information was used for

[167] The names of the people approached have not been given. As no formal refusal was given it would be incorrect to assume they were not willing to engage with this research.

political commentary on some of ARM's more contentious projects (either deliberately or accidentally). ARM was assured that this was an academic study. This was reinforced by a binding code of ethics produced and provided to them (Appendix C). It is likely their concerns were raised purely to inform the interviewer that their previous experience as interviewees had not been positive. Neither this nor any similar issue was raised by any other interviewee.

Once the data was obtained it was important to the credibility of this thesis that the primary interview data which contributed the major proportion of data to this thesis was handled in a professional manner. The audio recordings were transcribed using a word processor before being read and corrected with reference to the original audio recordings. These corrected transcripts were sent to a professional proof-reader recommended and employed by the University of Adelaide, who proof-read and corrected them as required. The proof-reader involved had no prior knowledge of the topic or indeed had ever proof-read architectural subject matter before. The audio recordings were made available to the proof-reader under the code of ethics provisions (Appendix D). Only minor queries were raised which did not affect the substance of the transcript.

The printed transcripts were returned to the interviewees with a cover letter dated 11 December 2003. The merge template file and the list of variables are given in Appendix D. Approximately one week (19 December 2003) after sending the transcripts a follow-up telephone call was made. Telephone calls were used to verify the receipt and status of the transcripts that were posted. Some of the interviewees returned the original printed or photocopied transcripts with their hand-written clarifications, whilst one interviewee returned comments via email. All these clarifications and corrections were integrated into the transcripts. Where there were specific areas that needed clarification follow up emails were sent to the interviewees. All follow up questions were satisfactorily answered, whether generated by the interviewee or interviewer. All interviewees contacted who had not returned the corrected transcript, expressed the view that the transcripts needed no amendments or omissions. As a final courtesy to the interviewees, a formal piece of correspondence was sent expressing gratitude for their continuing support of the study (Appendix E) dated 14 March 2005. A full record of interviewees, places, actions and times can be found in Table 4 (p.151).

First Name	Family Name	Interview Date	Transcript Sent	Follow up Letter sent	Follow up Contact Attempted
Simon	Shiel	20-Jun-02	11-Dec-03	19-Dec-03	12-Jan-04
Ken	Bool	20-Jun-02	11-Dec-03	19-Dec-03	12-Jan-04
Howard	Raggatt	8-Oct-02	11-Dec-03	19-Dec-03	12-Jan-04
Stephen	Ashton	30-Jan-03	11-Dec-03	19-Dec-03	12-Jan-04
Simon	Shiel	10-Oct-02	11-Dec-03	19-Dec-03	12-Jan-04
Ian	McDougall	31-Jan-03	11-Dec-03	19-Dec-03	12-Jan-04
Ian	Godfrey	29-Jan-03	11-Dec-03	19-Dec-03	12-Jan-04
Craddock	Morton	22-May-03	11-Dec-03	19-Dec-03	12-Jan-04
Bruce	Henry	22-May-03	11-Dec-03	19-Dec-03	12-Jan-04
Dawn	Casey	22-May-03	11-Dec-03	19-Dec-03	12-Jan-04
Peter	Wright	23-May-03	11-Dec-03	19-Dec-03	12-Jan-04
John	Mitchell	4-Oct-03	11-Dec-03	19-Dec-03	12-Jan-04
Michael	Keniger	11-July-04	11-Aug-04	19-Aug-04	21-Sep-04

Table 4 List of Interview Dates and Follow-Up Dates.

All the transcripts were sent in printed format rather than in electronic format, although one interviewee was sent (by arrangement), a word file and a copy of the audio disk. This was important for two reasons. The primary reason is, if the electronic versions were sent, corrections or omissions could have been made which were not apparent to the researcher. This allowed the corrections to be added to the electronic version and differentiate what were perfunctory changes and what were points to be clarified in the data. The corrections made by the interviewees carried the added significance that they had reconsidered the points made and believed the transcript to be consistent with the points they intended to express. The secondary reason was it could not be assumed that the recipient possessed the appropriate software to view the attached computer files (pdf[168]). Hence the printed version was sent to ensure that there were no complications in receiving and reading, correcting and/or annotating the transcripts.

Some questions were designed to clarify a point that may have been made in a previous interview by another participant about a particular event or sequence of events as suggested by Strauss and Corbin (1998 p.44). These questions were posed to triangulate or confirm the accuracy of information previously obtained. During the interviews a technique was also developed of basing a question upon an interesting line of thought expressed in a previous answer to keep the flow and to draw out a point that seemed significant to the interviewee but keeping the course of the interview moving in a particular direction.

To put the interviewees further at ease with the interviewer's direction, a verbal description of the methodology was given. Also this helped to dispel the perception in the interviewee's mind that these were questions that required categorical answers. However, the discursive content of each interview varied depending on the interviewee.

The interview questions were organised as a list of dot points that were designed to allow an answer that the interviewee considered appropriate. In addition to this list, a range of more detailed questions were prepared that were similar in subject to the dot points but more narrowly defined to elicit responses from more reticent interviewees. The reason for this parallel approach was that while some interviewees were able to elaborate on an interesting point contained or perceived to be contained in the question, others were more comfortable being asked questions which were obviously bounded.

[168] **P**ortable **D**ocument **F**ormat is a format produced by Adobe Acrobat. It is a document format used for the transfer of text and image based materials, and is platform independent.

Whilst all who took part engaged with the discursive nature of the interview some interviewees still preferred to give answers in a more categorical and truncated fashion.

To facilitate an ongoing and dynamic dialogue a set of *fall back* questions were formulated. When to use these secondary conversational tools was determined by the interviewer at times where the dialogue did not lead to an apparent follow up question. This ability to respond to an interviewee's replies is integral to the identification of major themes. This is one of the attributes that a researcher must comprehend as Gillham contends.

> In a research interview you are the research instrument, and you are not a standard product. Interviewing style, like writing style, is to some extent a personal business. No matter how much you learn about interviewing, it is your own personal resources which breathe life into the technique and, in a way, take over from it. You don't just imitate someone else you have seen interviewing in a way that impressed you. You will pick up clues and bits which you can incorporate, but they will be elements that fit *you* (Gillham 2000 p.4).

This approach to questioning aided the interviewees to understand that the methodology allowed, and moreover valued, their insights in addition to their intimate technical and contextual knowledge. The structure of the interview allowed an insight into the interviewee's more generic views on the architectural profession.

The venue and timing for the interviews was an important psychological factor in making the interviewee comfortable. The interviews were conducted in the interviewee's natural settings as suggested by Gillham (2000 p.4) and McCracken (1988 p.23). This was done to address a perceived imbalance of power. If the interviewer is perceived as a guest this increases the likelihood of obtaining insights from the interviewee. One exception was made due to geographic necessity and was conducted in a venue of the interviewee's choice. Hence, the interviews were all, except two (Michael Keniger and John Mitchell), conducted during the interviewee's normal working hours. This was an important issue as any additional data (drawing, documents, computer files etc.) the interviewee would want to draw upon would be readily available. There were clerical and IT staff that could, and did, find information as the interview progressed if necessary. Another advantage of interviewing in business hours was that the interviewee approached the interview in a professional manner presumably because it was in a professional time slot. It is considered that if the interviews were conducted out of usual business hours it may have taken on a social rather than business dimension. Each interview left a different impression of the personality of the interviewee. However, with the exception of one interviewee there was an awareness, expressed or assumed, by both parties that the interviewees had other commitments and as such there was a mutual understanding of the time constraints.

The interviews were conducted on an individual and confidential basis allowing the interviewees to express their personal views with the expectation that any contentious assertions would not be directly attributed. All but three of the interviews were conducted on a one on one basis. All except one were in an acoustically isolated setting. All interviews were recorded using a high quality recording equipment comprising of a (24-bit) mini disk recorder and a digital microphone (Appendix G lists the equipment used). This was important for several reasons. Primarily the interviewee had a perception of privacy which aided them to express their views in a frank manner. Also it aided in the accurate transcriptions from audio recording to word processor document.

All of the interviewees with one exception could be considered to be senior in their chosen professions. That is the interviewees were the project manager, the design architect, the project architect, the Director of the museum, the manager of the Commonwealth government department which commissioned the museum, the technical manager from the same department, directors of ARM, or similarly responsible positions. As the researcher/interviewer had requested the interviews, the balance of perceived power lay strongly with the interviewees rather than the interviewer. This was highlighted by ARM's *dynamic* timetable within which the interviews with their staff were conducted. With one exception the average age of the interviewee was 15-25 years older than the interviewer.

Early in this chapter I disclosed my tendency towards quantitative measurement. In keeping with this theme of disclosure I explain how I coded and analysed the data. As I am dyslexic I find the effort of reviewing text is not the most efficient use of my research time. Hence whenever appropriate I use audio recordings of the interviews to support their printed form. This served two purposes. The first, being the ability to review an increased amount of data in a shorter period of time. Secondly, the body language and visual cues in publicly available video recordings and documentary films in addition to inflections in audio recordings give an additional weight to a particular viewpoint or assertion. The importance of unspoken sentiments apparent from the inflections or body language adds an extra dimension to the interviewee's response.

Once the transcripts were corrected several devices were used to sort the data into streams. In the first instance the transcripts were read without coding to give an overview of the general direction or flow of the interview, and to measure the tone and context for any unusual speech patterns or out of context comments. Then the *find* function on the word processor was used to identify key words or repetitions of particular words, to identify a pattern for the researcher to review. The surrounding text was then read to contextualise the highlighted words to see if there was a similarity of context. A similar word processing technique was used to highlight blocks of text which were outlined to articulate a particular point of view or technical assertion. A sequence of colours was then used to define different strands that were previously identified; blue for political influence, red for transfer of information, etc. If more than one category was relevant to a single passage of the transcript a note[169] was attached to the passage of text. To delineate this overlap, the colour of the font was changed to signify the second theme. This device also became invaluable in identifying which excerpts of the transcripts would be the most appropriate to be placed into Chapter 2, 'Contextualising the NMA' and Chapter 5, 'Synergy at the NMA'. Due to the various viewing scales at which word processors can display text based information and the contrasting colours a whole transcript could be viewed at once to determine the frequency and pattern of a particular theme by colour. This technique was extended to the electronic references and additional working documents which were gathered (in word processor format) as part of the literature review. Audio editing equipment was also used to cut pertinent parts of the conversation into *sound bytes*[170]. When collated by theme these sound bytes were played and arranged consecutively to create a narrative.

These codes were developed to identify categories or classifications and to aid in labelling the primary patterns emerging from the data. The data analysis uses information taken from the interview once placed into recurring themes to be used for theory building. The coding and analysis continued until theoretical saturation was observed, as defined by Huberman and Miles (2002). Primary to secondary codes were continually compared until a coalesced final code was derived, as described by Patton. "*Theoretical saturation is simply the point at which incremental learning is minimal because the researchers are observing phenomena seen before*" (2002 p.26).

[169] A note in this context was the attachment of a comment field within the word processor document.

[170] Audio recordings were usually edited to less than 20 seconds in duration.

The narratives that were produced from the interviews were then broken down into codes. The codes were generated by the process of primary examination, followed by a more rigorous application of code assignment and designation. A code book was developed in the form of a word processor document. Primary thematic codes were formulated as an overarching series of categories to divide the themes into. The primary codes are listed below (in alphabetical order) with brief descriptions, and indicative examples for each of them.

1. *Personnel / Teamwork* deals with codes that were of a personal or inter-personal nature which impacted upon the cohesion and/or motivation of the team or individual within it, e.g. social events during construction.

2. *Political / Cultural Context* deals with codes that were outside the control of the project team due to political expectations and or social conventions, e.g. the impact of Government decisions on the project.

3. *Similarities and Differences* deals with codes generated from a comparison of major issues which held parallels or differences between the NMA and the GMB eg, the dissimilarity of the born digital or born physical approaches of the architects.

4. *Technological Factors* deals with codes that were generated by the project team's choice and / or specific use of the technology eg, the impact of incompatible formats.

Secondary codes were generated by subsequent or nested issues which emerged from the primary categories. The codes shown (Table 5, p.159) were subsequently allocated to the relevant sections / subsections of Chapter 5 'Synergy at the NMA'. Some of these secondary codes were similar enough to each other that they were combined in a single subsection.

Secondary thematic code	Section No.	Section title
History with computer technology	5.1.1	History and attitude to computer technologies
Attitude to computer technologies		
Problems with computer technologies		
Prediction of future technologies		
Historical perception on computer technologies		
Transfer of ideas to data	5.1.2	Transfer of ideas to data
Transfer of ideas to data by non-designers		
3d data for exchange		
Testing in virtual space	5.1.3	Dialogue between architect and computer
Dialogue between architect and computer		
Technology transfer	5.1.4	Technology transfer
Research & development in architecture	5.1.5	Research and development in architecture
Innovation under an alliance	5.2.1	The alliance process
Alliances elsewhere		
The role of the architect under an alliance	5.2.2	Architectural design under an alliance
Transfer of design intent to others	5.2.3	Transfer of design intent to others
Format / reworking of data	5.2.4	Format / reworking of data
Cultural resistance to change in the architectural industry.	5.2.5	cultural resistance to change for Architecture Engineering Construction sector
Perceived subtle strengths and weaknesses		

Attitude from the industry		
Insight into the work of others	5.2.6	Insight into the works of others
Perceived subtle strengths and weaknesses		
Social engineering	5.2.7	Social engineering
Pride in work		
The quality of people involved (social engineering)		
Hierarchical structure		
The role for non designer in design	5.2.8	Complementary knowledge
Harnessing others		
Acquiring knowledge from allied industries		
Learning from the alliance		
Self selection of personnel	5.2.9	Factors affected by personnel
Benefits of a flagship project		
Level of approximation in documentation	5.2.10	Level of approximation in documentation
Adversarial procurement environment	5.2.11	The Constraints and Opportunities of working with others
The constraints of working with others		
Limitations of subcontractors		
Problems with clients		
Perceived subtle strengths and weaknesses		
Identification of potential difficulties	5.3.1	Potential difficulties
Uncertainty of Costings	5.3.2	Uncertainty of Costings
Unfamiliar environments		

The cost/time control matrix	5.3.3	The cost/time control matrix
Perceived external concerns	5.3.4	Perception from government
Nature of government		
Initial concerns from clients		
Perceived external concerns	5.3.5	Perceived potential legal complications
Perceived potential legal complications		
The role of the architect under an alliance	5.4	The changing role of the architect
Architects losing their design		
The changing role of the architect		

Table 5 List of Secondary Codes used in Data Analysis.

The use of the Guggenheim Museum Bilbao (GMB) as a comparison to the NMA was intended to highlight an example of 'world's best practice' in a project similar to the NMA in some respects. However, the study of the GMB was not addressed using the techniques that were applied to the NMA study. The GMB portion of the thesis used literature review and a site visit as the main techniques. The initial literature review showed a tendency to either consider solely the technological implications of high profile architectural projects mainly in architectural journals or conversely, the effect finished architecture had over design directions. This effect was especially promoted in the GMB influence over design. In the initial literature study of the GMB, the literature available is prolific. Gehry's words and those of others from FOG&A have been published in various architecture journals (Novitski 1992; LeCuyer 1997; Stein 1997), as well as dedicated large format books (Forster *et al.* 1998; Friedman 1999; VanBruggen 1999; Raghed 2001) as main sources of data came from secondary sources (the literature). The literature that was of specific interest to this study includes works that had obvious parallels with the NMA. Consequently these texts were read in full and considered in context. Because of this large body of literature on the design and construction of the GMB there are multiple descriptions allowing for a greater reliability of data by triangulation.

4.3 Conclusions

Grounded theory requires an approach to theory building which is based in fieldwork, and informed by its context. It thus builds upon the emergence of a phenomenon found in a particular setting or project. Hence to be *in the field* and to be an *instrument* of the research, necessarily requires a well defined methodological structure and it also requires the researcher to understand the method employed and to conduct the research. This adherence to a method must be tempered with the understanding that the data is gleaned from individuals as part of an ongoing process.

The type of research questions under consideration were concerned with the interplay of cultural (interpersonal) and technological (computer based) factors and the combined effects of their interaction. Due to the wide scope of the research questions, a means to bound the research parameters to an appropriate level within the constraints of time and resources available was required.

The matching of the researcher to the research methodology is integral to the credibility of the research. This is because the methodology would need to be relevant to the researcher for the duration of the study (in this case more than three years). The interviews were conducted in their natural setting and in the normal work hours in a business-like manner with a clear understanding of what the interviewer-interviewee relationship was and what the purpose of the research was.

The strategies and techniques used to collect, code, and analyse data, were dynamic enough to stay within the methodological framework and produce a reliable outcome that adds to the existing literature.

5 Synergy at the National Museum of Australia

This chapter develops four themes, ‘Computer Technologies’, ‘The Acton Peninsula Alliance’, ‘Project Constraints’ and ‘The Changing Role of the Architect’. It covers the history of, and attitude to, computer technologies within ARM and the transfer and dialogue with information between the technology and the people involved. It gives an overview of the spectrum of technologies used by the Acton Peninsula Alliance partners on the NMA project.

5.1 Computer Technologies

This section is divided into five areas covering the data gathered concerning computer technologies at the NMA project.

The technical paradigm for the use of computing in architecture at the time of the NMA and the GMB projects was “*digital in the foreground*” as Branko Kolarevic[171] (2003a p.v) categorises it, in his preface to ‘Architecture of the Digital Age’. The characterisation and prominence of the technologies used at the NMA and the GMB is consistent with the notion of foreground technologies. Mainstream and commonly used technologies such as emails would then be considered as technology in the background.

The use of email to send specific information between groups and/or individuals at the time of the NMA was widely accepted as a standard means of communication. Predominantly this media was used to send static information, e.g. text and images to a predefined group or individual(s). There were no difficulties or substantial issues at the NMA project with the technical competence required for sending and receiving emails. During the research interviews, whenever emails were mentioned, they were so in the same vein as telephone conversations, i.e. a technology that was widely understood. None of the interviewees mentioned emails as a technological factor either helping or hindering, but merely as a way to communicate. Hence, the use of email represents technology in the background in the context of the NMA project.

[171] Branko Kolarevic is an Associate Professor of architecture, founder and director of the Digital Design Research Lab (DDRL), University Pennsylvania and author. *See* http://www.gsfa.upenn.edu/ddrl/.

A computer technology that was initially in the foreground at the NMA was a web based information system. This information system known as 'project web' was administered by Lend Lease for use by the project team. During the NMA project this technology was in transition from being in the foreground to the background. It was not universally assumed that all aspects of the project web were familiar to the same extent as email. Moreover, it also required an active engagement by the participants to seek the information rather than having it passively delivered. The project web was used extensively to update information, which mainly consisted of static information (e.g. images, text, 2D drawings). This information was viewable by web browsers which allowed access to formatted files containing more detailed information. Some of the files available on the project web were held in the form of CAD files.

This notion of the acceptance of technology as commonplace within the literature is supported by Peters and Walker *et al.*

> Much of this technology has been available and in use for many years and many do not associate these items with technology. The telephone, fax and photocopier are good examples of this and demonstrate how this technology is expected within an organisation without question (Peters *et al.* 2002 p.464).

The use of CAD files to explain the design was only of benefit to those who were sufficiently technically literate and engaged in the project to extract the information they required from it. The CAD files, unlike the static information contained in images, could be manipulated, interrogated and edited by those with the ability to do so. This situation places the CAD file closer to the foreground than any other technology as it required a greater level of engagement with computer technologies to be able to add value to the process.

The three computer technologies outlined above (email, web site and CAD) were situated along a continuum[172] from commonplace and accepted to exotic and selectively used. This difference in the amount of engagement of these modes of transfer influences the relative levels of acceptance by parties with specific technical mastery. Hence the context was influenced by the level and type of technical interactions between those responsible for the generation and use of design information.

[172] The three outlined technologies do not represent the complete technological spectrum of architectural computing used. It is only those commonly used by most of the Acton Peninsula Alliance partners.

The move from one technology to another is rarely seamless. The way the computer technologies were used fundamentally affected the success of the NMA and GMB projects and highlights the difference in approaches between ARM and FOG&A.

5.1.1 History and Attitude to Computer Technologies

This sub-section gives a background to selected ARM project work prior to the NMA project. It situates the NMA as part of ARM's body of work. ARM was practising architecture before the wide spread adoption of CAD in architecture, and had developed a strong architectural philosophy independent of computer technologies. ARM have been practicing architecture as a group since 1980, and before that as individuals (Ashton [interviewed by author] 2003).

ARM's attitude towards computing, especially as manifest in their body of work previous to the NMA project, shows they are a practice that is willing to embrace new technologies and ways to work. Australian architect and author Brent Allpress describes how ARM used a variety of CAD packages to both generate and document the NMA, "*cheap packaging software was used to unfold the complex 3D figures into buildable developed 2D cladding surfaces. ARM's attitude to this technology is opportunistic and resourceful.*" (Allpress 2004 p.112). This is indicative of ARM's approach to their previous work.

ARM has a body of built work which distinguishes them as a practice with a disposition towards pushing the boundaries of form and social comment in architecture. They are familiar, as are FOG&A, with complex and controversial architectural projects in both the pre- and post- digital environment.

ARM's previous work shows their desire to subvert what they considered were the traditions of Australian architecture. This is evident in works such as Storey Hall, Melbourne Victoria (Figure 50, Figure 51 p.69). This complex building was the subject of most interest prior to the NMA project, as featured in Illing (1995), Kohane (1996) and Day (1996). Storey Hall, a university lecture hall for the Royal Melbourne Institute of Technology, is a landmark building for Melbourne and Australia. However, it is significantly smaller in scale than the NMA. It had a client (Royal Melbourne Institute of Technology) who was actively commissioning university buildings by influential Melbourne architectural practices[173]. Prior to ARM's work, the building was used as a feminist educational headquarters and a catholic centre. Also, it was located between two traditional Melbourne institutional buildings on Swanston Street, one of the city of Melbourne's main thoroughfares. Given the complexities of the site most architectural practices would have generated a more referential design solution. Faced with this complex set of factors[174], ARM used forms taken from fractal geometry (Jencks 2001), specifically the Oxford scientist Professor Roger Penrose's[175] work of aperiodic tiling, to inform their form. The most comprehensive paper to investigate the use of Penrose tiling at Storey Hall is 'Aperiodic Tiling and the Generation of Architectural Forms', (Ostwald 1998) [176]. Contrary to its appearance it was partly generated by manual means (Ashton [interviewed by author] 2003). Due to the complex geometries used to generate its façade, Storey Hall is distinguished by being atypical with the streetscape. This idiosyncratic treatment of an existing urban fabric prompted the regulatory authority to place an unusual condition on the conduct of the work. This condition was that the scaffolds which covered the work in progress remained in use until completion of the work, even though there was no constructional requirement (Robert McClelland Victorian Minister of Planning, 1992-99, (ABC 2000)). This level of controversy is a consequence of ARM's unorthodox approach to architecture.

Preceding Storey Hall was a project to remodel the interior of the Victorian Art Centre Lounges incorporating the Amcor and Commonwealth Bank, Victoria Arts Centre Melbourne (1996-7). The lounges, which were a re-fit of two private lounges, (Figure 57, Figure 58 p.166), display the same love of ambiguities, technological interventions and challenging visual representations. ARM used familiar items out of context to provoke thought. To evoke memories they used everyday artefacts set into transparent resin, including strips of 35mm film stock, mosquito coils, and 5¼ inch IBM floppy disks placed within tons of glass balls (marbles), used to create a work at once familiar and ambiguous. McDougall in an interview for the documentary 'In the Mind of the Architect', comments that ARM's inclination to tease out what is hidden manifests itself in these projects as the re-presentation of familiar items re-contextualised (ABC 2000). The panels which formed the visually

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[173] As outlined in the Australian Broadcasting Corporation's 'In the Mind of the Architect' (ABC 2000).

[174] As outlined by Norman Day, the Australian architect and architectural journalist (1996) and David Clark (2000), a US based Australian architect and journalist.

[175] Professor Penrose, who won the 1988 Wolf prize jointly with Stephen Hawking on their understanding of the universe, formulated a system for randomly tessellating space using only two geometric forms known as the kite and the dart. *See* http://en.wikipedia.org/wiki/Roger_Penrose.

[176] Michael Ostwald, is Professor of architecture at Newcastle University, Australia.

immediate part of the project were fabricated by ARM staff at their offices. Howard Raggatt personally positioned these outcast elements in the moulds (Raggatt [interviewed by author] 2002). This personal '*hands on'* approach to cladding panels would be repeated later at Storey Hall, where, as McDougall describes, "*elements of the outcast city are returned*" (ABC 2000).

This desire to subvert the conventions of architecture is also evident in the manual manipulation of elements which evolved into the unorthodox use of image reproduction equipment in the generation of the façade design for the Howard Kronberg Medical Clinic, Footscray, Melbourne (1994). The clinic takes its façade design from the pixilation of a deliberately degenerated photocopied image of Robert Venturi's famous 'mother's house', Vanna Venturi House, Philadelphia (1964).

The Victoria Art Centre Lounges, the Howard Kronberg Medical Clinic and Storey Hall show a love of ambiguity and cultural references and are smaller scale precursors to the many cultural references that would influence the NMA design. ARM's interest in documenting fuzziness, as shown at Storey Hall and the Howard Kronberg clinic, has led to an innovative approach to producing architecture borne of imprecision so that it can be documented. In the forms of the NMA, this desire to document fuzziness required a similar technological underpinning to their previous projects, as Raggatt recalls,

> [F]or instance around the time we were doing Storey Hall we were interested in this idea of the blur and exactifying this blur which came from the photocopy which started off about copying something, a distorted copy and ended up being about looking at the copy and seeing all the fuzzy bits and then the interest in how do you precisely document something that's fuzzy (Raggatt [interviewed by author] 2002).

He continues explaining his view of the relationship between something as ambiguous as an idea with a level of precision.

> [W]e are interested in precision as a way of documenting something that is too problematic to document any other way. A different idea of the word precise and to do that we just needed technology to do it (Raggatt [interviewed by author] 2002).

McDougall considers ARM to be a practice which has cultivated a culture of exploring the possibilities made available by new technologies. "*I think probably over the years we have built up a culture within the office that pushes things*" (McDougall [interviewed by author] 2003).

Figure 57 Amcor Lounge, Resin Panel Wall, Victorian Art Centre, Melbourne.

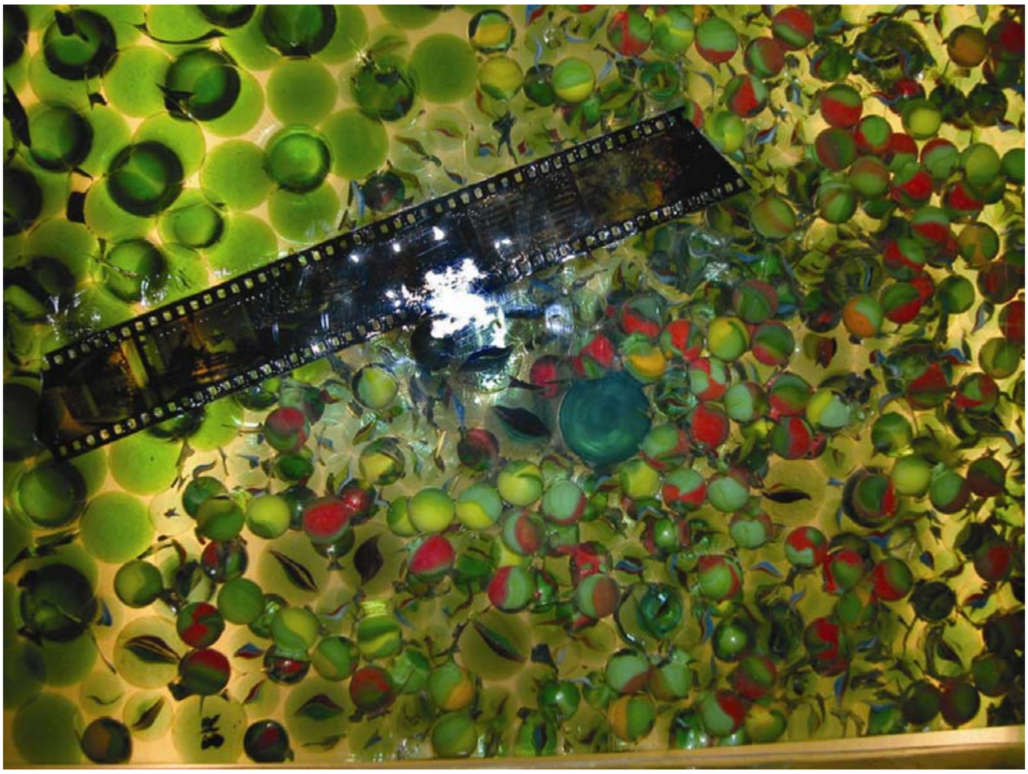

Figure 58 Amcor Lounge, Resin Panel Wall, Victorian Art Centre, Melbourne.

The culture ARM tries to advance, actively considers how computer techniques impact upon their design in a philosophical as well as a pragmatic way. This is articulated by Raggatt when answering a question about whether the tools (computer technologies) were an extension of their philosophy.

> [T]he tools we needed were just these precision tools on the one hand but they're also tools that seem to be culturally inappropriate as well. We think that maintaining that idea of the hand held was really about the new craftsmanship craft. You don't do it through the hand held anymore. You do it through virtual generations although we're again sort of… ironically the sophistication of form and so on that's producible. By producible I mean contractible in any reasonable sense (Raggatt [interviewed by author] 2002).

ARM has not formulated a prescribed policy on the upgrade of computers in their office. This underlines their predisposition to an evolutionary use of technology rather than as a philosophical intention to have the latest available technology. When asked if computer systems were purchased for a particular project, Stephen Ashton replied, "*No, we've never done it like that. We've always just done it one step at a time*" ([interviewed by author] 2003).

On large scale projects information may need to be retrieved and manipulated at short notice. A manual drafting approach was inflexible and could not adequately address the complexities of a building such as the NMA. Transforming metaphor into form required computational power. Raggatt states regarding larger projects, that there is no viable alternative to CAD, "*It is not an option anymore. On larger projects you can't… you can't have a whole lot of people hand drawing something*" (Raggatt [interviewed by author] 2002).

Ashton repeatedly characterises computer technologies in terms of the outcomes rather than the processes "*We have never had as an objective a paperless office*" (Ashton [interviewed by author] 2003). In answer to a question about their attitude about investing in technology, he replied, "*We are always pretty cautious about changing software*" (Ashton [interviewed by author] 2003). This pragmatism also extends to their choice of software packages "*[I]t is a philosophical commitment to doing things digitally but not doing them in the big bang*" (Ashton [interviewed by author] 2003). This notion of incremental change is further described by McDougall.

> Our tradition is the Australian tradition - bits of make do and using 3D studio now or Rhinoceros, same sort of stuff. In fact, it is interesting that all that software comes out of animation. All the software we use comes out of the film industry. And because it is surface modelling we try and make do with that. It is not as precise but it does the job

> pretty well just as well and it is transferable from AutoCAD which is good and it is way more, because it is to do with shape modelling. It is not architectural software which ArchiCAD and things like that are way too limited in the way that they make shapes but we do use that from day one (McDougall [interviewed by author] 2003).

This selective approach has been an established practice in ARM's offices for a number of years. ARM constantly try to subvert the form rather than allowing advances in computer technologies to dictate what forms are available to them as designers. This desire to go beyond the bounds expected by the software makers has been a feature of ARM's work, as Ian McDougall explains the philosophy behind ARM's first use of CAD.

> We used fully computer drawn plans on Brunswick Community Health Centre in 1989. We were using it as a design tool then we used very early software string and binder twine ideas of how you use software, using standard software to try and do things (McDougall [interviewed by author] 2003).

This is reiterated when Ashton says "*We are not ideological about using digital per se it's just an idea*" (Ashton [interviewed by author] 2003). Ian Godfrey[177] characterises ARM as a forward looking company that pushes the limits with a unique and idiosyncratic approach to form generation.

> A company like ARM are very special and exceptional and they would see the value of employing an animator, whereas I imagine most of the mainstream firms around probably wouldn't see why you would employ an animator (Godfrey [interviewed by author] 2003).

Raggatt's sentiment about the use of computer technologies as a more efficient and effective way to realise ARM's complex designs is shared by Frank Gehry when he asserts that computers have brought his highly complex designs to fruition.

> The computer has allowed me to realise some of the shapes I have been exploring and heretofore haven't been able to justify or realise. I started trying to do stuff like this in the Vitra Building and the Weil am Rhein and we didn't have the computer and it was very difficult (Blackwood 2000).

FOG&A's response to the difficulties of adequately documenting their designs using conventional descriptive geometries led them to an object orientated solution, the logical next step according to Godfrey.

[177] Ian Godfrey, architect and founding member of the International Alliance of Interoperability in Australia.

> An object orientated 3D modelling tool takes it to the next step and that requires a completely different way of approaching the use of CAD systems; they are really building modelling systems. A different way of organising practice and establishing skills in a practice (Godfrey [interviewed by author] 2003).

Godfrey qualifies this further explaining that training is required for this new way of thinking "*We have got to get people trained to understand how you think and work with object modelling*" (Godfrey [interviewed by author] 2003).

FOG&A's attitude to technology was far more in step with Godfrey's assertion than ARM, whose previous work exemplifies the practice's desire to push the boundaries of design in increasingly idiosyncratic ways. The advances in computer technologies which facilitated complex methods to animate models shows a desire to manipulate technologies not usually considered being the domain of the architect. As Peters *et al.* assert the purpose of most technologies is efficiency in the essential activities of an organisation.

> The purpose of most technology is to carry out essential activities of an organisation more efficiently. There is little point investing in technology if it does not achieve this function (Peters *et al.* 2002 p.465).

This point of view is based on the precept that computer technologies are primarily for cost and project programming control. ARM primarily used computer technologies for efficiencies in generating architectural forms. Whilst FOG&A's use of technology at the GMB was certainly primarily employed as a cost control measure, there is a marked difference in ARM's approach to the efficiencies offered by technology.

As professions specialise, architects are becoming generalists due to the amount of information needed to operate. Many of the tasks that make up the architect's skill set could and probably will be greatly aided by technology yet to emerge. However, between introduction and widespread use there is a temporal disparity. Traditionally the architectural profession acquires sufficient knowledge to operate but not to master emerging technologies. This necessarily leads to a less systematic and more ad hoc approach to computer technologies which the architectural profession considers will become quickly redundant or superseded.

5.1.2 Transfer of Ideas to Data

This sub-section examines the methods that were used at the NMA to convey the architect's ideas underpinning their design.

There are inherent dangers in trying to convey conceptual ideas with static images or uncontextualised information. These dangers were articulated in the following example given by Michel Foucault (1926-1984), a twentieth century political philosopher.

> Borges quotes a 'certain Chinese encyclopaedia' in which it is written that 'animals are divided into: a) belonging to the Emperor, b) embalmed, c) tamed, d) suckling pigs, e) sirens, f) fabulous, g) stray dogs, h) included in the present classification, i) frenzied, j) innumerable, k) drawn with a very fine camel hair brush, l) etcetera, m) having just broken the water pitcher, n) that from a very long way off look like flies (Foucault 1974 p.xv).

Foucault uses this reference to illustrate the problems with translating meaning between written languages, making a salient point about the loss of integrity in the transfer of meaning. Similarly the recipient of design information must have a common frame of reference with the author of that information. That is, a contemporary of the author of the 'Certain Chinese Encyclopaedia' would most likely have found nothing strange in the categories outlined by Borges. However, Borges' frame of reference was sufficiently different that the translations of these categories were accordingly met with a complete lack of comprehension, hence its use to illustrate a point by Foucault in 'The Order of Things' (1974).

ARM's use of technology to facilitate their vision at the NMA was extremely inventive. The initial forms generated by ARM for the NMA project were not generated using artefact to file technology[178]; the initial 3D form making was conducted directly on the screen.

In the development of the NMA, ARM used a mixture of CAD programs to generate 3D design surfaces from which the 2D working drawings were generated.

Keniger, a member of both the NMA integrity panel and design review panel, states this use of 3D design surfaces was a first for Australian architecture (Keniger [interviewed by author] 2004). This claim is supported by Brent

[178] Artefact to file technology is sometimes called reverse engineering. The process uses a physical model to make a 3D CAD model.

Allpress[179], in his article in the Australian Architectural Review, *Surface Values* (2004). The 3D surface models carried no additional information beyond their physical definition of the internal and external surfaces. ARM used an aesthetically driven approach to sculpt the space generated by the Boolean sequence, as seen in Figure 21, Figure 22, and Figure 25 p.38. This approach to CAD modelling created many opportunities for ARM to experiment with surface driven architectural form. They subsequently used these ideas on projects like their competition entry for the Spencer Street Railway Station, Melbourne[180].

ARM consider the use of technology to be empowering their imaginations: "*We like the idea of being able to build ideas*" (Raggatt [interviewed by author] 2002). Unlike most architects he uses a philosophical point of departure in preference to a more traditional form/function driven approach. The manifestation of these ideas is best conveyed using computer technologies as Keniger asserts,

> [T]here is a very strong underpinning [of] ideas but the ideas, many of them are to do with abstraction which is hard to model without a digital tool so when they are talking about Boolean caves and so on that it is hard to describe that without using a machine (Keniger [interviewed by author] 2004).

This is supported by Godfrey with his statement "*The CAD file, through its links to an appropriately structured database can model reality*" ([interviewed by author] 2003).

The use of computer visualisation to inform people involved in the project does not extend to the visiting public. The notion of how the metaphor is perceived by visitors to the NMA is considered by Raggatt,

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[179] Brent Allpress is a lecturer at the Royal Melbourne Institute of Technology and co-editor of Architectural Design Research.

[180] ARM's competition entry for Spencer Street Railway Station, Melbourne, Australia was not the scheme chosen for the project. The chosen project was a joint venture company, Grimshaw Jackson (comprising of Nicholas Grimshaw's and Darryl Jackson's practices).

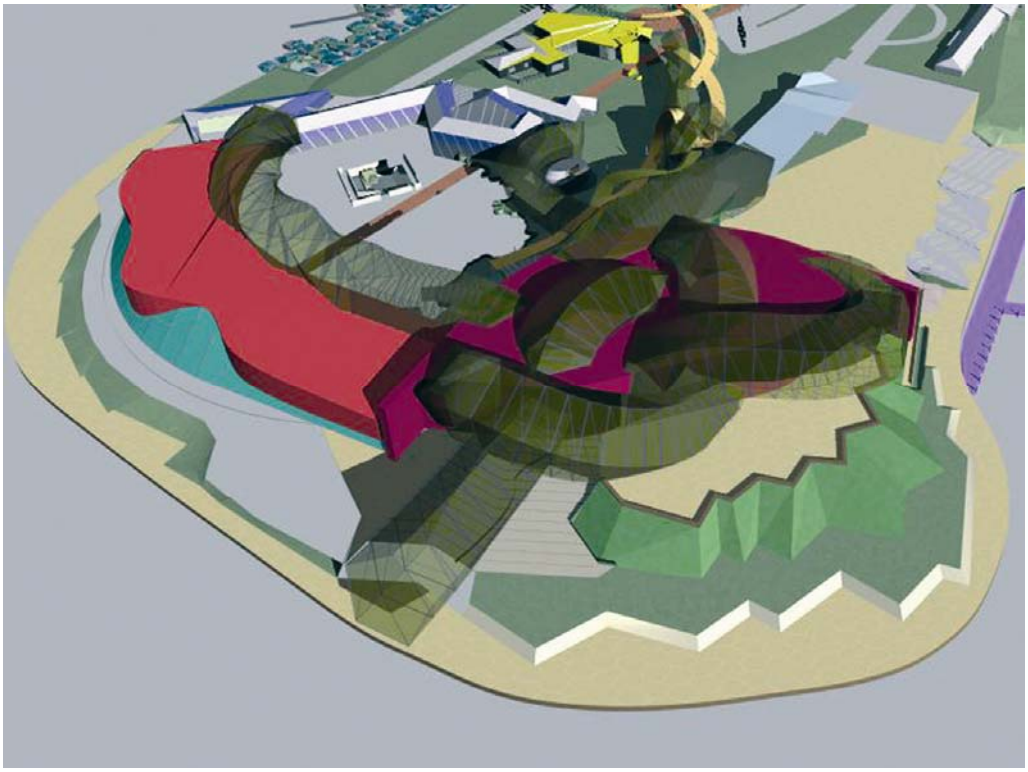

Figure 59 NMA, Alternate Solid Modelling Form Study.

Figure 60 NMA, Alternate Solid Modelling Form Study.

> In that sense there is probably a new appreciation for form. I think, though, for instance people when they view the hall at the national museum one suspects, and probably only proper that they can't understand that it is formed as a cast of a subtracted knot because that is quite difficult to understand and therefore they probably read them as kind of gestures. But in fact the documentation, as you say, shows the exquisite precision of that process. It sort of documents that thinking so that as far as history is concerned, as historical documentation, it's clear that it isn't just some sort of gestured figure (Raggatt [interviewed by author] 2002).

The NMA was modelled on a highly metaphorical notion of Australian history and popular culture. The manifestations of these metaphors are complex in both form and idea. The NMA project used a mixture of techniques to convey meaning from the highly articulated 3D CAD model through to images of Boolean sequences to convey what the project was in a contextual manner.

5.1.3 Dialogue between Architect and Computer

This sub-section deals with the interaction between the ability of the computer to process the *what ifs*, and the designer's ability to think laterally (Figure 59, Figure 60, p.172). Most offices are undergoing or have undergone a transition from the traditional pen and paper of an architectural practice to the *paperless*[181] practice. In this transition CAD has moved beyond the threshold of the electronic pencil and the *pin bar* layer systems of the early 2D systems into the area of constructible complex rule based design. This has created an environment in which new computer technologies are being used to design and document complex works of architecture beyond the ability of a traditional manual design process of pen and paper. When asked whether ARM commenced with a blank screen in preference to a blank piece of paper Raggatt replied,

> Yes, the paper is used to scribble essentially the kind of framework of the ideas but then we would and we may even have physical aids - bits of rubber or paper or usually some sort of soft material or something - it could even be small blocks and then we would really start drawing in virtual space straight away. Everything we do we would have a 3 dimensional virtual quality before anything (Raggatt [interviewed by author] 2002).

Other than a few hand drawn sketches the modelling for the NMA was done using digital, rather than manual means; ARM did start with a blank screen.

[181] Paperless is used in this thesis to denote a work environment which was primarily electronic based rather than paper based media to produce and store information.

FOG&A did not start with a blank screen on the GMB project; they started with manual sketches and physical models.

The 3D CAD model was also used to analyse other facets of the spatial/technical interaction. One such interaction was the use of the model for analysis of shadow and solar penetration:

> We used it for shadows. We used it to work out how much sunlight was getting into exhibition spaces. It was used for the acoustic analysis in the Main Hall (Ashton [interviewed by author] 2003).

When asked about their view on modelling purely virtual spaces, Raggatt expressed a view that physical rather than virtual forms were the practice's main interest during the following exchange.

> **JPS** You have people working here that do nothing but produce virtual environments?
>
> **HR** With no intention of building…
>
> **JPS** If I came to you as a client and said I want a virtual shopping mall, knowing what you understand about space and buildings…
>
> **HR** Stuff that you want to sell off the net but you want to be able to walk around…
>
> **JPS** We want someone to walk through it and we like your architecture. Could you please design us a virtual space… a virtual shopping centre.
>
> **HR** We are doing one of those for Mortgage Central which is a... I think the intention is still to build it but the difference of producing a virtual one. The nice thing about the virtual one would be it wouldn't have normal restraint obviously of the potentially physical one. It would have all of the design, more of the design potential. If someone came to us with a project like that we would be very, very interested because it would be what we normally do most of our time doing that but it would be at the very imaginative end of the project, which of course we are pressing toward. So it would almost be the ultimate project except that architects by definition as opposed to side producers or something have this 'It might be atavistic or something', but we have this commitment to… ultimately to the physical city I think. So although we do all this stuff we tend to tire of it if it is not firmly bolted in the physical world (Raggatt [interviewed by author] 2002).

He continues,

> I guess at an ideas level we are interested in the idea of making things that we can't draw, which is a kind of a way of contesting the idea of the architect as a kind of drawer or artist or something like that, and to see it more, whereas the potential to translate almost

> directly an idea that you can't even fully imagine yourself. Though you know the kind of thing that you are going to get out of it, you don't actually know exactly, and you can then make this thing in virtual space and gradually refine it. But then even there you can't even quite understand it and you can drive around it and sort of look at it. There are then techniques that turn that into a physical thing that you can see precisely what you have done, but even when you can see what you have done you can't really. In order to document it in space, these complex figures, you have to use computers because I don't think you could actually determine where the things are in space to build them - not accurately without computer systems, so such as the windows which are a part of a knot that pop out of the hall (Raggatt [interviewed by author] 2002).

There is a reluctance to rely entirely on non-physical modes of representation within ARM:

> So we still probably depend heavily on just the virtual model for making our decision but we also find that at some point we just have to go physical to just… surprising how the whole sense of scale and lots of those issues are very difficult to observe in virtual space. I think you seem to end up needing to give it that physicality at some point (Raggatt [interviewed by author] 2002).

ARM used a 3D model more as a visual aide than as a repository of design data for documentation, as Simon Shiel, one of the ARM architects most involved with the digital manipulation of the surface model, points out.

> The 3D modelling was done primarily for complicated exterior surfaces, all those known surfaces, basically everything that needed to be checked visually and was complicated (Shiel [interviewed by author] 2002).

The 3D surface model was predominantly a visual aid, he continues, "*They serve as a kind of instant reference for understanding the rest of the 2D work*" (Shiel [interviewed by author] 2002).

Raggatt sees the future of 3D models as a design development tool,

> We can start looking toward using those models as part of the design development process rather than having to be an end process or a milestone process. We can actually integrate them fully into our conceptual design (Raggatt [interviewed by author] 2002).

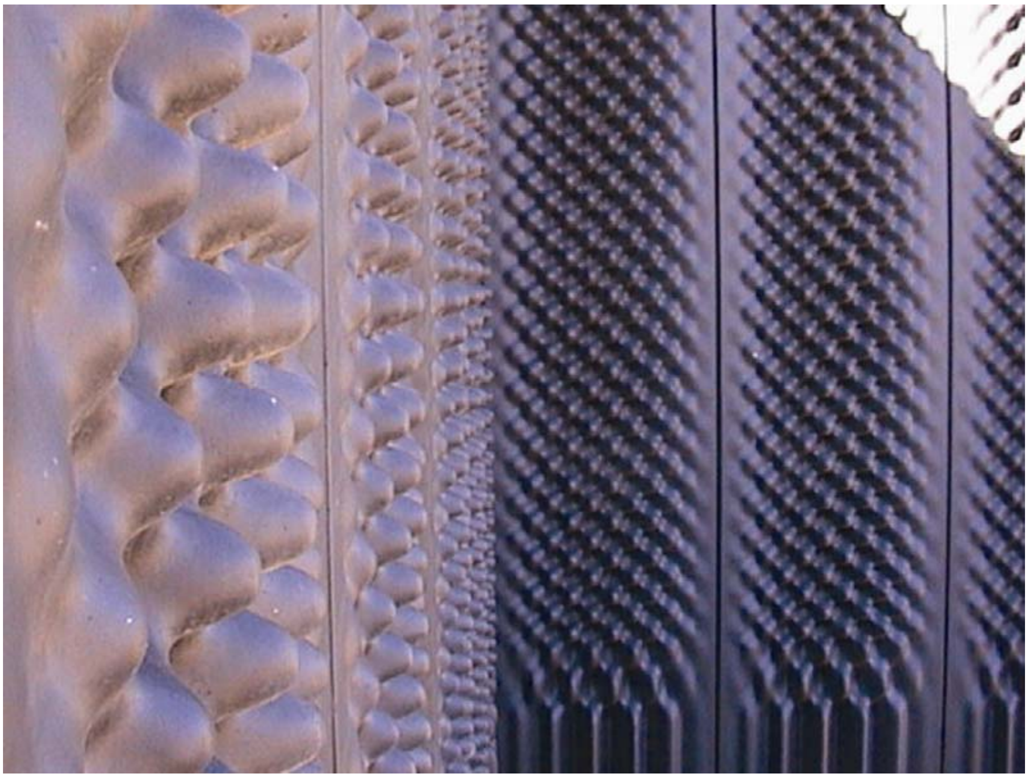

Figure 61 NMA, Dimpled Pre-Cast Panels.

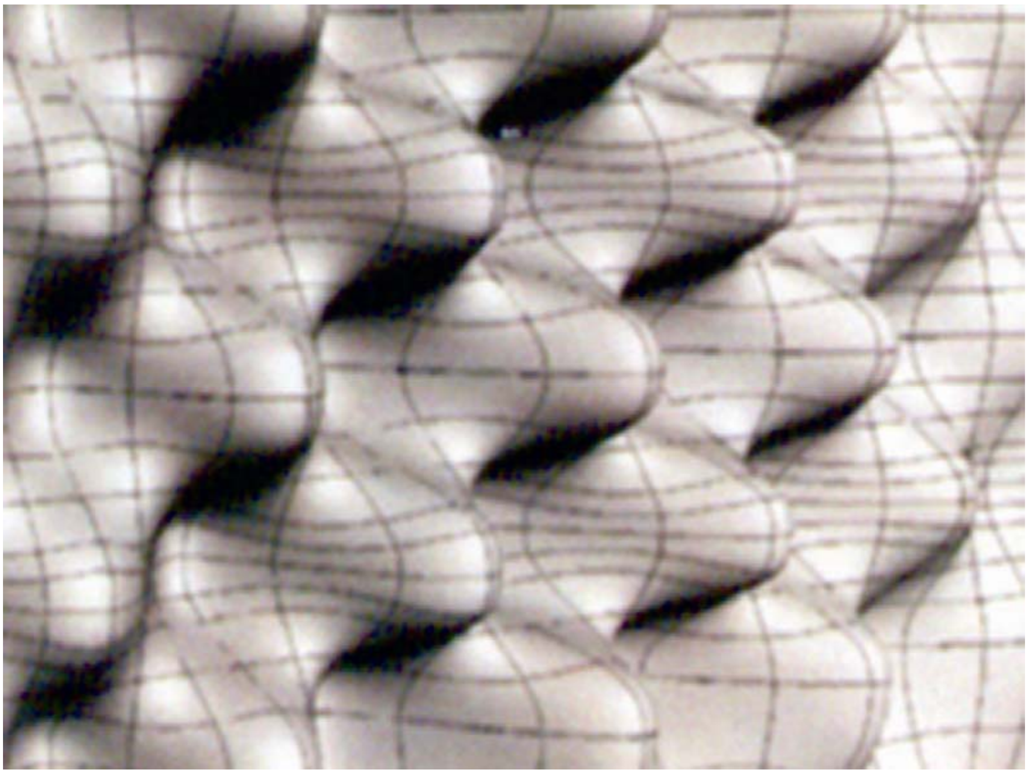

Figure 62 NMA, Dimpled Panel File.

Ian McDougall elucidates the use of the 3D model for testing alternate materials, "*[W]hat the technology allows you to do is explore really quickly the widest range of materials ……*" (McDougall [interviewed by author] 2003). Further to McDougall's view, John Mitchell asserts that alternative testing of materials and other building parameters are an obvious advantage in efficiencies to both designers and contractors.

> You can start to simulate performance. OK what happens if we change the percentage of this, or if we change the construction type? What happens if we rotate the building 5 degrees, what if we take all the windows out of this façade? So you can have a dialogue with the engineer because he can give you this quick feedback and the architect now has a much more useful opportunity to simulate and plan his performance. This is coming back to true design (Mitchell [interviewed by author] 2003).

He continues,

> The model shows the clash; the plumbing going into concrete footings, brick walls resting in space because the foundation has been one thickness of a beam out of place. They are classic problems because they are being done in 2D, and this is the benefit of the object model. These sorts of things don't happen because it is so easy to see that you have not done it correctly whereas in a 2D drawing you are always in 2 projections instead of 3 and you just miss it (Mitchell [interviewed by author] 2003).

He continues,

> [C]lash detection is one and from the customer point of view the coordination of multi-disciplinary systems clash detection is a very powerful tool. The second one is logic, does every room have a door, otherwise we cant get out of it. Is there a route from every room, every space of type room to the exit, to the external. (Mitchell [interviewed by author] 2003).

He concludes, *"Contractors are starting to see the benefit of object model data but designers actually architects should see that the object model is the environment for design"* (Mitchell [interviewed by author] 2003).

Before the advent of rapid prototyping machines[182] the facility was not available to generate artefacts directly from digital files. A physical artefact generated from a 3D digital file is seen by ARM as a positive contribution to the dialogue between the architect and the computer, as evident by the use of

[182] Rapid prototyping machines is a name given to a number of various technologies that can produce a 3D artefact from a CAD file within a relatively short period of time, usually 4 to 24 hours.

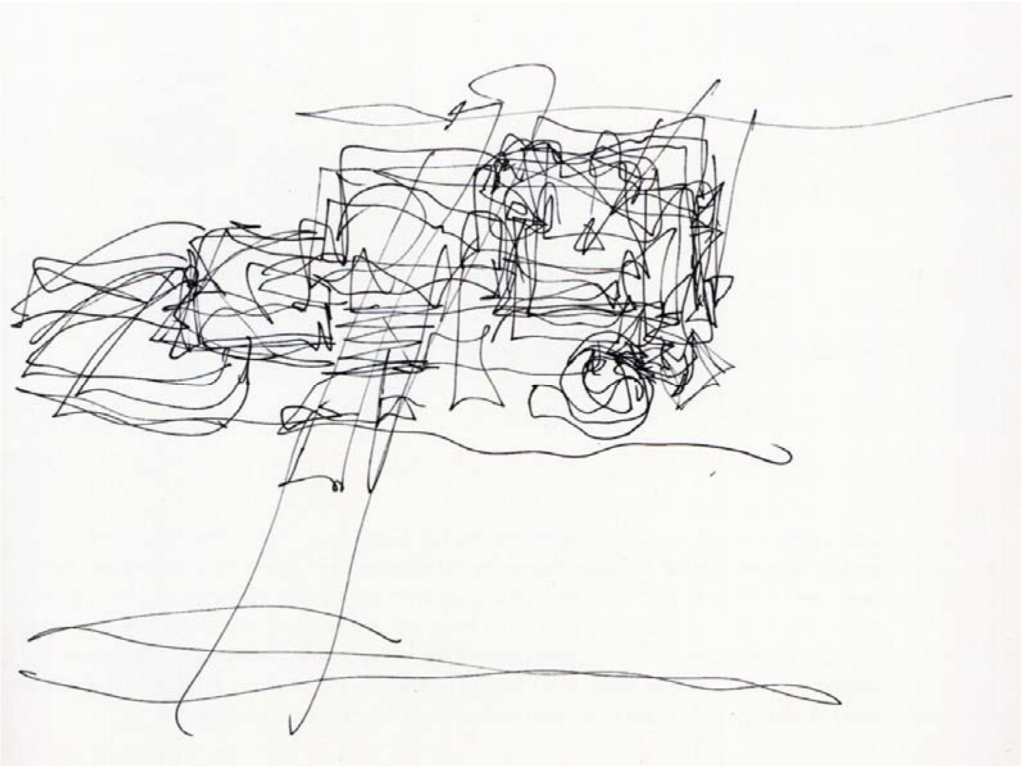

Figure 63 GMB, Early Sketch.

their systems to fabricate the panels for many of the external claddings (Figure 61, Figure 62, p.176). The significance of the physical artefact to data file is that it establishes a relationship previously only available in reverse; a 3D CAD model made physical rather than a 3D artefact measured and made digital.

ARM's selective use of multiple technologies is in contrast to FOG&A who used a single proprietary system (with the exception of BOCAD (2004) - a steel milling software package which can interpret the CATIA database) throughout the GMB project. The conceptual design for the GMB was initially developed on paper (Figure 63 p.178). From Gehry's sketches, the project progressed through a series of physical models and then used a FAGO arm[183] to convert it to electronic form. They then used CATIA for the design development, documentation and delivery (Novitski 1992). The seamless delivery from concept to realisation at the GMB project was a product of one package.

[183] A high tolerance spatial measurement device used originally to measure anatomical details for medical use.

This dialogue between architect and computer technology cannot be reduced to a generalisation. Godfrey saw a divergence in the way CAD was being used, into the separate areas of designers and CAD operators in architectural practices.

> [R]espect of computer applications within the profession. I see a sort of dual paradigm of the CAD operators and designers. …. which in many architectural practices, many but not all of them, sort of split the practice and provided a duality (Godfrey [interviewed by author] 2003).

This delineation added an extra level of complexity as in the worst case a designer would instruct a CAD operator who would interpret those instructions, hence decoupling that direct connection between architect or designer and the form making CAD abilities. Godfrey goes on further to qualify his position when considering the role non-designers exerted on architectural design. This was because the CAD operators enjoyed a closer working relationship with the technology; they were in a position to influence what was produced from that technology.

> Those of us who were advocates pioneering at that time are pretty horrified to see how the profession adopted that split paradigm to computing and to have AutoCAD operators basically having a big input into the way buildings were designed was not really what people had in mind (Godfrey [interviewed by author] 2003).

Both Raggatt and Gehry love to break the rules when form making, and both have engaged with the computer's ability to take their concepts and turn them into architecture. It has been suggested by Lindsey that Gehry's sketches post-CATIA are more capricious than those pre-CATIA. The suggestion is that FOG&A understands the ability of the software to realise his initial sketches hence he has increased the flamboyance of his sketches. He is trying to identify the boundary of constructability by ongoing dialogue between the sketches and the computer's ability to generate forms from it. Gehry's drawings have no doubt been influenced by the degree of freedom that the computer has allowed (Lindsey 2001 p.54).

The ability to generate large amounts of digital design data at early stages of the GMB allowed the architects a large degree of freedom in generating designs which could not be considered viable without the improved computer technologies. Whilst ARM extensively used computer technologies they did not use the same facility for the seamless transfer of data as FOG&A. However they did use the technologies available to them in a way that connected previously unconnected areas of architectural endeavour. This, underpinned by the procurement method, allowed an innovative dialogue between the designer's motivations and the computer's ability to represent the architect's vision in a commercially viable timeframe.

5.1.4 Technology Transfer

This sub-section will look at technology transfer and the skill sets that it has affected. The take up of unfamiliar technologies is indicative of the ethos of embracing new ways to work. This required the fostering of pragmatic relationships which combined the evolving technology with the context in which it was placed; for example, the procurement environment. The willingness to undertake technological transfer played a role in facilitating successful relationships between parties which did not initially share compatible technologies.

One such example of this interaction was the 3D surface CAD model that the architects used. This was a model that could not be manipulated by the structural engineers without instruction from the architects, as Ashton explains.

> We taught them how to use the software. So it was sort of a technology transfer going on there so they could use our software. They didn't actually do the shop drawing in our software, they do it in their own software but they needed to be able to operate our model so they could check things (Ashton [interviewed by author] 2003).

A cross-fertilisation of skills was noticed by Casey during the project.

> I certainly think there was a transfer of knowledge there as well. So I think there was much more transfer of knowledge than through a normal construction because they also used the one system which never normally happens in terms of the internet and all of that. That never happened before; everyone keeps their own systems (Casey [interviewed by author] 2003).

She continued by saying that it fostered a series of dynamic relationships which utilised the various parties' strengths in cooperation.

> [W]hat happened; I thought very well, was the exhibition designers and our museum staff did really work very closely so there was some knowledge exchange which assisted there. And I think we assisted, we produced for instance with the builders' documentation about what sort of material you should use in developing displays because you have got to have non-toxic material and light levels and all of that, so I

> wouldn't mind betting that out of this project the building side and the smaller contractors picked up a lot of experience and I certainly know that the central area of Peter Wright's area assisted those smaller (Casey [interviewed by author] 2003).

ARM's desire for complex form generation led them to use a technology which was primarily developed for generating and manipulating 3D forms for visualisation. This is in contrast to the software used by FOG&A as it did not come with the added 'object oriented'[184] functionality that CATIA offered, as aerodynamics are about how the physical world interacts, whereas visualisation is concerned with appearance.

FOG&A did not push architectural software to the limits as a reasonable person may think from looking at the GMB. They simply took a product from another industry and shaped it to their means. The experience of Rick Smith of FOG&A, an aerospace computer expert, and his and others' use of CATIA software shows in the GMB how successful an individual can be with an ability and inclination to span this gap. James Glymph also brought a wealth of CAD knowledge with him to FOG&A (Lindsey 2001).

The near seamless data stream of FOG&A's output was generated by a package that was designed for multiple suppliers and fabricators. The CATIA package was a known quantity for design to fabrication, whereas the 3D MAX animation modelling software used by ARM at the NMA was not. Hence there is a clearer connection between manufacturing industries and the GMB than between the NMA and the procurement systems which influenced the way in which the NMA was procured.

5.1.5 Research & Development in Architecture

In this sub-section Research and Development on the NMA is considered. It shows that R&D is rarely an option for practicing architects and was not a client encouraged activity of the NMA project.

When Craddock Morton, an experienced Commonwealth public servant and the manager of the Commonwealth Government department overseeing the museum project (which acted as the defacto client), was asked whether the Commonwealth Government envisaged a component of the budget to be used by the architects for a research and development fund he replied,

[184] Object oriented is an approach to CAD systems which 'see' objects with additional properties, not just start and end points for 2D vector lines.

> It was an issue which I don't think ever arose because any architectural problems and the cost of researching or solving them had to be built into the overall budget sum that we had, and there would have been a substantial amount of preliminaries in terms of R&D. But during the life of the project when we hit problems as we quite often did because you have got to understand we were making decisions all the time in terms of the ways that we could enhance qualities thereby decreasing costs, or we could make savings of at the same time maintaining quality. There were quite a lot of changes made and we had to constantly take design decisions (Morton [interviewed by author] 2003).

The Commonwealth Government saw itself as not having an articulated or even un-stated policy with regards to research & development used in the construction of the NMA. However, the Commonwealth Government was concerned with the budgetary position and the financial impact of creating architectural *firsts*. Craddock Morton explains that the Commonwealth Government department's position on research & development was a matter between the alliance partners.

> I think it is fair to say it wasn't driven by the client but it wasn't opposed by the client either. The architects had their space but in doing what they were doing they had to take the rest of the alliance along with them, which included the client. In terms of encouraging R&D and new technology and new ways of doing things as Bruce [Henry] said it was much more in the exhibit side of things (Morton [interviewed by author] 2003),

As architecture is a competitive field there is little time for uncommissioned research & development or the pursuit of new technology for the sake of intellectual curiosity. To step off a well worn track into unfamiliar terrain when you are dependent and depended upon seems counter intuitive to productive gains.

Godfrey cites an overseas example of successful use of object oriented modelling due to a forward looking government policy.

> There are some impressive degrees of integration; the place that it is most advanced is Finland. There is some superb work there. Basically, the government committed to… it's just amazing the government has committed that by 2010 the Finnish building industry will use object based modelling as the major underpinning technology (Godfrey [interviewed by author] 2003).

As Godfrey asserts, the pace of research and development and the corporate will to make new technology successful is paramount if architecture is to fully utilise the opportunities offered by advances in computer technology.

> We heard time and again that was a necessary prerequisite for 2D CAD introduction. You needed a director who was committed and who was prepared to take risks. Without that you can have the smartest people in the world in the organisation and nothing will happen (Godfrey [interviewed by author] 2003).

That ARM used more than one new (to them) software package on the NMA project bears testament to their predisposition to find new insights into their design via the functionality afforded by the computer. This philosophy was underpinned by the collegiate ethos of the Acton Peninsula Alliance.

Godfrey categorises the building industry as being unable to finance a realistic level of research and development, as he also characterises the industry as being a major driver in the adoption of new technologies in the AEC sector, "*the building industry has no capital. It's notorious for how little it spends on research and development*" (Godfrey [interviewed by author] 2003). Research and development in the Australian AEC sector is not as prominent as it is in other areas of industry such as the automotive industry. Hence any major advances in this sector are the product of a long gestation period characterised more by trial and error rather than by systematic research and development.

The history of the Disney Concert Hall highlights the influence of the research and development at the GMB. Both the Lewis house and the GMB show how vital the research and development activities were to the success of the post-Guggenheim Disney concert hall, as Glymph states "*The project, begun in 1989 and halted in 1994 due to budget concerns, benefited from more acceptance of computing in design when it was restarted, post-Bilbao, in 1997*" (Glymph in Snoonian 2002 p.3).

As Gehry asserts, research and development funds given to his office during the Lewis project returned dividends for subsequent projects.

> During this period Mr Lewis in Cleveland asked me to do a house for him which I didn't really want to do. It was another rich guy's house and I had trouble with that for some reason, my socialist background or something, but he begged me to do it and wanted to do it so we started work on it and I realised he would probably never build anything like that but he enjoyed the game of it and he got me to get Philip Johnson involved, Klaus Oldenberg involved and Frank Stellar and Peter was having a lot of fun and I was too because it lasted five years and we were able to develop and evolve technology for glass curtains that is used here in this building. We were able to evolve the computer to the wall systems of bending steel, the skin systems we were able to exploit. It was a five year, I call it a private McArthur

> grant that Peter gave me and paid for five years of architectural research. It really paid off in here [GMB] and in several other buildings (Gehry in Blackwood 2000).

Gehry's experience with Peter Lewis is extremely uncommon. The benefits of Gehry's R&D efforts at the Lewis House are obvious in his work at the GMB. Traditionally neither architects nor their clients have the time or resources to investigate the connections between the intentions and the systems which delivered them. As Cocke asserts "*Where does a profession where profit margins are already so low get the money and time to develop these new tools*" (Cocke 2000 p.55). His assertions are supported by the Australian Bureau of Statistics figures which show after tax and other duties the construction industry operates on extremely small margins compared to the financial risks it assumes. "*Total operating income for the construction industry on 2000-01 was $97.4m. Total operating expenses was $89.6m. Total operating profit before tax in 2000-01 was $7.7m*" (Australian Bureau of Statistics 2004).

5.2 The Acton Peninsula Alliance

This section considers the structure and operation of the Acton Peninsula Alliance. Most traditional procurement methods are based on an adversarial system which presupposes that there are individual issues about design that are most appropriately resolved through contractual means. This led the individuals on site to be wary of any situation which might lead to professional or personal conflicts. This section also outlines the strengths and weaknesses of the procurement method and explores the connection the method had with the use of computer technologies. It highlights the major role that the human factors contributed to on the operation of the system, as any new computer technology should be understood in its specific context.

An economy of design information or the 'as needed' approach to design information is implemented using as few points of perspective as can practicably (safely) be given. This is due to a combination of the constraints of time and potential misunderstandings leading to the possibility of legal action.

> The alliance agreement provides for a total potential quality award of $3 million, which can be earned by the commercial a80lliance members through the achievement of outstanding quality on the project, and for a total potential penalty of $2 million for poor quality (Independent Quality Panel 2002 p.35).

The Acton Peninsula Alliance partners were made up of the following members as shown in Table 6 (p.186),

	Members
Client	Commonwealth Government of Australia, represented by the Construction Coordination Committee and supported by the Department of Communications Information, Technology and the Arts' Construction Coordination Task Force.
Acton Peninsula Alliance members	ACT Government. Commonwealth Government. Architects (a joint venture of Ashton Raggatt McDougall and Robert Peck von Hartel Trethowan). Exhibition Design Anway and Co. Project Management Bovis Lend Lease. Security and BMS Contractor Honeywell. Building Services Contractor Tyco International.
Sub Alliance Members	Structural Steel National Engineering. Facades and Glazing G James. Landscape Urban Contractors. Audio Visual Canberra Professional Equipment. Exhibition Fabricators Classic Resources, Design Craft, Stag Shopfitters, UTJ. Object Mounting Thylacine Exhibition Preparation.
Specialist Consultants	Landscape Architects Room 4.1.3. Structural Engineers Ove Arup and Partners, Taylor Thomson Whiting. Traffic Engineers Ove Arup and Partners, Hughes Trueman. Mechanical Engineers, Electrical Engineers, Fire Engineers Bassett Consulting Engineers. Fire Engineers Ove Arup. Communications Engineers Diverse (Tyco). Security Engineers Honeywell. Civil Engineers, Hydraulic Engineers Young Consulting Engineers. Lighting Vision Lighting. Project Managers TWCA (up to design development), Acton Peninsula Alliance (post design development). Quantity Surveyors Slattery Australia (up to design development), Donald Cant Watts Corke (advisors to Commonwealth), Wilde & Woollard (BoQ). Access Consultants KLCK. Acoustics Bassetts, Eric

	Taylor and Associates.
Project Management Team	Craddock Morton (chief general manager); Peter Wright (project manager); David Waldren (design manager – buildings); Garry Eggleton (cost manager); Philip Johns (design manager – exhibitions).
Architectural/Landscape Project Team	ARM/Robert Peck Hartel von Trethowan — Steve Ashton, Howard Raggatt, Ian McDougall, Robert Peck, David Waldren, Ken Bool, Alan Ball, Allan Flynn, Andrew Hayne, Antony McPhee, Catherine Evans, Chris Reddaway, David Homburg, David Murrell, David Pryor, Diana Jones, Doug Dickson, Ivo Tanevski, Gustav Kroyherr, Jacinta Vines, Jan van Schaik, Jesse Judd, Lilliana Andjelkovic, Lorenzo Gelati, Natalie Plumstead, Neil Masterton, Nevena Bresoska, Nikolas Koulouras, Paul Dash, Paul Minifie, Peter Ryan, Poh Raggatt, Rod Newton, Sally Hieatt, Simon Shiel, Sue Adams, Sue Dove, Tim Wright. Room 4.1.3 — Richard Weller, Tom Sitta.

Table 6 Acton Peninsula Alliance Teams and their members.

As part of the overall philosophy driving the Acton Peninsula Alliance, the alliance partners were coalesced into one unified and recognisable entity as a deliberate strategy. As Peter *et al.* attest, “*The Acton Peninsula Alliance is the corporate identity established to separate individuals from their own organisations and form a team specifically focused on the NMA / AIATSIS project*” (2002 p.18).

The alliance system was ultimately adopted as it was seen to be the only method that could conceivably deliver the NMA within the required project parameters. Initially the partners needed to instigate a management structure incorporating senior members from the alliance partners who could commit their partnership entity to particular courses of action. To satisfy this they set up an Alliance Leadership Team (ALT) (Table 9, p.193) which was responsible for the project, and who then set up a Project Management Team (PMT) (Table 10, p.194) to be responsible for the management of the project, with its members drawn from the client body and the commercial partners.

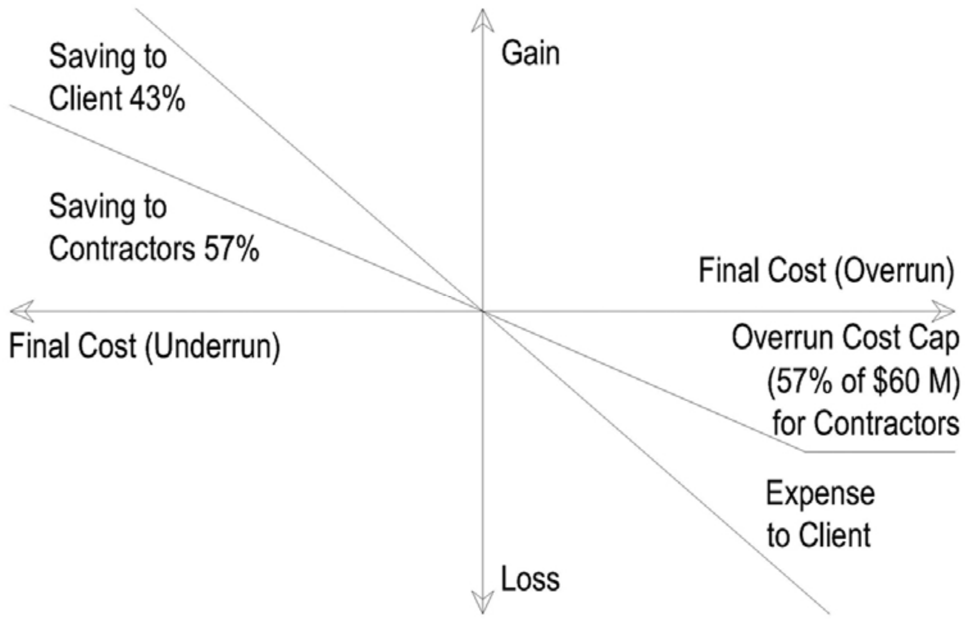

Figure 64 Acton Peninsula Alliance Cost Implications (Peters *et al.* 2002).

This consequently led to a more inclusive and collaborative set of relationships. The Acton Peninsula Alliance replaced the usual request for information and other contractual devices with two independent panels. A Design Integrity Panel (Table 7, p.188) oversaw project issues which impacted upon the architectural design of the completed building. Similarly, an Independent Quality Panel (Table 8, p.190) considered matters of finished quality. Both panels were made up of individuals from the various partner entities.

> The Independent Design Integrity Panel was formed to protect the original design concept from inappropriate change. The project alliance had been established to reward participants on successfully achieving time, cost and quality. The concern was that an over-zealous team focussed on being innovative to achieve outstanding results in time, cost and quality might erode the original design intent (Peters *et al.* 2002 p.51).

This new Government-instigated procurement environment contained many initiatives aimed at improving what was considered to be a less than perfect existing system. This was a conscious effort to provide a template for future projects "*The Commonwealth Government: wanted to lead the way or the future of the building construction industry*" (Peters *et al.* 2002 p.15).

Panel	Member	Company
Design Integrity Panel	Professor Michael Keniger	Head of the School of Architecture and Planning, University of Queensland, architectural advisor to the CCC during design competition
	Mr Leon Paroissien	Former Director, Museum of Contemporary Art, Sydney, previous member of the Evaluation Committee for selection of the exhibition design team

Table 7 Design Integrity Panel Members (Peters *et al.* 2002 p.51).

The following subsections will examine how this previously unused procurement system was perceived by those involved and how it altered their behaviour from the more traditional way of working.

5.2.1 The Alliance Process

This sub-section outlines the issues concerning the procurement system at the NMA. It gives an insight into how the alliance system was structured and used, and what the expectations were. The understanding of context is integral to understanding what was achieved with technology.

> The Acton Peninsula National Museum Project uses an alliance concept which is a radical departure from the traditional lump sum fixed time tender that has characterised many of the projects completed in Australia and overseas (Peters *et al.* 2002 p.336).

This was a first for the AEC sector. Peter *et al.* point out "*The Acton Peninsula Development is the first major building development in Australia awarded on the basis of a joint alliance contract, including the building and services contractor*" (2002 p.451).

The underlying culture and the personal experiences of the people involved determine whether they consider computer technologies as hostile, empowering or marginalising. These competing perceptions are based on disparate understandings and perspectives of how they are to be employed.

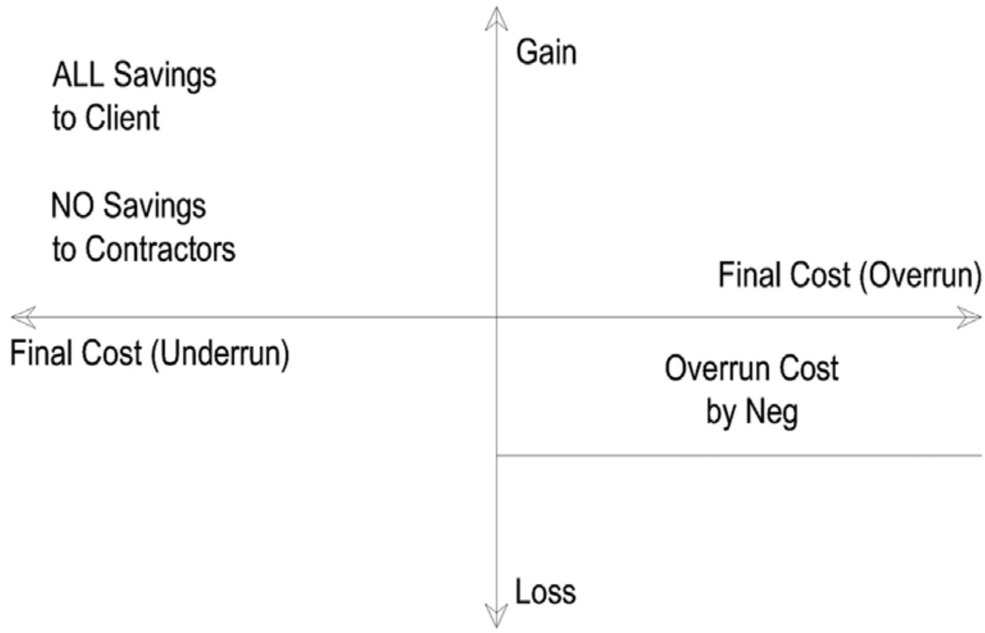

Figure 65 Cost Implications (traditional).

At the NMA and the GMB, computer technologies facilitated the design, documentation and distribution of data amongst those who needed it in very different ways. However, the computer technology was not the sole reason for the success of the NMA. The manner in which the project delivery team approached the connection between the procurement system and the computer technologies which facilitated the interchange of information was crucial. There was a general feeling (amongst the interviewees for this thesis) that the alliance process reshaped the traditionally ascribed roles. Consequently this unfamiliarity required participants to re-examine their usual ways to interact. This non-traditional procurement environment allowed for the architects to be contractually engaged on the basis of their design concept in much looser terms than under a traditional procurement environment.

> The architects were selected on the basis of a design concept ... Therefore, DCITA considered that it was important for integrity of the design concept to be maintained until development of full design documentation (Auditor-General 2000 p.100).

The novelty of this new procurement system also concerned the Government solicitors who suggested:

> A slightly modified traditional fixed lump sum contract. Blake Dawson Waldron, one of the external solicitors, had reservations but recommended that it was necessary that the contract be specific for

Panel	Member	Company
Independent Quality Panel	Professor Michael Keniger	Head of the School of Architecture and Planning, University of Queensland, architectural advisor to the CCC during design competition
	Mr Leon Paroissien	Former Director, Museum of Contemporary Art, Sydney, previous member o the Evaluation committee for selection of the exhibition design team
	Mr Ron Black	Management Consultant and former general manager of ACT Capital Works and senior executive at the National Capital Development Commission

Table 8 Independent Quality Panel Members (Peters *et al.* 2002 p.53).

> the particular project – not an *off the shelf* type of contract (Peters *et al.* 2002 p.14).

This unfamiliarity prompted the CCC [Construction Coordination Committee] to qualify under which set of conditions the alliance process could be replaced by a traditional procurement method.

> The CCC however reserved the right to alter its decision and revert to a conventional lump sum tender approach if any of the following occurred:
> - The winning design team strongly objected to an alliance
> - A risk reward regime proved difficult to define, and
> - The quality of the tenders indicates a lack of interest from major players in working within an alliance framework (Peters *et al.* 2002 p.14).

Due to the novelty of this system and the resulting absence of a template for how to define innovations such as risk/reward system, the partners developed in consultation with the client the benchmarking process. The risk reward mechanism was a financial argument that contracted the alliance partners together in a contractual device which would return a share of any cost savings to the partners but would also make them liable for any losses (Figure

64, p.187). This arrangement is a major departure of the traditional method of allocating financial liabilities within a building project (Figure 65, p.189).

The most significant or driving issues for the successful outcome of the NMA project were identified by Peters et al (2002) as the following:

- The Commonwealth Government allocated a fixed budget for this project and the client body (DCITA) expressly stated in their initial contact with the possible alliance partners that the budget was absolutely to remain unchanged.
- Due to the celebration of the Centenary of Federation, and a pre-arranged visit by Her Majesty the Queen for 12 March 2001, the timescale of the project also could not be changed.
- Due to the significance of a national museum, the client body required that the quality of the finished building be of a high standard.
- The complexity of the museum required that the development of a brief be an ongoing proposition. To this end it required an ongoing co-operative relationship between the client, the alliance partners and the end users.
- In contrast to the complex nature of the design, it was envisaged that the buildability of the museum was to be resolved within the parameters of the timescale and budget.
- Due to the Commonwealth Government's desire to raise the probity of the construction industry, they took a pro-active approach in raising their standards.
- The integration of the architects, exhibition designers and construction teams was a large management task.
- Due to the traditional practice of full documentation followed by variation, the NMA's client body did not require full documentation.
- There was a concern that the high level of risk and cost was being carried by the Government.

No system other than project alliancing was seen to be able to satisfy the drivers above. Hence the expectations were that a joint venture was the only viable way to realise this project within the pre-defined constraints of the project. This expectation was tempered by the unfamiliar position the client (or their legal advisors) would find themselves in.

> Jim Service[185] said the construction industry needs to be given more time. We had to build this he said, 'Dawn, look at a joint venture'. That's the way we should possibly look at in terms of between the services and the engineers given that the services and the builder, given that services are a significant component of the building and so we did have a project management team at that stage and we got advice within the department that you can go with a joint venture and all the advice that was coming out of Attorney-General was: Who do they sue? (Casey [interviewed by author] 2003).

The Government's legal advisors were concerned with the newness of the system.

> The response from the Australian Government solicitor was relatively negative towards the alliance approach proposed. One of the key arguments against the use of alliancing was *that it was new* (Peters *et al.* 2002).

This new legal environment in which the alliance partners were operating was not only of concern to the Commonwealth Government's lawyers, but also to the architects. The reason for the architect's concern was not primarily legal but was more concerned with the authority to finish a design in the architect's particular manner. McDougall comments that this redistribution of design influence could adversely affect the adoption of these alliancing systems for future projects.

> I think the failure of it being taken up widespread is you have to give up the positions of power to consolidate into a powerful entity with various participants, hybrid participants and particularly the government were strong in… by strong I mean confident enough to say, 'We will surrender the position and come to the table as a participant' (McDougall [interviewed by author] 2003).

Raggatt describes one view of this unfamiliar environment, when he states, "*We're not really used to operating like that because we are just professionals*" (Raggatt [interviewed by author] 2002), comparing this project to previous works that ARM have undertaken.

[185] James Service AO, Chairman of the Advisory Committee on New Facilities for the National Museum of Australia (NMA) and the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS).

Role	Name	Company
Solicitor	Graham Thomson	Mallesons Stephen Jacques
Accountant/Probity	Mick Allworth	KPMG
Facilitator	Andrew Hutchinson	JMJ Associates
Client	Craddock Morgan (observer)	Department of Communications, Information Technology and the Arts
Client	Dawn Casey (observer)	NMA (Director)
Architect	David Waldren	Ashton Raggatt McDougall Robert Peck von Hartel Trethowan
Exhibition Designers	Philip Johns	Anway & Co
PMT Representative	Peter Wright	Bovis Lend Lease (Civil & Civic)
Construction Manager	Goran Adzic	Bovis Lend Lease (Civil & Civic)

Table 9 Acton Peninsula Alliance Leadership Team Members.

This environment where innovations were encouraged gave rise to many project management initiatives, as Peter Wright, the project manager for the NMA project with over 30 years experience of major projects in the construction industry, recalls.

> Out of the hundred things we tried eighty per cent were successful, twenty per cent weren't but we fixed that really quickly because if it didn't work we stopped it and tried something else; whereas in a much more structured environment where the contract is an inch and a half thick and you would need to seek approvals and all sorts of things (Wright [interviewed by author] 2003).

As the environment was not strictly constrained by legal documentation, greater latitude was allowed by experimentation within the bounded project delivery system. This flexibility allowed a greater degree of freedom to implement change than the alliance partners were accustomed to in their previous experiences.

> The iterations, did you say? Oh, I think the alliance made it possible for there to be more iteration because the contractual relationship was more fluid. That is, the contractual architecture between all parties was more fluid than it is in normal building situations so there weren't big contractual penalties for going back and rethinking something or

Role	Name	Company
Client	Craddock Morgan	Department of Communications, Information Technology and the Arts (director)
Client	Margaret Backhouse	Department of Communications, Information Technology and the Arts (NMA Design Coordinator)
Client	Steve Costello	Department of Communications, Information Technology and the Arts (Alliance Secretary)
Architect	David Waldren	Ashton Raggatt McDougall Robert Peck von Hartel Trethowan (Design Manager)
Exhibition Designers	Philip Johns	Anway & Co (Project Manager)
Contractor	Peter Wright (Chair)	Bovis Lend Lease (Civil & Civic) (Project Manager)
Contractor	Goran Adzic	Bovis Lend Lease (Civil & Civic) (Construction Manager)
Contractor	Gary Eggleton	Cost Planner
Client Advisor	Bruce Henry	Bovis Australia (Manager)

Table 10 Acton Peninsula Project Management Team.

> changing something even quite deep into the process provided there was a reason to do so (Ashton [interviewed by author] 2003).

Although the alliance process created the flexibility to implement change an intangible, but integral, component to the success of the museum project was the goodwill of those involved. This discrete quality defies easy quantification.

> [I] think probably the way it could have been, could have been a lot more difficult than it was. The degree to which the alliance participants were committed to alliance philosophy was generally high and that commitment is in a way quite a subtle thing and not easily documented (Raggatt [interviewed by author] 2002).

This illustrates that the lines of demarcation were not as neatly defined as the alliance partners' previous projects. This led the partners to developing new management and construction techniques. Notwithstanding the museum's complexity the innovations in this project were seen as being more significant in terms of the management philosophies than construction or design technologies. Peter Wright recalls, *"A lot of the stuff we had never done* *before, not so much the physical building, more the management approaches and the contracts we set up"* (Wright [interviewed by author] 2003). He continues by explaining how this impacted upon how he perceived his actions were viewed by other members of the alliance partners,

> [W]e were a little bit of a law unto ourselves, some of the organisations who were members of the alliance, especially the one I was working for at the time, not so much the senior members but the middle managers who weren't involved in the project struggled a bit with that because they saw us - well me - as a bit of a maverick off doing our own thing (Wright [interviewed by author] 2003).

The structure of the alliance allowed more latitude with ways to work but the risk/reward mechanism demanded a more focussed approach. This risk/reward mechanism was viewed as not only facilitating innovation but systematically advancing it. It explicitly negated any perceived benefit to an individual alliance partner, as described by Dawn Casey.

> [I]t really forced people to look at innovation and looking down the barrel at a one and a half million dollar overrun and no-one is going to give up on parts. Like some of us would say, 'Well, Howard take down the loop', and we couldn't agree on that and we stalemated so people had to come up with great ideas, and that is what it did. You'd talk to James [G James] and they did some really clever things - people who were doing the structural engineering, the façade and the loop and for me that is what was good, it drove innovation, it really encouraged innovation (Casey [interviewed by author] 2003).

The disadvantage was pointed out by McDougall when he voiced concerns that the alliance process gave less design authority to the architect whilst exposing them to a greater financial risk, for example, a potential percentage of the overrun cost. However he does qualify this statement by stating that the project administration requirements for this project were less complex and time consuming than had been in his experience previously. He saw a difference in the responsibilities/authorities traditionally given to the architect and compares the alliance with motivation systems.

> The alliance side is difficult because people don't trust it because they don't know it. However, I think the risks are sort of less, certainly on paper under alliancing and even though we had to spend a lot of director time up front when it was being set up the process was… the actual delivery was a lot less on the legalistic side of it than we would usually have had. The paper trail side of it is way lower. The paper side of it is way lower on the design and construct contract or a novation where you are not doing traditional contract administration. However, you don't have the power to be a professional architect under that system because you are essentially working for the

> delivery contractor and so while your risk is still high, your professional risk is high. Your capacity to say that is a bad decision is reduced so in fact your risk is higher than under an alliancing system (McDougall [interviewed by author] 2003).

Wright supports McDougall's view of the change in traditional roles. He sees a very different role for the project manager under the alliance system. This role requires a more consultative dynamic than is traditionally the case. He outlines the difference in approaches to a potential problem.

> Traditionally out here, like on this site, if there is a problem the warring parties will come in and sit down and they will look to me to make the decision. Thump the table and say, 'Right, you do this and you do that', and they are happy and they go away, whereas on the museum where the design was really quite difficult to interpret the issues were complex. They weren't simple and we would sit around the table; it might take three hours or four hours to get a decision, but it wouldn't be the traditional me being a dictator saying, 'You were right and you were wrong. This is what we are going to do because I am really smart'. It was sitting around the table with ten people saying we have got an issue and, 'What are we going to do, guys? I haven't got the answer. Go through it in a logical way. What's the problem? What are our options? Which way can we go?' It's interesting when you canvas more feedback you get some really clever left field ideas. So I saw my role as very much trying to ensure that that the whole ethos was maintained, because you get a lot of people saying, 'That is a stupid idea', and you would say, 'Hang on, let the person get it on the table', because you want that person to be. You are not being soft and cuddly, you are just giving him an opportunity to contribute and feel that his views are being listened to and in a lot of cases - not all but some cases -some of those left field ideas that came on and someone would build on it, and it might not be what the initial idea was but it was enough to spark some ideas. So it was more about building on ideas and suggestions than saying me as a traditional project manager (Wright [interviewed by author] 2003):

He continues by stating his preference for an alliance structure by giving the example of his project at the time of the interview. In this project he has adopted as many of the innovations taken from the museum as were practicable. He goes on to describe the benefits to this current project.

> Now it's not as pure as the one at the museum because our contract is not an alliance arrangement although I have tried very hard for it to be more relationship-based than contractual based, and it's going well. Out of a score of ten they are sitting on four now which is nowhere near as high as what we hoped but at least we have got a score of four, zero being business as usual. There are maintenance manuals, as constructed drawings; commissioning is also underway now and not being left till the end. Operations and maintenance manuals take months to deliver after practical completion. We have

> made a commitment that they will be there on practical completion. So those things are working (Wright [interviewed by author] 2003).

Casey, McDougall and Wright all share the opinion that the alliance process required less contractual documentation and this, coupled with a less adversarial mindset, meant there was less need for formal correspondence. Formal correspondence has traditionally been used to request a response to a query. However, it also could be seen as a precursor to, and evidence for, a potential legal dispute. The absence of any formal correspondence could be seen as indicative of a change in the culture reframing the traditional bargaining positions. This is highlighted when Peter Wright states "*The numbers of letters I wrote to the client you can probably count on one hand, which is unheard of - absolutely unheard of*" (Wright [interviewed by author] 2003). He goes further when asked how this compared with a job of similar scale,

> Well, we just finished a job prior which was a $300 million project for the Department of Defence and simply because the contract was different I had files and files and files - not that it was acrimonious, but it was just formal correspondence. This one the formal correspondence was I would suggest almost zero. The reasons for that were: one, we were located in the same space; and two, the contract was such that it was not prescriptive. It did not tell you that you had to achieve something. You had to go through the process. The contract in really crude simple terms stated, 'Go out and build a really great building'. There is more to it than that but basically, go out and work together as a team, set up your own systems, and deliver a fantastic finished product and do it in a manner that is equitable, fair with a no blame culture, working in a true team (Wright [interviewed by author] 2003).

Wright's characterisation of the lack of adversarial activity was shared by others involved in the project. "*Its focus is on outstanding results and not protecting one's turf and contractual position*" (Peters *et al.* 2002 p.7). This less litigious environment was also seen as an effect of the alliance process by Morton when he qualifies his lack of experience with this type of project.

> [B]asically we had to generate a new culture because had we operated in the normal adversarial way we would not have got there in time. So generating a new culture meant instead of us sitting down and fighting for whose fault it was and looking backwards, the new culture was to turn that completely around and sit down and work out what the challenge was, what the solution was and how quickly we can put it in place. As I say again for us it wasn't a new culture because we didn't know anything ourselves but for the rest of our partners it was a very new culture (Morton [interviewed by author] 2003).

The alliance process with its inherent transparencies of reasoning between parties allows for innovative solutions to problems which would have traditionally been resolved with litigation or lengthy, time-consuming and acrimonious arguing. McDougall summarises this when he says, "*It doesn't remove the conflict entirely but at least it puts the conflict into a much clearer perspective*" (McDougall [interviewed by author] 2003).

Keniger gives an example of where he believes the alliance structure demonstrates its advantages over traditional structures.

> This overlap between the construction and the fitout of the exhibits could have been problematic rather than the successful outcome of the collaboration between the quite disparate areas of expertise. The placement of the exhibits into the shell of the building was a further demonstration of the value of the cooperative ethos that seemed to pervade all aspects of the project (Keniger [interviewed by author] 2004).

Bruce Henry[186], the technical manager for the NMA, also characterised the Acton Peninsula Alliance as the most crucial element in the on-time completion of the museum, "*We had to do something to build it in that timetable. I just can't imagine how else you would do it*" (Henry [interviewed by author] 2003).

The reluctance to do things differently is not only a common trait of those with experience of the adversarial system but was also reinforced by the Commonwealth Attorney General Department's misgivings regarding the difficulty of attributing and quantifying legal responsibilities. The way to apportion responsibility is more clearly defined under the traditional adversarial system.

The lasting impression left by the Acton Peninsula Alliance experience was that even when a project delivered under an alliance was not perceived as a success, the alliance could still be seen as a major factor in lessening the negative outcomes of a project. This is articulated by Bruce Henry.

> There was a project prior to the museum - BHP hot brickette up in Western Australia somewhere which was not as successful a project but the general consensus is if there wasn't an alliance it would have been even less successful. So it is relative (Henry [interviewed by author] 2003).

[186] Bruce Henry is now the manager of the project consultant company Xact. He was formerly the Technical Manager for the NMA project.

Over the years the industry has accumulated an understanding of the conventional procurement methods and is conversant with the avenues for legal action based on previous experiences. The alliance procurement system still contains many unknowns as it has not been used enough to allow a critical analysis of its strengths and weaknesses based on completed projects. The alliancing system promotes the idea of all parties contributing to all problems, and as a result of this there is a change to the level of authority an architect can impose over a design solution without reference to other interested parties. Stephen Ashton qualifies his support for the alliance process when he says,

> I don't want to say it is some sort of Elysian fields for architects, it's not - most of it is business as usual but when you get to the problems then they are treated differently, I would say (Ashton [interviewed by author] 2003).

This new culture relied upon the acceptance of all those who were involved in it. Hence, the senior people in the project needed to lead by example. The notion that senior personnel from the alliance partners advocated strongly the benefits of alliancing systems added to an overall feeling that the NMA project was more a collective effort than direction passed down through a hierarchical structure. This structure led to a greater connection to and transparency of decision making which increased the feeling of ownership beyond the narrowly defined hierarchy, as Wright states.

> I am passionate about it, but the key, and I tried to stress it earlier, this whole thing is about leadership. For it to work you need people like Dawn who are senior people within their section or group or firm or company or government agency to be committed to it and passionate about it. To give you an example: Dawn was passionate; Craddock was passionate. Craddock reported directly to the secretary of the department, Dawn reported directly to her chairman of the NMA Board. I reported directly to a company that I worked for (Wright [interviewed by author] 2003).

A major factor in the success of the NMA project was the acceptance of the guiding principles and stated aims of the alliance, at both company and personal levels. The goodwill that was generated by the equitable and ethical treatment of all the partners created an environment where both successes and difficulties were considered as products of the entire team. Hence, any pragmatic devices (such as the enabling computing technologies) were largely accepted as an opportunity to increase the efficiency of their working relationships.

5.2.2 Architectural Design under an Alliance

This sub-section deals with how the alliance process affected the traditional understandings of architectural design. A theme that emerged is that of the integrity of architectural design as it was affected by the procurement system. The NMA project as part of the alliance structure incorporated two panels charged with the responsibilities of maintaining the quality of the finished product and maintaining the integrity of the architect's design. These panels were an innovation of this particular alliance structure and were mandated as part of the original negotiations. This relationship-based method of delivery was mediated / arbitrated by a design integrity panel. This panel developed a definition of design integrity at the NMA, as stated below.

> The intellectual and physical persistence and manifestation of the design concept; the conceptual aspirations of the project and how these are sustained and fulfil in the final product; and … having no part or element wanting, unbroken, material wholeness, completeness entirety … (from the shorter Oxford) (DCITA 2002a p.11).

The independent review panel was mandated with implementing this definition:

> The independent review panel was comprised of four members and was set up to assist the design integrity working group to
>
> - establish appropriate processes for measuring design integrity;
> - undertake ongoing monitoring and assessment of design integrity; and
> - provide regular written reports on design integrity to the Alliance Leadership Team (Design Integrity Panel 2002 p.5).

In addition to the Design Integrity Panel, an Independent Quality Panel was set up.

> The Independent Quality Panel was comprised of three members and was to provide independent expertise and accountability for the measurement of quality. Specifically the Quality Panel was to
>
> - provide independent verification of the benchmarks, including any subsequent changes should these prove to be necessary;
> - provide independent verification of the procedures for measuring the benchmarks, including auditing arrangements;
> - provide a final report to the Alliance Leadership Team recommending the final total quality score; and
> - provide ongoing advice throughout the project on quality-related issues to assist the project in obtaining the highest possible quality score. (Independent Quality Panel 2002 p.8).

Keniger, who sat on both the design integrity panel and the independent quality panel, describes how the panels were seen initially and how the perception of them changed during the course of the project.

> At first there was the sense that the operations of both the design integrity and quality review panels were treated with reserve, suspicion and with a measure of cynicism. These negative reactions were gradually overcome as it was realised that the panels were not a form of 'style police' or 'glorified clerks of works'. The panels came to be seen as proactive and as contributing directly to the success of the project. They worked within the collaborative spirit of the Alliance but their independence enabled them to question the standards and internal mechanisms of the project. They also encouraged the involvement of others to assist with the resolution of problems (Keniger [interviewed by author] 2004).

He continues by recalling a specific example of how the panels contributed to the project.

> An early incident was the matter of the knot steel work adjacent to the lakeside entrance to the Main Hall. Despite the best efforts of the steel contractors the complexity of the geometry and the intractability of the material had contributed to a less than satisfactory result – or so the Quality Review Panel thought. Discussion of remedial actions involved a mini think-tank amongst panel members, the client, the architect and the construction team. As a result all later similar steelwork was of a far higher standard and the initial glitch was modified (Keniger [interviewed by author] 2004).

Whilst the alliance process was successful in financial terms, Howard Raggatt has reservations about whether the design integrity survived the alliance process. The use of a panel which was charged for budgetary reasons with a function traditionally the domain of the architect has led him to the conclusion that the design influence of the architect under an alliance is reduced. He asserts that the alliancing system effectively and efficiently delivered a product as defined by a panel rather than a project defined by the architect. He continues by making a comparison between the delivery systems of the NMA and the Federation Square project in Melbourne.

> If the Federation Square budget was as rigorous as the National Museum's, then you could probably compare the two delivery systems. The traditional system as long as there's a… especially if there is a bottomless pit of money, which more or less is Federation Square, then clearly that works best from the architect's point of view. It might all be very hard but at the end of the day the architect has authority to instruct everybody to build exactly as they, more or less exactly as they are contracted to do. Obviously, there are difficulties if you don't document something right. Well then you've got to fine

> them. That's not the alliance process. The alliance process is just the delivery product for a cost and on time. It's got nothing to do with delivering the architect's work (Raggatt [interviewed by author] 2002).

When asked to expand on his views regarding the most significant aspect of the alliance he continues, "*It's delivering that product. The architect is a member of that team to deliver that product. The team is not there to deliver the architect's product*" (Raggatt [interviewed by author] 2002).

Architecture is very rarely only the province of the architect, and is usually a series of design adjustments and compromises to suit the many external variables which must be addressed. How these variables affect the architecture is a matter of perspective. Casey is of the view that the alliancing system did not adversely affect the architecture. "*I don't think the architects lost their design. In fact, if anything it was enhanced*" (Casey [interviewed by author] 2003).

These differences in perspective and the architects' role in defending their design are described by critic Dimity Reed[187], in the ABC television documentary 'Inside the Square'. Using Federation Square as a comparison, she comments that against a backdrop of inevitable compromises the architect should be more philosophical about the amount of compromises required. "*The architect's role and their intellectual responsibility is to fight to maintain their vision and little bits get chopped off all the time, but if its only little bits it's not too bad"* (Dimity Reed in Balendra 2003).

Wright describes the difference between his experience on the museum and his previous experiences navigating between the architect's vision and the artefact. He does this by contextualising one particular positive effect in relation to the on-site dynamics.

> If you get these people discussing it, with these people so you close that gap much, much smaller and it becomes this sort of arrangement and that's the vision, that's the physical side of that sort of interaction. If you can get that interaction more and more all the time there comes a point when you have got to stop but the ability for those two to complement each other and that gives you a much better outcome. The old way is to say, 'No you silly fellow, I am smarter than you, this is how you will do it'. And this guy says in the classic Aussie accent, 'Righto mate, f---- you. You are not going to listen to me, its going to take me twice as long and I am going to make a buck out of this, so f---- you' (Wright [interviewed by author] 2003).

[187] Dimity Reed, Adjunct Professor of Urban Design at RMIT, Melbourne architect and a leading commentator and writer on architecture.

Wright's view from a project management/delivery point of view advances a case for strengthening the delivery of architecture through increased collaboration. Not everyone involved considered the alliance process as being an advantage to delivering the overall vision. A perception held by Casey was that Raggatt as the designer was far more concerned to defend the design integrity of the architectural design than the other parties were to defend their respective contributions. "*Howard would have sacrificed his profit, I think his money to maintain integrity in his architecture, …"* (Casey [interviewed by author] 2003).

These relationships were tested by the outcome of deliberations of the Design Integrity Panel, which called for specific alterations to be made to the project which disproportionately affected some of the partners. An architectural element deemed by the panel to be expendable was eventually retained due to the arguments advanced by the partners. However, the issue of the Grand Entrance Canopy was a matter of ongoing debate about its necessity, form and materials. In this instance it was considered by the panel that the mediated solution met the requirement for design integrity although it was not the architect's preferred option. The design integrity process in this case allowed, or required, ARM to rework the design until it conformed within the necessary project constraints as detailed in the Design Integrity Panel's report (DCITA 2002a).

Control over the final product and the role of the architect in an alliance are still a matter of some debate within ARM. The debate centres around a difference of opinion about the level of control architects have in a traditional design and construction environment (Raggatt [interviewed by author] 2002; Ashton [interviewed by author] 2003). Traditionally the architect's financial liability in a project is only of concern to architectural practices if a discrepancy has potential to become a legal issue requiring an adversarial dialogue. The Acton Peninsula Alliance's prohibition on legal action against others coupled with the potential for a collectively incurred overrun cost changed the nature of the areas of financial concern.

The introduction of independent quality and design integrity panels required a non-traditional and innovative discourse between the parties and a dialogue between the architects and others to ease these financial concerns. It gave ARM an opportunity to use the knowledge of others more productively without concerns about financial penalties. These opportunities were not mediated or arbitrated but explored by the architects as part of a team.

The targeted risk reward mechanism placed ARM in the unusual position of being potentially financially responsible (with their partners) for any overruns. There were significant design elements that were either eliminated or were not completed as indicated in the original project design documents. The example of the final design of the grand loop illustrates this point. It is a testament to the cooperative nature of the alliance system that the seemingly more extraneous (less necessary) elements of the architecture were usually retained.

A major difference between the NMA and the GMB was the use of independent design integrity and quality control panels at the NMA. Due to the nature of the agreement between the parties to the Acton Peninsula Alliance, an independent design integrity panel oversaw matters arising from issues about the design which were or could have been altered as part of any proposal for cost saving (DCITA 2002a). The quality review panel considered matters arising from the finished quality of work (DCITA 2002b). These innovations were fundamental elements in the successful delivery of the NMA but as a result ARM lost some control over the final version of the work.

5.2.3 Transfer of Design intent to others

This sub-section deals with the various manifestations of the transfer of design intents. As the design of the NMA was highly iterated, metaphorical and geometrically complex, the main vehicle for conveying this transfer was through computer technologies able to generate the forms. Also, secondary technologies were used to underpin the continuity in the design philosophy from the architects to the people charged with its construction. This gave the workforce an understanding of what was to be delivered. This advanced the idea of documentation as *idea* rather than contractual document. This in turn increased the dialogue between the parties. This dialogue aided the understanding of what the final project was *to be*.

If not informed about the significance of the design elements and how they are a commentary on the Australian story, the highly metaphoric design could lead to an uninformed conclusion about the validity of the design, as Casey explains,

> It does need to be explained but when it is explained people fully understand it and fully appreciate it. It's much more visual. The impact of the metaphor for the average person more so than some other architecture that people talk about. But it is not easily… you do have

> to explain it, but once, when it is explained, people can understand it and appreciate it (Casey [interviewed by author] 2003).

There has traditionally been a disparity between the designer's understanding of the influences that inform the design and how the builders interpret it. The practice of building, unlike design, uses many different trades. The experience of architecture on paper or in virtual space and the experience on-site are very different. Normally the former is an experience driven by philosophy and a sense of optimism about the possibilities of form making or functional analysis, whilst the latter is an experience informed by the pragmatics and complexities of construction. Therefore ARM needed to increase the understanding of what the NMA project was about to aid the transition from virtual to physical.

Images of a philosophical and symbolic nature were used rather than technical data to give a feel for the *big picture,* to increase the level of ownership felt by the whole workforce. To this end a sophisticated collection of both metaphorical and visually accurate images were presented to the workforce during the project. Graphical representations were essential in communicating the aims of the design in a variety of ways. Hence, graphical representation was important in explaining the complexities and subtleties of the project. Peter Wight considered these presentations very useful in bridging the gap between the design intentions of the architects and the design understanding of the workforce (Wright [interviewed by author] 2003). These presentations were done to add perspective to the working drawings. The greater the level of triangulation (multiple points of view) that exists, the better the understanding of the project. Consequently, the workforce would have a greater sense of confidence in their abilities to execute the design in accordance with the design's requirements. The working drawings and the metaphorical image presentation work together because one is static and technical and the other is about ideas; they are not mutually exclusive.

The architects, engineers and project managers were co-located in the same open plan office. The bunker mentality sometimes inherent in professional relationships was not given a fertile environment in which to flourish. An additional positive effect of this co-location was that all the members of the on-site representatives of the alliance partners were aware of the design intents due to their close physical and auditory proximity to the ongoing iterations of design, as Peter Wright asserts when talking about his relationship with one of ARM's site architects. "*He could talk the same language. He sat next to me in the open plan of work and I could hear him and we could talk*" (Wright [interviewed by author] 2003).

A shared vision is a fundamental tenet of successful teamwork. In corporate terms this vision is normally expressed as a vision or mission statement which is designed to be a succinct definition of an entity's strategic direction. With buildings, however, traditional practice is that large groups of contractors and subcontractors interpret architect's drawings as legal documents rather than the documentation of design intent. At the NMA, the workforce was given additional insight into the design intentions of the architect. This was achieved by the design architect, Raggatt, delivering a slide show presentation on-site during the early stages of the project. This aided the workforce in gaining a higher understanding of what was in the architect's mind than was usually the case, as Keniger explains.

> [G]enerally the people on site felt they were informed, the architects met with the contractors, the people building it and explained the design and they didn't explain it in any old terms they had to explain the ideas so you would go around the building and talk to a subbie and he would say I am doing a window that is part of the great knot, and he knew where he fitted and what fitted (Keniger [interviewed by author] 2004).

The use of visual images to elucidate an architectural theme at the NMA received positive responses. The flow of design intent was greatly aided by imparting some of the architect's motivations through visual means to the people who would construct the building. Wright expands on this idea.

> He used objects and clever slides of pictures of things to explain what the idea is. And that is something that doesn't normally happen on projects and something I have done here and I will do on other projects where you get the people who are doing it to understand what's the vision, what are we really trying to do here, and it's not a con. You are genuinely trying to get the people who are physically doing the work, physically, I mean, laying bricks and welding steel, to understand why they are there. From their own point of view they are there to get wages but they are also… ninety nine per cent of the people want to get satisfaction out of it. They want to understand it and get satisfaction out of it and walk home and say, 'Shit, I'm really glad I did that piece of steel work really well because I know what the architecture, the vision is'. Therefore you are contributing to this vision (Wright [interviewed by author] 2003).

These innovations helped to move towards a universal understanding of design intentions, which had a positive effect on the relationship between the designers and those charged with the construction, as Wright explains through his understanding of previous experiences.

> We redefined the relationship between the workers if you like. There is the worker sitting down. Normally, he doesn't get told anything.

> Normally, he gets shouted at. Normally, he gets abused and very seldom a pat on the back and then also sees the architect or management up here as some being who is more intelligent, been to university, is almost a better person (Wright [interviewed by author] 2003).

The Acton Peninsula Alliance impacted upon the level of iteration which computer technologies allow, facilitating an ongoing design development process. This in turn underpins the dynamic nature of the relationship between the contractual parties. Hence in the design process both the technology and the contractual system were well suited to each other. McDougall describes how this process aids in the iteration/development of design ideas.

> The alliance actually attempts to or the alliance atmosphere overcomes that because it is a fluid relationship between client, builder and design team in as much as in they are one group. It ties them into being one group rather than the design team versus the contractor versus the client in some sort of separate rooms. The impact of that is that designs can continue. We would be strong believers in the idea that the more thought that goes into a design the better it is. It doesn't mean that it gets more and more refined, that it gets resolved. Sometimes it gets changed radically if you can think about it longer. The solution has more inputs into it therefore it comes out better. And what happens is there is no point where you rule the line and say, 'We have done that job now we are into dealing with the builder' (McDougall [interviewed by author] 2003).

Both contractual and cultural relationships differ from relationship-based contracting to traditional contracting systems as they develop a culture of highly defined demarcation. This subsequently leads to an insular and possibly prejudiced view of others involved in the project. This, coupled with the architect's passion to deliver their undiluted vision, opens up opportunities for greater interplay of ideas between parties.

The architects explaining the philosophy behind the architecture increased the level of ownership the tradesmen felt for their part. The workers on site understood their contribution to the integrity of the architecture.

> Howard Raggatt from ARM, we used him on a regular basis… the bricklayers and the carpenters - we sat down with them and he would give a forty-five minute presentation about the concept of the design, why the design is the way it is and a lot of symbolism and he was very good because he was very articulate and he knew how to pitch his words to the people who were around the table. A lot of the guys would struggle to speak English. He was able to in very simple plain terms, and yet at the same time sit in a group of academics and talk in a very theoretical way. So he was very articulate and had the ability

> to pitch the words and yet after an hour they would walk out and say now, 'I understand why he wants that thing to curve. I don't necessarily agree with it but I understand why he wants it to curve and why he wants it to look like this' (Wright [interviewed by author] 2003).

This inclusive matter of conveying design intents was also to investigate issues which concerned the Design Integrity Panel and the Independent Quality Review Panel, as Keniger recalls:

> The Design Integrity and Quality panels concerning key issues were guided by three dimensional drawings abstracted from the digital model. Where issues involved matters represented in conventional orthogonal projection I am confident that the information was extracted from the core digital model (2006).

He also recalls that the digital model was instrumental in resolving design issues.

> The redesign and refinement of the entrance canopy (Quality Panel) and the negotiations with the NCA of the design of the external amphitheatre and the impact on existing trees and lakeside landscaping (Design Integrity Panel). These issues were discussed and resolved using only the digital model (3D CAD) with "fly through" presentations being used for the discussion of the canopy. The digital model was also the key tool in the presentation of the design development of the Great Hall (3D CAD) and later guided the discussions of the impact of inserting the museum shop into the space (Quality Panel) (2006).

ARM used multiple CAD programs which required numerous data exchange processes. Despite this discontinuity ARM still produced design information acceptable to the other partners. Therefore, the mode of graphical representation, or the comprehension of form and architectural intent became a crucial element.

Effective 3D graphical visualisation allows any interested party to see the project in real time in a way that is universally understood. This provides a far more accurate understanding of what the project *is* and through the Acton Peninsula Alliance gave the other partners a sense of ownership of the design. Hence the use of a 3D surface model conveyed the spatial experience or portrayed a formal expression rather than generating a database of technical information drawn from the model. Nevertheless it required a personal explanation from Howard Raggatt to clarify what the design *is*, so the cerebral impulses could be translated into an understanding in the tradesmen's mind.

William Mitchell[188], in the 'Reconfigured Eye' (Mitchell 1994), stated we can no longer entirely 'trust our eyes' in an age when image manipulation is commonplace. Hence it becomes more crucial that multiple forms of representation or methods of understanding be made available to allow for a more complete picture, as illustrated in the fable of the elephant and the blind men[189] (Sillar 1968). The mixture of computer generated images and the willingness of the workforce to accept and engage with a highly metaphorically generated building form fulfilled both necessary components for the success of the project. The computer system generated a visual frame of reference and the alliance system provided the environment which actively engaged with the big picture via the visualisation ability of the computer technologies.

5.2.4 Format / Reworking of data

This sub-section deals with aspects of the NMA project which required a reworking of data formats. It considers the implications of non-interoperable formats.

The format of data placed expectations upon the members of the project team who were not familiar with this approach. Fortunately the nature of the Acton Peninsula Alliance fostered a willingness by the rest of the project team to facilitate ARM's way of working which encompassed transitions between software which are not usually required in architectural practices.

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[188] William Mitchell is Professor of Architecture and Media Arts and Sciences at Massachusetts Institute of Technology, and director of the Media Lab's Smart Cities research group and author. *See* http://web.media.mit.edu/~wjm/.

[189] The moral to this tale is narrow understandings of parts of a complex entity can easily result in an erroneous understanding of the whole. The Blind Men and the Elephant: A Hindu fable by John Godfrey Saxe from Elephants ancient and modern by FC Sillar and RM Meyler as follows:

The Blind Men and the Elephant occurs in the Udana, a Canonical Hindu Scripture.

It was six men of Indostan, To learning much inclined, Who went to see the Elephant (Though all of them were blind), That each by observation Might, satisfy his mind. The First approached the Elephant, And, happening to fall Against his broad and sturdy side, At once began to bawl: `God bless me! But the Elephant Is very like a wall!' The Second, feeling of the tusk, Cried, `Ho! what have we here So very round and smooth and sharp? To me 'tis mighty clear This wonder of an Elephant Is very like a spear!' The Third approached the animal, And happening to take The squirming trunk within his hands, Thus boldly up and spake: `I see,' quoth he, `the Elephant Is very like a snake.' The Fourth reached out his eager hand, And felt about the knee. `What most this wondrous beast is like Is mighty plain,' quoth he; `'Tis clear enough the Elephant Is very like a tree!' The Fifth who chanced to touch the ear, Said: `E'en the blindest man Can tell what this resembles most: Deny the fact who can, This marvel of an Elephant Is very like a fan!' The Sixth no sooner had begun About the beast to grope, Than, seizing on the swinging tail That fell within his scope, `I see,' quoth he, `the Elephant Is very like a rope!' And so these men of Indostan Disputed loud and long, Each in his own opinion Exceeding stiff and strong, Though each was partly in the right, And all were in the wrong! So, oft in theologic wars, The disputants, I ween, Rail on in utter ignorance Of what each other mean, And prate about an Elephant Not one of them has seen!

The usual mechanism for clarifying discrepancies in design information and other procedural aspects of a project is through a written document, i.e. Request for Information. The nature of Requests for Information means they could be seen as a means to safeguard a legal position rather than a desire to construct as the architect wishes. The Acton Peninsula Alliance ameliorates this phenomenon. If there are potentially no detrimental financial implications to the way data is received there is a greater likelihood that non-traditionally formatted design information would be accepted as it does not carry the risk of a mistake which could be financially detrimental to the receiver. This understated strength of the alliance process was facilitated by a far more flexible definition of what constituted design information. The positive contribution of a more flexibly defined architectural data was advocated by Casey in her comment "*I am always telling them not to make the contracts or even their specifications too detailed*" (Casey [interviewed by author] 2003). The receptiveness of the parties in exchanging design information allowed much greater latitude for the architects to extend the spectrum of what was considered design information into the more esoteric and expressive realm which suited ARM's approach to architecture.

The need to change the format of the electronic data provided a discontinuity of information at certain points during the design of the NMA. ARM used the reworking of the data as an opportunity to re-evaluate the appropriateness of the software tools being used to facilitate the exchange of design intentions. ARM used more than one software package which bears testament to their willingness to provide design information in a compatible format and to use several software packages exploiting their separate strengths as opposed to a single all-encompassing software package. The most pertinent reason for these translations between formats was that not all contractors involved in the NMA were able to use ARM's 3D drawing database. One example of a required change of format can be seen in ARM's transfer of drawing database from 3D Max to Rhino to accommodate Ove Arup & Partners'[190] preferred software package. The NMA project generated varying types of documentation dependent upon the expectations and technical literacy of the parties involved. This information was generated as 2D working or shop drawings. An example of this was the generation of a 2D (pdf) file for the façades which was unfolded from the 3D surface model for use by G James, the façade fabricator. This is indicative that the transfer of the design information was as seamless as the relevant parties could adequately sustain.

[190] Ove Arup were the structural engineers for the NMA project.

McDougall articulates his view that the formatting of data in conjunction with a desire to understand the data played a role in shifting some of the time from administration to design. The time that would normally have been dedicated to conflict resolution could be more productively used in design development.

> There is no doubt that the impact was that we spent a lot more time on design and documentation than we spent on stuffing around on responding to notices of delay and RFIs and all of that sort of stuff. That was almost nil (McDougall [interviewed by author] 2003).

McDougall's view of the advantages of transparent formatting is shared by Kolarevic (2003a). He extends McDougall's view to include possible errors that could result from an unnecessary reformatting of data. A lot of technical work is repeated to get the technical information in a format acceptable to a particular party, a point well made when he states,

> [E]ach participating party in design and construction creates its digital work from scratch--that is, from paper documents reproduced from the previously digitally generated information. Needless to say, this process is not only highly redundant and utterly inefficient, but it also compounds any errors that could occur in interpreting the information exchanged on paper (Kolarevic 2003b p.93).

These delays and re-presentations run the risk of the type of misunderstanding previously illustrated using Foucault's work, but moreover add to the timeline of the overall project as they cannot be commenced until the architect's modelling is completed. The system of work which eliminated layers of duplicated effort and eliminated time and additional fees for the project was a positive factor in the successful delivery of the project. Raggatt articulates a desire to extend their use of interoperable CAD modelling to further rationalise the flow of design information between parties when he states,

> [W]e would like to think as part of that new documentation model of things that instead of everybody documenting things over and over again, and send you on a course in building, that we could move much more toward engineers who would work much more closely with 3D documentation drawings (Raggatt [interviewed by author] 2002).

This comment highlights the desire amongst architects for a single coherent body of data which would represent an entire project in virtual form. He continues by recounting a previous experience of discrepancies in documentation and how they are usually resolved. "*All those things that* *usually end up on site get ironed out. Most of it gets ironed out virtually before we document the thing*” (Raggatt [interviewed by author] 2002).

There was an occasion during the NMA project where the 3D CAD model needed to be reduced to numerical format. The NMA project used a well formed 3D surface model technique and it also used a traditional tablature form x y and z table to inform the surveyors of the dimensions for the Main Hall.

> I think we ended up taking off 7,000 or so points for that for the surveyors to be able to set that thing out but other than that they just did it. For the secondary steel, secondary or tertiary steel, there was a 3D document (Raggatt [interviewed by author] 2002).

The transparency of design data is a familiar notion to people with similar aspirations to use 3D CAD models. Hence any improvements in efficiency provided by 3D CAD modelling rely heavily upon all parties who use the data to be conversant with extracted information from a model generated by a third party. Additional benefits in the form of cost savings from shop drawings were also realised, as McDougall explains,

> Shop drawings become way cheaper because you are giving basically a 100 per cent accurate model to a shop drawer to do the shop drawings so that is an area that normally an architect wouldn’t do, so our 3D model becomes something which is of great value to the shop drawers. Shop drawings go down and actually the people that pick that up are the contractors. They don’t pay us to do that. And it is not yet enough known that it is reflected in tender costs (McDougall [interviewed by author] 2003).

The cost savings realised through interoperability has been documented in research done in the United States. The most significant recent research on the costs involved in the regeneration of data is the National Institute of Standards and Technology report, ‘Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry’ (Gallaher *et al.* 2004). This report investigates the losses that United States Government facilities are reported to have suffered due to poor interoperability practices. This is an issue that affects all parties involved in the AEC sector.

> Owners and operators have the largest interoperability costs of all the stakeholders: over $10.6 billion, or about 68 percent of the total $15.8 billion of inadequate interoperability costs calculated for the capital facilities supply chain. This is because owners and operators carry the burden of ongoing interoperability costs during the operations and maintenance phase. They also bear costs during the planning,

> engineering, and design phase ($723 million) and during the construction phase ($898 million) (Gallaher *et al.* 2004 p. 120).

The report identifies the main impediment to the formation of coherent and complete information models,

> Extranets have increased AEC communication and added efficiencies but not to the level anticipated by many information systems users. There often seems to be some link in the process that does not work, many times the data integrity and reliability is a function of the data entry source. For instance, some organizations use disparate databases that are not interoperable. Critical data elements, such as cost, schedule, and quality performance, may need to be keyed in multiple times, thereby creating a multiple data entry problem. Often times, data entry is not performed in the field because of the press of time required to focus on other “more important” issues (Gallaher *et al.* 2004 p.62).

When asked whether the level of technical literacy in a subcontractor affected their selection to be used on a particular project Raggatt replied,

> Increasingly the capacity of subcontractors to produce stuff from files is strong, I think. With the National Museum for instance, nearly all the… or a lot of the steel work was, the drawings for that were 3D drawings. I think we might have run out of a little bit of capacity there. At the time it was really busy. You had the Sydney stuff still going on from the Olympics so I think the industry was pretty cranked up at that point and some of the contractors came from New Zealand doing bits which was because the contract ran off a website. It was impossible to get a way of coordinating. Everything was virtual anyway, so everyone could load it on and it was analysed there anyway. So it didn’t really matter where they were and I guess the next step is that they wouldn’t be in the country (Raggatt [interviewed by author] 2002).

He goes on to articulate a vision of a universally understood surface model,

> We like to think the processes and what we used to fantasise about has moved quite rapidly in this direction where the architecture could be done as a series of surface models, exterior, interior and all the materials now put through it so we could walk through and all those sorts of things. And then that could be used as a direct model for testing structures and regarding some of that as an iterative process and those models could then be handed across to subcontractors who usually have either a slightly different format for stuff or a slightly different degree of precision (Raggatt [interviewed by author] 2002).

John Mitchell outlines the diverse nature of data standards as a side effect of the proprietary concerns of major architectural software producers in commercial competition with other software producers and hence reservations about the amount of transparency in their drawing databases.

> There is no one big killer application in the construction industry, there are so many processes and functions and to make it all successful and make the transition from the current technologies we have to make it open and that is a conscious decision by the community (Mitchell [interviewed by author] 2003).

He points out there is a movement towards an open data exchange standard advanced by the International Alliance for Interoperability (IAI), when he continues,

> If we [IAI] have learnt anything we have to get off of proprietary data formats, we have to have open data. Most government clients are increasingly refusing to buy solutions that have proprietary data which are a disaster for them (Mitchell [interviewed by author] 2003).

He cites an advantage of moving towards this, which Gehry has already utilised with his extensive use of prefabricated elements.

> Increasingly you will have more subassemblies that have the assurance of dimensioning that enable it to be connected on site without error. You will get better quality product manufacturing (Mitchell [interviewed by author] 2003).

The NMA project generated information which needed to be regenerated in different formats for different purposes as a manual procedure. By comparison the GMB used subcontractors who already possessed the skills to understand and manipulate complex 3D models.

The flow of information (and the expectations) was different for the GMB. The move towards a CAD package that could handle the geometrics that FOG&A wanted to capture led the office to CATIA. This in turn meant that subcontractors and in the case of the GMB the structural steel fabricators could dispense with the normal routine of redrawing the architect's drawings as shop drawings. The practising architect and author, Andrew Cocke recalls a salient point made by Gehry partner James Glymph, "*Glymph points out a surprising fact; the cost of producing and reviewing shop drawings in a large project far exceed the architectural and engineering fees*" (Cocke 2000).

Gehry's vision was seen through from the digitisation of the physical model (Stein 1997) to architecture without a *required* rework to suit transfer. The requirement of change of format was incorporated in ARM's way of work. As Shiel asserts, "*ARM embrace compromise*" (Shiel [interviewed by author]

2002) including compromises made due to the technical limitations of computer technologies and of others. This is in contrast to the relatively unfettered development of the GMB.

These changes in format helped to create a context more open to re-examination of design data than on the GMB project. As design architects, ARM was given the uncommon facility to iterate the design for a longer period than normally required due to the redundancy of contractual drawings. By comparison, the GMB data was embedded in a data stream which required no significant change in format and hence did not *require* FOG&A to reconsider the design in light of the next format.

5.2.5 Cultural Resistance to Change in the AEC Sector.

This sub-section deals with the Australian AEC sector's preparedness to embrace innovation which impinges upon its traditional patterns of work. In Australia in 2003, the Cole Royal Commission chaired by the Honourable Terence Cole, retired Supreme Court judge, into the building and construction industry was highly critical of the industry's reluctance to change, amongst other things (Cole 2003). The inflexibility often associated with the building industry could be seen as a product of tradition, or the trade associations which they represent. These trade associations have been cited by Commissioner Cole as stifling innovation and not predisposed to invent new ways to work.

The view that the people within the Australian AEC sector do not embrace changes to their customary way of working is supported by Casey's comments regarding her experience with the resistance she encountered when trying to advance project alliancing within the sector.

> I got such a hard time within the department and went going around talking to people about it, architects, not only our architects but architects and project managers just to test it and everyone was totally opposed to it. They said you are absolutely mad and especially when I talked to architects, I said that this will give you a say. You complain that builders completely demolish your design. The builders say you guys keep on designing so why wouldn't you want to do this when you can have a real say in it (Casey [interviewed by author] 2003).

This predisposition to accept innovations reluctantly is demonstrated by the Royal Australian Institute of Architects' initial refusal to endorse the design competition for the National Museum (Keniger [interviewed by author] 2004). The Royal Australian Institute of Architects could be seen as custodians of the architectural profession‘s traditional way of working and as such was less comfortable with an architectural relationship which was outside their previous experiences. Whilst the Royal Australian Institute of Architects were involved with the museum project their initial reaction was to distance themselves from the design competition (Keniger [interviewed by author] 2004). Keniger recalls the circumstances surrounding the competition.

> What happened was the client agency was the department of communication and technology of the arts and theatre, they had not run a capital major works budget and all of a sudden they got the go ahead from the government for the national museum which they had been pushing for twenty odd years. Told to proceed and told it had to open on 1 March 2001, or whenever it was and the budget was x. so they immediately dived in and launched what they called an international competition in a hurry (Keniger [interviewed by author] 2004).

He continued to say,

> The first I heard of the competition was a call from the president of the then AIA saying would I like to assist the selection panel and I didn't think anything of it, I rarely say no to anything, that is why I am here, and so I said I would be happy to and it was a few days later that I heard there was an enormous ruckus, the institute had dis-endorsed the competition but in discussion with the client agency and the government had agreed to nominate two advisors, myself and another from Melbourne who advised on the competition probity (Keniger [interviewed by author] 2004).

Casey also made the point that the Royal Australian Institute of Architects was reluctant to be involved in this project as it did not adhere to the institute's established criteria for architectural competition. When asked about the Royal Australian Institute of Architect's negative reaction to the method used to select the architects, Casey cited what she believed to be the main reason for their reaction, "*Because they wanted to run it*" (Casey [interviewed by author] 2003). This reluctance to embrace unfamiliar systems of work can be seen as a symptom of a wider sceptical view held by some, as John Mitchell asserts when considering how some architects perceive the tangible output of this profession.

> Some elements within an office considered that documents were the real output of the system and need a guarantee that any new system could do exactly what they could do with their current systems if not better (Mitchell [interviewed by author] 2003).

He gives an example of a personal experience with a large international firm of architects, when he recalls their attitude to technological change "*The opposition both direct and indirect to us was just extraordinary and I learnt so much from the politics of the cultural change, its an enormous problem*" (Mitchell [interviewed by author] 2003).

The reluctance to change is not just confined to procedural issues but is also more deep seated and cultural. There is almost a paradoxical view of the AEC sector which views their problem solving capabilities as high but its ability to systematically apply the lessons learnt on the micro level to the macro level as low. While the ability to find innovative solutions to specific problems was seen as high, the industry as a whole was seen as slower to embrace innovation as Casey and Wright have previously mentioned. This argument is supported by Gann, who states that the construction industry is good at solving problems as they arise but poor at using those experiences to formulate strategies to prevent them from recurring.

> In spite of an innate ability to deal with change, construction is not generally viewed as an innovative sector, either by those working within it or by outside observers. Innovation prompted by the need to solve problems, often needlessly created elsewhere in the production process, generally lacks direction and can result in further problems which others have to rectify. Hence the paradox of change: construction has internal dynamics that generate innovation, but not necessarily of the type that leads to lasting improvements in performance (Gann 2000).

The consistency shown in embracing micro changes and resisting macro changes has been cited by Brian Atkin[191], as a major factor in the spread of partnering.

> One internationally known factor influencing the spread of partnering in the construction sector is clients' and contractors' awareness of partnering ….. deep seated patterns of behaviour, routing, and familiarity with traditional approaches to purchasing, tendering, formulating and evaluating contracts inhibit change; all this in combination with a lack of genuine "trust" (Atkin *et al.* 2003).

Godfrey, speaking as a founding member for the Australian chapter of the International Alliance for Interoperability, articulates that organisation's view that major obstacles to the increase of efficiency are a reliance on *business as usual* when he states "*[T]here is a strong bias for delivery based on familiarity, even if this includes a number of acknowledged or inherent problems*" (APP

[191] Brian Atkin is Professor and Vice-President of the University of Nottingham Malaysia Campus.

1998 p.21). These inherent problems are seen by Mitchell as indicative of the AEC sector worldwide "*The construction sector was the last industry sector to adopt IT in a proactive way and this is a worldwide phenomenon*" (Mitchell [interviewed by author] 2003). John Mitchell asserts when relaying an anecdote from Patrick MacLeamy IAI International Council & Executive Committee Chairman and CEO of Hellmuth, Obata + Kassabaum, Inc. (HOK),

> His key argument was when I step into an aeroplane or my car I have a product quality expectation that the multi-curved door seals perfectly and is air tight and never leaks and when I turn the key the engine starts perfectly. Unfortunately I am embarrassed to tell you that most of our completed buildings we should expect that the client will ring up and say the roof leaks, or a window leaks (Mitchell [interviewed by author] 2003).

Godfrey also sees a deficiency in the uptake of computer technologies in the AEC sector when he states that the success of object oriented CAD is contingent on how the building owners/financiers perceive its worth as an asset management tool. He cites for the Eureka Tower in Melbourne, the relationship between architects and builders and their commitment to using the technology as a best practice example.

> The relationship between Fender-Katsalidis [architects] and Grocon [builders] is very close because they have joint ownership of the Eureka project and that is going to be interesting because they are both committed to using technology to drive the project, the design and the delivery part of it. But when you go on further in the building's lifecycle and you get into the building owner and manager. However, there is a long way to go before building owners and managers and financiers like the big building funds even realise that there is a reason - a value - in having a deep understanding of their assets (Godfrey [interviewed by author] 2003).

He goes on to say,

> In IAI we always thought we have to know who is driving all this: where are the drivers in this sector. We always felt that the number one driver had to be the building owners. The number two drivers are the builders and the number three drivers are the designers (Godfrey [interviewed by author] 2003).

Wright sees the alliancing process as potentially unnerving for those unfamiliar with it. Fear of the unknown is a natural and foreseeable consequence of any system used for the first time. Hence at the NMA, apprehension of exactly how the system would work would be a natural reaction by those financially linked to the outcome. "*[I]t might take a bit longer, it might be a little more* *unnerving because you don't quite know where you will end up*" (Wright [interviewed by author] 2003).

This resistance to macro change from within the AEC sector was also experienced at the GMB project. *"Glymph acknowledges that the sharing of electronic data between architects and subcontractors has "run up against a lot of traditional relationships"* (Novitski 1994 p.111). In Bilbao, the local architectural and construction community was overwhelmed not only by the project's scale but also by its complexity. *"It's not buildable is what C'esar Caicoya, the architect hired by IDOM to help supervise the project, is told by colleagues who see the finished model of the museum…"* (Stein 1997 p.76). The resistance was less at Bilbao because the method of procurement extensively featured a high percentage of pre-fabricated elements. These pre-fabricated elements were fabricated by subcontractors who were accustomed to this method of procurement due to their previous experiences in the aviation industry. However Glymph sees the US AEC sector as more adversarial and sees in the future the most significant obstacle to a more sophisticated procurement environment as

> Overcoming adversarial relationships among designers, engineers, and contractors (what Glymph calls, at least in the US, "the Wild West atmosphere" of construction); a higher tolerance for risk; educational changes that emphasise the wise use of digital tools rather than mere facility with them (Glymph in Snoonian 2002 p.3).

The alliance system at the NMA devolved a lot of authority traditionally held by client representatives and senior managers to the members of the Design Integrity and Independent Quality Review panels. This led to the perception of a threat to the existing hierarchical organisation that refers such issues up the hierarchy within the individual companies. Such a devolution of authority changed the dynamics to the advantage of those on site. This flatter hierarchical structure encouraged a speedy resolution of problems on site.

All the parties to the Acton Peninsula Alliance were linked to the financial outcomes and as such were keen to have the latest version of the design data. Without the Acton Peninsula Alliance in place it is likely that the main players would have relied more on legal action to clarify points of discrepancy whereas the Design Integrity Panel and Independent Quality Panel of the Acton Peninsula Alliance took the adversarial element out of what may have proven an antagonistic situation. An example of this was the Commonwealth Government illustrating their goodwill by using their contingency fund to reimburse the alliance partners for an unexpected cost overrun caused by unforseen ground conditions.

5.2.6 Insight into the work of others

This sub-section considers the advantages inherent in working at a closer proximity than usual with others involved in the same project. A theme common to the success of complex projects has been a closer than usual working relationship with other professions. These relationships gave a more considered and sophisticated understanding of the requirements of other professions. There are advantages to a closer understanding of what other professions do (Kieran and Timberlake 2004). The alliance process facilitated an environment in which traditionally problematic exchanges between the design professions were reframed by an insight into the challenges of others. As Ashton explains, the positive benefit of the alliance's promotion of inclusiveness led to a reduction in adversarial posturing.

> We were able to put it on the table and say, 'We think this is the best way to do this. We haven't done this before but this is how we think it will work. What do you think?' and they can say, 'Yeah, let's give it a go, or don't, like let's try something else'. It was much more that sort of thing and plus we could involve the engineers, the steel fabricators, the shop drawer all in the same meeting without having any of the silly little contractual games going on like there are many times in a normal arrangement where you couldn't just go straight to one meeting involving all those people. You would have to have a pre-meeting to work out what you could and couldn't say in front of them because maybe they hadn't been signed up yet or maybe you would be giving them information which would affect their price and all that sort of stuff (Ashton [interviewed by author] 2003).

Another major advantage of the Acton Peninsula Alliance was its structure which allowed ARM more contact with patrons in earlier stages than they would normally have had exposure to. In this new working partnership the architects believe they are learning far more about their work (Ashton 2002). This is also articulated by Ian McDougall when he described the Acton Peninsula Alliance as "*a dialogue*" (McDougall [interviewed by author] 2003). The Acton Peninsula Alliance also allowed the other alliance partners a voice in the design/quality of this flagship project. This egalitarian approach to design integrity / quality yielded an increased engagement with sub contractor knowledge.

The alliancing system changes the traditional dynamics of problem solving to include a wider circle of potential contributors of solutions. It also exposed the design professionals to processes they were previously unfamiliar with, as Ashton continues.

> [I]t gave me a better insight into the way the constructors think because you are much more exposed to that than you would normally be. Gave you better insight into the way some of the major contractors operate (Ashton [interviewed by author] 2003).

Another feature of the NMA project was the co-location of the design professions on-site. This led to a transparency in communications and the fostering of personal relationships due to the amount of time spent in the same workplace, as Wright recalls.

> [N]ormally there are the mechanical, electrical, fire and communications fellows. They would normally have their own site sheds. There would be four sheds out there and they would be sitting in them. I said, 'None of that. You are all sitting in one big shed', and I moved my services engineer out there so he is sitting out there with them, all with the services manager and there are no offices - all open plan, big plan bench in the middle. They can overhear everybody, they can shout across the room because they are all interrelated (Wright [interviewed by author] 2003).

Keniger supports Wright's assertion and places this co-location into a larger project-wide context.

> There were all sorts of complexities which could have gone horribly wrong but the alliance process was taken up in a good spirit and I think what really made it work was the dedication of the client. The client invested a lot of management time into the alliance process and the fact that on site the architect, the client, the exhibition designers and the contractors all worked out of the same site hut (Keniger [interviewed by author] 2004).

Wright reinforces the transparency of information when he says "*Speaker phone was used extensively, extensively*" (Wright [interviewed by author] 2003), discussing that even when communications were via telephone the preferred mode of interaction was collectively, that is, on speaker phone for all to hear.

The insight into the work of others is a discrete phenomenon and all parties that expressed an opinion into this aspect of their interaction considered this experience to be positive in nature. None of the interviewees expressed a negative experience by gaining an insight into the work of others. The increased access to not just the personnel but moreover access to the processes of their partners gave the alliance partners an increased understanding to constraints and opportunities they faced on a day to day basis and how their own profession could affect these experiences.

5.2.7 Interpersonal Dynamics

This sub-section considers the interpersonal dynamics between individuals at the NMA and how strategies were put in place to maximise their potential contribution. Wright uses the term social re-engineering to convey the sense that this was a different way to interact on a personal level. This required a re-evaluation of traditional adversarial relationships. This reframing of personal relationships was seen by Wright as invaluable when addressing project-wide problems.

> Look, I think it was the challenge. We had no idea how we were going to build it really. The drawings we saw on the tender table were conception sketches, artists' impressions and perspectives. It didn't scare us, that is not the right word, we did look at each other and say, 'How are we going to do this?' but simply by good communication, sitting down getting the right relationship with subcontractors and I call this social re-engineering almost (Wright [interviewed by author] 2003).

Extending the group of people who would usually decide an aesthetic direction to the tradesmen involved engenders a feeling of inclusiveness which manifests itself as a heightened level of ownership for their role in the project.

> We did the same thing with the exhibition design, because we had some American exhibition designers and we had one big night in this site office where we set up slides and we got the whole site shift come down and listen to an hour's presentation from our American friends explaining what the exhibition is about and what we are trying to show. And that engendered all sorts of discussion that was quite interesting because these people had never been involved, never been asked to make a contribution or comment on. Being a museum there are all sorts of controversial things but they got involved. Here are the bricklayers and welders getting involved in almost, I suggest, an academic discussion about what should go in the museum and how it should be presented in a museum. So they took real ownership. It wasn't just coming to a job and doing a job and we tried hard to do that (Wright [interviewed by author] 2003).

Wright continues.

> Look, we could have done a heck of a lot more but we did a heck of a lot more than I had done before so those sorts of things I am talking. I think you will find people like Steve Ashton and those guys will take some of those concepts onto their next jobs because they are very valuable. You don't understand people do want to do a good job. People want to provide good quality but unless you help them understand what you are trying to achieve and you have a common objective the focus for this kind of objective was quite amazing, quite profound that people knew the complexion (Wright [interviewed by author] 2003).

Wright identified areas in which he would have preferred more discretionary resources. He considers the notion of rewards in purely monetary terms to be limited in its ability to show appreciation for the work undertaken. He would like to have taken the alliance risk/reward ethos further down the reward path than the alliance allowed.

> I would have liked to have been able to reward some individuals within that sixty person team. We did that by acknowledgement, in other words each monthly report I would speak to other people and we would identify half a dozen people each month who had done something over and above what we would expect them to do and it didn't quite work, but basically the first couple I would give them a letter saying, 'Thanks, you have done a fantastic effort' and I would like to have done more, not necessarily monetary. It could have been four days to go on full pay leave and, 'Here are plane tickets for you and your wife to the Gold Coast'. A few things like that which are real, a piece of paper is good but you are genuine about rewarding people doing an outstanding job (Wright [interviewed by author] 2003).

He continues, "*Rewarding them is not just rewarding, when giving a slab of beer it is rewarding his bigger self, the family*" (Wright [interviewed by author] 2003). However he continues by contextualising the underlying reason for encouraging ownership of the building by the trades is to increase the levels of quality and productivity.

> A few things like that which would have been more community-based and we spent a million dollars on a computer infrastructure we could have used that in some different ways and that would have been much more holistic. We would have been embracing the families and I won't be backward in saying this, but the reason for doing some of this is to get more commitment and productivity - that's 80% of my reason for suggesting it. 20% is it is good and people learn some things. This is about business as well (Wright [interviewed by author] 2003).

He continues to say this level of social interaction could have been extended to include more project-wide social interaction.

> I would have liked to have had more social interactions. We had three or four functions. We had a Christmas party one year and we had a trivia night one night where Craddock was the trivia quiz master, which we had fifty people which was great (Wright [interviewed by author] 2003).

When asked about a topping off ceremony he replied,

> Yeah, we had a couple of big parties. We had an Open Day for the staff which was good, and employees and subcontractors. We had two Open Days for the public. I would have liked to do a bit more with the staff and the people and the subcontractors on the job. I would have liked to thank them. And you'd be strategic about that. You would plan when we should do those events at particular important times, when you needed a drive (Wright [interviewed by author] 2003).

One example of the type of project-wide recognition of the workers was an entry in a publicly accessible database which signifies the work done for the alliance, where the names and area of contribution were recorded for posterity.

> It is even to the extent, we had a little exhibition for the team who built the museum within the museum, and it stayed there for about twelve months, downstairs in the narration gallery. But also you could walk in there now and press the computer image and call up your name because we got all the names of the people involved in the project on a database so I could go in there and press 'W' and my name would come up, with a great list of names. Peter Wright project manager - that is still there now (Wright [interviewed by author] 2003).

Wright summarises the benefits of what he terms social engineering in terms of the traditional variables of timeframe, project scale and budgetary constraints, which are often considered the only significant variables in design and construction. He identifies that there is a desire amongst tradesmen to contribute for personal satisfaction.

> So we tried really hard to just create this environment of a group of passionate, committed people working for one single objective and that was: a budget, a quality, a date and some personal satisfaction (Wright [interviewed by author] 2003).

What Wright categorises as social engineering could in more generic terms be considered as simply providing a more rewarding and transparent set of relationships facilitated to achieve a collective goal. There are parallels with Gehry's request for proposals. However, at the GMB the relationships were more business to business rather than Wright's person to person view of social engineering.

5.2.8 Complementary Knowledge

This sub-section addresses how complementary knowledge was used to enhance the NMA project. One of the advantages of the alliance system is the complementary knowledge gained through the synergy created via a no-blame culture. McDougall outlines one example of this synergy as being the facility to bypass traditional lines of, and types of, communication. This allows the designer to engage in a dialogue with the people most directly responsible for the fabrication.

> What alliancing did in that case was actually allow the designer to work directly with the people who make things so it becomes a two way street. You can design something to a sort of general intent and then sit down with the guy who is likely to make it, and he will say, 'No, you can't do that but you can do x, y and z'. So you modify the design or change it radically to still do what the designer wants it to do but it is a two way discussion (McDougall [interviewed by author] 2003).

The benefits of this dialogue were not only realised in financial terms but also in what the architects gained in understanding the other alliance partners' skill sets. As Shiel points out, the benefit to this dialogue was the improvement of the architecture due to the dialogue with the non-design professions. "*[W]as less important than the architecture and a lot of that comes as feedback back and forwards from the people who are actually building it*" (Shiel [interviewed by author] 2002).

Due to the unfamiliar environment in which the alliance partners found themselves, alliance facilitators were employed to advise the partners on the most appropriate behaviour towards other alliance members. If it had been a conventional Design and Construct contract there would have been no need to bring in specialist facilitators. These specialist facilitators represented an overt desire for complementary knowledge that did not exist amongst partners. The Commonwealth government realised at an early stage that they required knowledge that did not exist amongst alliance partners, as Morton explains.

> We brought in a whole lot of expertise………Because it was Commonwealth and public funds we had the appropriate advisors and technical advisors we spent a lot of money on expert advice because the nature of this department is this is a task which is outside our normal realm. And the only way we could do it was bringing in this expertise (Morton [interviewed by author] 2003).

Due to the risk/reward mechanism all the alliance partners used their individual skills by concentrating on a particular problem which led to solutions based more in practicality than in philosophy. However, there were examples of solutions to problems from unexpected sources. This contributed to the project's timeliness and the quality of its finish. These indistinct lines of demarcation did create occasional frictions, but the protagonists used the directness of this method of communication to the advantage of the project by the immediate use of complementary knowledge.

> Howard and I screamed at each other. Certainly, Peter will tell you too he occasionally screamed at Howard and we all, it was quite cathartic and we all enjoyed it afterwards. After a beer and that sort of thing but as I say the architects still design, the builders still built but in terms of problem solving it wasn't, it had to be done cooperatively. So Bruce is quite right, there was blurring in that way but quite often it would be fair to say the architects were stuck for a solution which the builders could say, 'I think we can build it this way'. And I mean particularly in relation to the Main Hall one sometimes got the impression it was being made up as it was being built (Morton [interviewed by author] 2003).

When asked whether this new environment lessened the identity of the designer Morton replied, "*Howard was the designer, absolutely no question. Howard was the designer*" (Morton [interviewed by author] 2003).

Wright asserts that by allowing other parties not usually expected to offer solutions to have their opinion heard, the level of cooperation allowed privileged information not traditionally available to be seen, with the expectation that the information would be used for the good of the project.

> We were totally open about the costs to a certain level within the alliance. We would unashamedly put up cost reports and go through detail on money which doesn't usually happen. We might have tailored it just a little bit just to handle some really sensitive stuff but we were pretty open and as you know there were rewards and we would talk through the rewards and we would say, 'Currently we are scoring pretty low on this. Now how can we lift the score, guys?' and because they were asked for their contribution and people like me and others when someone would say something and someone else would have a go at them you would try and say, 'Let him finish', and everyone felt they were getting the opportunity to contribute to the big picture (Wright [interviewed by author] 2003).

Wright continues by giving an example of an instance of this dynamic and immediate exchange of information between architects and fabricators.

> We had - and I am not exaggerating when I say this - we had a foreman, like a building foreman, one of the guys like a welder from the subcontractors, and the architect sitting at the computer screen rotating the 3D image around on the screen, saying, 'How the hell are we going to hold this together?' So what I try to do is break down this hierarchical sort of arrangement where this person is expected to know all the answers, and believe me they don't, they just don't. They have a vision but they don't know how to put it together. This person may not have the vision but he is bloody good at putting it together, so if you can narrow this divide and get this group of people respecting and appreciating the skills of these people and these people respecting the skills and the visions of those people you change it to that and you sort of get that (Wright [interviewed by author] 2003).

The organisational structure which allowed this direct line of communication was formulated by Wright. In the following quote the diagram Wright alludes to was a diagram of overlapping circles (Venn diagram) showing the overlaps of expertise and where best the relative energies could be employed.

> [W]hen I wrote the bid document for our tender I spent two days trying to work out the organisational structure. It was something like this [*points to paper*] and basically we said in a sense the project, that's the project. Or, I think I did this for the presentation. These are the members of the alliance and the project sits in between, everyone's energies are going to the project, are going to the outcome. They're not about shunting or pushing of risk and responsibility and that's in a sense how we try to work it on-site (Wright [interviewed by author] 2003).

Due to the project's absolute timeline and fixed budget the Acton Peninsula Alliance partners needed to use innovative approaches to solve problems allowing them to stay within the project constraints. The imposed imperatives required the partners to reassess many of the traditional modes of discourse and lines of demarcation. An example of this was given by Wright when he recalled a situation where a steel worker was having problems understanding / fabricating a particular element. This challenge was overcome by the steel worker and a site architect examining the element using a 3D computer model to explore alternate means of fabrication. The timely resolution to this conflict was due to the 3D capability of the CAD model and to this new cooperative dialogue. It placed the site architect and the steel worker in a working environment new to both. Because of their contractual interdependence, what was best for the project was best for the alliance partners. The alliance system encouraged all interested parties to contribute constructively to the project in an inclusive and holistic manner, "*It was very interesting, often the resolution of a problem came not from the obvious person*" (Keniger [interviewed by author] 2004).

This inclusive way of addressing design problems is supported by Casey when she recounts the situation of a design solution that would traditionally be the domain of the architects being supplied by the builders. The timeline for the completion of the in situ floor conflicted with the need to erect scaffolding to fix the ceiling of the Main Hall. Different parties took on responsibility for design solutions that they would usually not be involved in. This particular programming conflict was resolved when the builders agreed to lay marble floors as opposed to the originally specified in-situ concrete. This resolution would not have been likely to be offered in a traditional procurement environment. In this case a perception that the flooring proposed was inadequate for its purpose.

> [I]n the long term it wasn't going to work but they came back and what they [project management team] did was all agree that we put more money into that, to put the marble down because that was going to be long lasting and better quality in the long term (Casey [interviewed by author] 2003).

Casey saw the advantages of the alliance system as having similar outcomes for more than just museum buildings when she says, "*I don't think you have to do it just on a museum. I think you can do it with a range of buildings*" (Casey [interviewed by author] 2003). Ashton gives an example of how the budget influences the choice of materials. "*This thing is clad in metal and pre-cast [concrete] basically and that is because of the budget* " (Ashton [interviewed by author] 2003).

Whilst at the NMA the acquisition of knowledge from others could be seen as serendipitous, the acquisition of knowledge used by FOG&A was by an innovative 'requests for proposals' (RFP) methodology. Paolo Tombesi[192] explains how FOG&A have understood and improved the way they used external expertise:

> The office [FOG&A] has by now refined its idea of architecture as sculpture by qualifying it technologically: architecture is a spatial practice consciously defined by the use of a few particular manufacturing technologies (casting, cutting, rolling and milling) applied to a few particular materials: generally concrete, steel and stone. RfPs have thus become the first methodological reflection of a process of architectural specialisation the strategies of which have been extended to the work-breakdown structure of the building process (and hence to the planning of its procurement). The linking of language with construction has strengthened FOG&A's position in the process. The office can now deal directly, at a design level and with

[192] Paolo Tombesi is Associate Professor in Architectural Design and Practice, University of Melbourne and author on design specialisation and the economics of architecture.

> considerable leverage, with the specialists responsible for over 50% of the building cost…. If early RfPs were an attempt to gain information that was not available within the office, they are now a way to control the selection of suppliers and subcontractors and to steer their work (Tombesi 2002 p.86).

Complementary knowledge is especially integral to FOG&A's success as a practice. When Giovannini describes the level of diversity amongst Gehry's staff, he asserts that a project would normally

> Involve not only Gehry's vision but also sophisticated office backup, from the model making shop, to on-staff computer engineers, to seasoned partners who tell Gehry how many curves a project can afford (2001 p.72).

The way in which external expertise was used at both the NMA and the GMB can be seen as a productive side effect of the relative procurement methods. These methods both took a systematic and concerted approach to implementing changes or initiatives based on the expertise of others. The regime also allowed (especially at the NMA) for non-experts to participate in debates which they would traditionally be excluded from. The inclusive nature of this collective problem solving approach led to the individuals involved assuming some ownership of not just their own particular issues but also the wider good of the project.

5.2.9 Factors Affected by Personnel

This sub-section considers the issues which are best categorised within the confines of human judgement and endeavour. There are many factors that were characterised by the interviewees that were more a matter of personalities than of job descriptions. As Keniger points out (with some pride) *"the tradesmen on site were using computers."* (Keniger [interviewed by author] 2004). Wright posits "*one of the structural steel workers is an artist*" (Wright [interviewed by author] 2003). These two statements were indicative of the ethos which pervaded the project. Wright recounts the sort of connection tradesmen had with the completed project.

> You see a bricklayer walking around with his kids, he gets quite emotional and say, 'That's what I did' and the kids say, 'Gee, dad'. It's very powerful. Dad goes home and the kid knows what he's been doing (Wright [interviewed by author] 2003).

This view of events is shared by Casey when she says, "*I just got the feeling and I still have the feeling they really bought in and owned this project including the quality. … They are truly proud of it*" (Casey [interviewed by author] 2003).

Keniger argues that the motivation to be involved in a successful flagship project overcame the traditional adversarial mindset. He also believes that the pride shown in the contribution individuals made to the project was reflected in the attendance from tradespeople on various open days, as he recalls,

> There was definitely a sense it was a flagship project and that there was a sense of pride in bringing it together and the fact that they actually brought tradesmen out of retirement because of the complexity of some of the junctions. These older chaps had had some experience with the tricky sheet metal work or whatever and they were a delight to have to feel that their skills were of interest to younger people and they were the people solving the problem on site and there was a genuine sense that the making of the building was interesting to the people making the building and it was extraordinary going around on open days and see different tradesmen showing their family which bits they had done and what was involved here or what the problem was there and you will never take that away. That is part of the story of the building so it came from the team rather than from client imperative or client philosophy (Keniger [interviewed by author] 2004).

These examples of tradespeople showing their work to their families shows an ongoing connection with the museum, and their understanding of their significance to the design integrity. As Ashton recalls, "*[Y]ou actually had workmen on the site talking about design integrity - if we do this is that a problem for design integrity?*" (Ashton [interviewed by author] 2003).

ARM has a reputation within the architectural profession of embracing innovation, and as such, attracts personnel who share that philosophy. ARM's predisposition, as expounded by McDougall, for innovation manifests itself in their ability to transcend traditional ways to work and embrace a new procurement system as part of their overall practice philosophy.

> [I]n fact, we didn't know enough about the delivery process to know whether that would work or not, and I think it is more to do with the culture we had about both in terms of always asking more out of a project than it could possibly deliver so that is just a culture of 'too much is never enough' (McDougall [interviewed by author] 2003).

The alliance process benefited from the active support by senior management of the project as Wright explains.

> Senior directors and senior executives from all of the companies involved in the alliance were represented on the leadership team board so you don't take these things lightly and you need the commitment of that senior level for it to work (Wright [interviewed by author] 2003).

Whist there was a substantial involvement of senior managers from the alliance partners there was also a collective ethos about the organisational structure. One manifestation of this was that if a confidential exchange of views was needed an 'ad hoc' arrangement was made as there were very few private offices. As Wright explains

> If I had to talk to someone I would kick Craddock out of his office and talk to him or use one of the small conference rooms. Didn't have to do much counselling. Everyone was bloody pumped, they were really enthusiastic (Wright [interviewed by author] 2003).

When asked about whether the level of enthusiasm was motivated by the nature of the project he replied,

> I think being a museum helped, no doubt being a national icon helped. But I reckon the right leadership and the right people you could be building something like this (Wright [interviewed by author] 2003).

Morton considered the most important element of the museum's success was a 'phenomenal team' when he discusses the most important factors contributing to the unexpected success.

> People still say they don't know how it happened, but it happened and it was bloody hard work. It happened because it was bloody hard work and we had a phenomenal team (Morton [interviewed by author] 2003).

He continues "*I think that was enormously important and I mean if you had the same set of circumstances with a different team it just wouldn't have come off*" (Morton [interviewed by author] 2003). Mitchell supports this view when he considers a successful implementation of a new system of work for a major international firm of architects and the importance of the contribution of one individual to the success of that project.

> He was a proper champion. If he was out of his depth or he thought that there was some other advice he needed, he would constantly come and have a dialogue with us and this was a very productive thing (Mitchell [interviewed by author] 2003).

Due to the unfamiliar nature of the alliance structure and the inter-reliance of the parties, the various partners needed to be confident that they were entering into an agreement with like minded partners. This supports the notion that the alliance partners self selected to some degree. This self selection was seen by Casey as an appropriate way to select partners.

> I would use the alliance process for selection of people even if I never use the alliance as a contract method because what we did was select people who could work in a team. Now they were the least likely building company that, if you looked at who built museum before or equivalents, they weren't the ones yet when you interviewed and lived in a couple of days with that group they were the best ones in terms of being able to work in a team (Casey [interviewed by author] 2003).

Wright saw one of his more significant contributions to the alliance process as being an evangelist for project alliancing. He credits how he was seen to embrace the alliance system to be of value to his day to day operations as the project manager. He goes on to say,

> Traditionally project managers manage the time, quantity and cost. I had to do all those things. I had a team but there was a much more important role over and above what I call the traditional role of a project manager that I had to… that was much more about the way you behaved, more so than the things you did (Wright [interviewed by author] 2003).

Some of the personnel that worked on the museum subsequently worked on another major Commonwealth Government project in Canberra with Wright. He credits this ongoing connection with their previous experience of the alliance system at the NMA. It made those staff quicker to embrace new building innovations, more so than those who were unfamiliar with the NMA project.

> [S]ome of the same people are still here and they have an understanding of what we did at the museum so that's probably making it a bit easier for them to embrace here (Wright [interviewed by author] 2003).

The experience of working on the NMA project has left Wright with a feeling that any system based on a traditional adversarial mode of working rather than a relationship-based procurement system is destined to be a less favourable experience. Hence his decision to move himself to a position where he could exercise more control over the procurement methods chosen, as he explains:

> I was with Lend Lease for 24 years I… subsequently left, so that's probably part of a little bit the environment, on the museum as well. I kept saying to myself, 'What am I going to do now? If I go back to Lend Lease now after doing this magnificent project, what am I going to do when I go back? Do I really want to go back and do a little office building in an archaic delivery system? (Wright [interviewed by author] 2003).

This sentiment by Wright and the previous sentiment by Ken Bool, ARM associate and project architect for the NMA, and Ashton highlights the effective way to deliver a project and moreover a more enjoyable experience due to its negation of the more adversarial elements. This is a phenomenon that Gehry, principal of FOG&A architects, indicated was an integral component in the success of his projects when he stated,

> I love that process of getting a group in this case two or three hundred people together on the same page as you do the building and the energy that flows from that community of people makes it possible to do better and better work, I think. For me anyway I think that it inspires me, makes me want to do better to work harder and I enjoy it (Blackwood 2000).

Repeatedly during the interviews, mention was made of seemingly unrelated individuals and their contribution to explain where a particular solution came from. This was indicative of the project's ethos of the collective good. This notion of 'credit where credit is due' promoted individuals to positively contribute to the project in ways in which a more structured and rigidly organised hierarchical system would have made more problematic. A rigid hierarchical system would have actively discouraged the type of involvement at a personal level that was integral to the success of the NMA.

5.2.10 Documentation

This sub-section discusses the impact that the format of the documentation had on the Acton Peninsula Alliance. There is a growing acceptance of 3D as a legitimate form of documentation as opposed to an experimental or visualisation environment (Kolarevic 2003a). Not all the other parties involved in the NMA project were accustomed to communicating design information via a 3D CAD model (Ashton [interviewed by author] 2003). Hence, 2D representations needed for construction were generated from 3D data models which were not universally accepted as a primary data format. As Raggatt points out, only a percentage of 3D design data was used by the more technically literate subcontractors.

> Increasingly the capacity of subcontractors to produce stuff from files is strong, I think. With the National Museum for instance nearly all the… or a lot of the steel work was, the drawings for that were 3D drawings (Raggatt [interviewed by author] 2002).

Shiel goes further to say "*Most of the DWG*[193] *files are actually just 2D*" (Shiel [interviewed by author] 2002). The emphasis on 3D as an aid to documentation as opposed to visualisation in a 3D surface model allows for a greater level of autonomy for structural and service engineers, which is not afforded in the same measure to consultants using a building information model. This is supported by Shiel when he talks about the data exchange with the structural engineers and how a dialogue between architects and engineers was facilitated by the interoperability of the 3D design data.

> [A] lot of it was done in New Zealand and they would send us a 3D model in DWG format. We would then insert that 3D shop drawing which shows every bolt and every flange of all the steel (Shiel [interviewed by author] 2002).

The seamless flow of information requires a general level of acceptance and sophistication from design to assembly. The 3D model used at the NMA was highly successful at conveying the architect's intent. The ability to use 3D modelling became a factor in the selection of fabricators.

> It was partly to do with who had the capability to do it in 3D because not every shop drawing firm is interested in doing things in 3D, so we had to pick people that wanted to do things in 3D or could (Ashton [interviewed by author] 2003).

Raggatt criticises the inefficiencies of not virtually modelling the impact of design development.

> [S]o they are not on our site trying to solve all these niggardly problems they end up with when things don't fit (Raggatt [interviewed by author] 2002).

His comments seem more poignant when considered with Michael Keniger's description of what he believes is the current best practice paradigm for the realisation of complex architecture through advances in technology.

> [W]e're no longer bound by the need to make repetitive equivalent units as the basis of your construction because all that would happen is the digital information would go to a cutting machine and it didn't care what size you wanted it would cut the panel to shape so every

[193] DWG is the most common file extension for computer aided drawing files introduced by Autodesk, DWG is the native format for AutoCAD.

> piece of glass for instance could be a different shape and form and every piece of cladding if necessary could be a different shape. So there is an enormous part of, probably it is the first time there has been a genuine intersection between the use of digital techniques to design and digital techniques to communicate and digital techniques to manufacture (Keniger [interviewed by author] 2004).

The practicality of architectural computing demonstrates its potential most effectively when performing tasks which require large and complex calculations. The efficiencies gained due to the computational speed are apparent in this anecdote from Cocke regarding the Experience Music Project, Seattle, FOG&A.

> We asked them to price some components on the building, giving them a file which we used on the concert hall would take a couple of weeks. That same component done in two-dimensional AutoCAD would take a couple of months (2000 p.24).

Not only does the data model cut down on waiting time for documentation but it also allows a reduced failure rate. The potential conflicts which account for a significant proportion of construction failures can be reduced by effective use of a 3D data model as John Mitchell asserts.

> The architect exports the model to the electrical engineer, the electrical engineer designs the services, he exports back the electrical sub-model, the architect is able to coordinate it so the business model for this is that most architects fail in the documentation and coordination, if you look at the statistics 30% of the failures on the constructions site are due to design or poor documentation (Mitchell [interviewed by author] 2003).

He continues to elaborate on the future direction of documentation.

> Documentation will become redundant. I have been arguing this quite a while; I really see it quite simply as a fact becoming quite clear. We are not going to give documents to the people in our collaboration we are going to give them an extract of the model (Mitchell [interviewed by author] 2003).

As Cocke indicated, it would take much more time to reproduce an element from a 2-D representation than from a 3D data file. Due to the inefficiencies involved it would be detrimental to the morale of the project team to invest several months in 2D work when the same work could be completed in 3D within a couple of weeks. The future of documentation is one of the areas which will be most affected by a move from traditional 2D paper based documents to a 3D information model. The major change is more likely to be more cultural than technical. The notion that documentation is the ultimate deliverable format of an architect's vision would be usurped by a view of documentation as primarily a by-product of the data model.

5.2.11 The Constraints and Opportunities of working with others

This sub-section addresses the perceived limitations and opportunities of operating within a system which devolves design integrity beyond the traditional methods. As John Mitchell asserts, architecture is, and has historically been, a collaborative and information based endeavour.

> Its an absolute fact and the challenge for any practices today that wants to exploit IT in the construction sector is not in fact adopting new technology internally it is being able to exploit the benefit in collaboration with the partners. Architecture is one of the most collaborative tasks of all the professionals and we rely on information from so many people (Mitchell [interviewed by author] 2003).

However the design professions, especially architecture, have historically been more concerned about the quality of the finished output than their collaborators. This in turn leads to the perception that any compromises made in favour of cost or expedience suggested by non design parties will have less regard to the quality of the finished product. McDougall highlights one area of concern about the connection between architectural design and project delivery under an alliance structure.

> The negatives were the contractor, the people responsible for the execution of the project, have an equal status so they towards the end of the job and after the job can reasonably say, 'We think the job is as good as we think it needs to be'. So the standards the design team bring are usually higher than can ever be achieved (McDougall [interviewed by author] 2003).

Ashton gives one example of the limitations some subcontractors experienced by being unable to interpret design information given as a 3D data model. He gives the example how the cleats were positioned for the Main Hall ceiling.

> [W]e couldn't find any surveyors in Canberra that had the ability to deal with the model so we had to sit down and actually extract all of those x,y,z points from the model and give it to them as a table and then the way they did it was with a bloody plumb bob and chalk marks on the floor (Ashton [interviewed by author] 2003).

He continues to explain how the data was translated into a format the surveyors could utilise when he says, "*We manually extracted it from the model and we manually set it up. I think it was done in Excel*" (Ashton [interviewed by author] 2003). He continues to explain his perception of whom within the AEC sector has least embraced the notion of transferring design information in a 3D database.

> Services engineers are pretty bad at it; they are not interested in it yet. They are the ones probably under the most threat but at the end of the day we are still going to need engineers so they will just have to learn how to interface with 3D software and indeed they should be working in it right now I would argue (Ashton [interviewed by author] 2003).

Raggatt also believes the services engineers are slow to embrace these innovations in design data when he says "*… the mechanical still tends to… lag behind*" (Raggatt [interviewed by author] 2002).

Bool remarked that the level of engagement with the integrity of the design was not of the same level in a subsequent ARM project, the Victorian War Memorial (Bool [interviewed by author] 2002). This level of engagement with the museum project changed the expectations of some to how a major project of this kind could be undertaken. Keniger acknowledges this when he says "*I think there were people, guys working on site, who found it very hard to move back onto the more conventional project*" (Keniger [interviewed by author] 2004).

Gehry understands the benefits of working with an engaged project-wide team including the clients, and to this end is seen as devoting a lot of effort in his relationships with the clients.

> Frank cares more about his clients than all the rest put together. If they were not that caring, you'd just throw up your hands, because it's just a game. It's a game- playing and ego. Its not that he doesn't have an ego... and then it gets down to another principle: it doesn't matter how good the architect is; in the end, the building is only as good as the client (Friedman 1999 p.19).

Gehry understands the effect clients can have on a project when he said in an interview *"I walk away from a billion dollar project because I don't think I could work well with the clients"* (ABC 1999). He also knows the opportunities an enlightened client can present him. *"[T]he Lewis house was the most important thing in my life and that it gave me the equivalent of a Macarthur grant and ideas for Bilbao"* (Friedman 1999 p.113). The data model allows architects to develop a more meaningful and mature dialogue with other design professionals as John Mitchell asserts.

> The real benefit is that for instance the HVAC engineer can do endless thermal analyses. The architect sends him the model and in the data for the walls say, there are material selections with implicit performances. This has a transmission factor of xyz. The mechanical engineer wants to know that there is that area of glass and the transmission of glass is this and there is this area of external wall because these are big determinants of thermal performance (Mitchell [interviewed by author] 2003).

The constraints imposed by others, from both within the design professions and from the clients, impose varying degrees of compromise, not only in technical matters but also in the interpersonal relationships which have previously been cited as crucial in the success of the NMA project.

5.3 Project Constraints

This section discusses the impact the transfer of design data and the procurement method has on the project constraints of cost, time and quality. The most commonly accepted means to assess a project's success is to measure the performance against time/cost/quality indicators and the trade-offs made between them. The most traditional method used to demarcate responsibilities on such projects is a closely bounded definition of work to be carried out versus the remuneration for that work. The Acton Peninsula Alliance redefined these traditional boundaries of money versus responsibility.

At the NMA these factors promoted an environment which financially rewarded (via the risk/reward mechanism) the sharing and transparency of information between parties which was a significant departure from the traditional procurement environment. One example which could be seen as indicative of this cooperative approach when Wright recalls that all parties would "*unashamedly put up cost reports*" (Wright [interviewed by author] 2003) which, he continued, was very unusual in the Australian AEC sector.

5.3.1 Potential Difficulties

This sub-section deals with some of the challenging situations that the Acton Peninsula Alliance partners encountered. ARM and FOG&A have both taken leading roles using different approaches into areas which have the potential to seriously affect their practices' financial viability. They have a history of undertaking complex projects which increase the risk of a misunderstanding between the intended design data and the finished architecture.

Morton, the NMA client liaison, believes that the procurement system and the interchange between parties was the major factor in the museum staying on time and on budget.

> There is certainly absolutely no doubt in my mind had we not gone down that route we wouldn't have had a project in time for March 2001 as we had to have (Morton [interviewed by author] 2003).

Contractual relationships and cultural relationships inherent in traditional contracting systems develop a culture of highly defined demarcation. This subsequently develops an insular and possibly prejudiced view of others involved in the project. The alliance structure, however, allows for the architects' desire to deliver their vision and provides opportunities for a greater interplay of ideas between parties.

The traditional adversarial relationship requires that participants safeguard their legal liability in a traditional paper-based contractual manner. The external legal advisors in this process still adhered to adversarial contractual practices. Casey explains what she sees as an external perception of the process.

> I think if you are external to the processes you would see all these pitfalls, what people perceive as pitfalls, when in fact they were really opportunities, like the pitfalls that government saw, most people in government saw, that you didn't have your specification all mapped out when that is just like a security blanket (Casey [interviewed by author] 2003).

Wright gives his perception of the differences between the clash of perceived authorities and responsibilities within the project team and how this was addressed during the NMA project.

> The people who have the baggage tend to be more cynical about this whole thing about: How can the architect be committed to working in a team arrangement? They never have before and 'I am not going to change my attitude' sort of thing. And that went for the architect as well. Grubby builders - they are not really concerned about the architecture. But the way we tried to change some of those things was…(Wright [interviewed by author] 2003).

There was no facility to return to the client for additional resources as the Commonwealth Government were adamant about a final price for the museum, an amount set before the competition entries were called. Also, there was an absolute timeline on the project which was to coincide with the opening in March 2001 as a showpiece event for the celebrations of the Australian Centenary. As two out of the three variables were fixed any unforseen complications would necessarily require skilful negotiations between the alliance members if the one remaining factor (quality) was not to suffer as a result of the commercial pressures. All the interviewees concur with the final published material that there was no substantial issue with the quality of the finished building.

5.3.2 Uncertainty of Costings

This sub-section deals with the factors that affected costings in an unforseen manner. The context of any project creates a unique set of opportunities, and constraints. There was a foreseeable uncertainty associated with a process which set the budget prior to selecting a final design and then selecting a design which was more complex than usual to quantify. This is particularly significant in light of Peters *et al.*'s assertion concerning the phenomenon of some parties committing to an agreed price in a lively expectation that additional funds will be made available as the project requirements are modified. This uncertainty associated with building costs is not an unusual occurrence, as Peters *et al.* state,

> Open or pre-qualified tender competition almost always results in acceptance of the 'cheapest' fixed price for the specified work using the traditional approach Tenders are called after the completion of design and the construction cost is then assumed to be 'fixed'. However, in practice the design is almost never finalised which results in opportunities for claims for 'extras'. The final end cost of a project, however, also includes the costs of design changes approved during construction, charges based on errors or omissions in contract documents used during the tender period and other claims made for consequential delays arising from cost claims noted above (2002 p.339).

Henry underlines the point that even within this successful project there were still issues to deal with concerning authority, responsibility and resources,

> There was a lot of argument even before my time but the Commonwealth had… set a budget before the competition and the competition was to set a design to that budget. And the competition participants came in with their own estimates of their designs and there was always an argument, continuous argument that the design was more expensive than the budget and I think even some of it wasn't disputed but even when they got within agreement range they were still disputing. So there were a lot of issues around that type of thing (Henry [interviewed by author] 2003).

When asked if the original estimates were hard to quantify, he continues,

> Certainly. I think there were two sides to it to look at. It is harder to build and harder to know what your cost base is because everyone was flying blind, really trying. How do you square meter rate the hall ceiling? (Henry [interviewed by author] 2003).

Morton reiterates this point when explaining the rationality for the risk/reward structure used at the museum.

> Because we were working with the risk reward structure we had set up because of the contract and the way the Commonwealth was expected to perform and the way that the alliance partners were expected to perform, so I knew and they did too that there was a fixed sum of money, that no more money would be forthcoming and that we had agreed on a targeted price to produce the product. And at the end of the day if that targeted outturn cost wasn't met and there was a cost overrun the cost overrun was being substantially borne by the commercial partners rather than the Commonwealth (Morton [interviewed by author] 2003).

The aesthetic complexities of the NMA were less of a factor than appearances suggest. They were constructed within the constraints of time and budget. This could largely be attributed to the financial penalties the architects and others would be liable for if the agreed outturn costs were not met. Casey expresses the view that the uncertainty of costings was more of an issue to those external to the process. She continues by voicing her opinion that she did not share the same trepidation as the solicitor general's department.

> From that point of view the complexity of the design for me didn't have cost worries; it had much more time worries in the sense that could we do it in what was an unusually short time to build a building of that complexity. But working as we did in the alliance framework we were assured on a daily basis that we were keeping pace and that the time frame was going to be met. So as I say with that sort of assurance in place and no real reason not to accept the assurance the sort of unusual aesthetics of the design was always a positive (Casey [interviewed by author] 2003).

The government was unequivocal about the amount of funding it had allocated for the National Museum. This led to the perception that the funding for this project was treated by the government as purely a matter of economics. The museum was given a loose comparative international figure which was then discounted and enforced unlike comparable flagship projects internationally. McDougall places the government's decision to use a discounted notional figure for the completion of the National Museum in an industry wide context.

> They did some comparisons with other world facilities and said OK and then decided we will only allocate 80% of the funds. Just because it is a political decision. So Federation Square is another example massively understated and there is sort of a tradition with Spencer Street Station is another one. A tradition of saying to get the project going, this is an industry problem, we will state the project as this and we know it is going to go up and up and up. No-one will admit that but everyone says, 'Oh, that seems a bit tight. Oh well, we can justify the changes later on' (McDougall [interviewed by author] 2003).

McDougall's sentiments concerning the post rationalisation of the common practice of knowingly underestimating outturn costs to the commissioning bodies has been an issue for concern raised in the Acton Peninsula Final Report.

> An entire "claims industry" has developed over past decades to advise contractors on how to claim for extra work, and client representatives on how to counter such claims. The system is widely in disrepute but unsophisticated or inexperienced clients are generally unaware of the advantages of alternative procurement paths and/or these options appear more complicated than the 'traditional' approach. The apparent attraction of the 'traditional method' gaining the 'market' or cheapest price, at least initially, is widely attributed to its continued popularity (Peters *et al.* 2002 p.339).

Raggatt sees the inability of the Commonwealth government to adopt a more flexible approach to the funding of the museum as symptomatic of its approach to the NMA project in general. He sees the government approach as fundamentally about delivering a project at a certain time for a certain price with no consideration given to unforseen circumstances and/or the architect's considered opinion regarding changes to the project.

> In that sense it is more like every other project like most architecture in a way where it is very clear early on that there is a modest budget to deliver something, and a project like Federation Square there's a… it's not fair to compare a first budget because the project's changed a lot but it was 124 million or something. Something's happened and it's very, very different. Whereas the National Museum was 154 million on day one and delivery, it never changed and that is a kind of… on one level that's kind of absurd idea. I tend to think for a public building that no one even knows what it is at day one. No one knew what it should be but they knew exactly what it was going to cost and when it was going to be delivered and then they developed something in between (Raggatt [interviewed by author] 2002).

Raggatt views the rigidity in the allocation of resources as inappropriate with the cultural and financial investment made for a National Museum project. He continues, making a direct comparison between the Federation Square project and the NMA project, as one of control over the finished article as the most significant factor in the outcome of the success of the project.

> A project like that you probably need 30-40 million or more probably to have done it as you liked it. And that's very little amount of money spread 40 million over a hundred years amortised, that is a hundred year building [Federation Square] That's what you should do for that quality building if you want it to last 200 years, not designed a cost and a time (Raggatt [interviewed by author] 2002).

He continues giving an analysis of the Federal Commonwealth Government's return on the resources allocated to the museum, when he concludes "*Certainly, the Federal government got fantastic value out of everyone…*" (Raggatt [interviewed by author] 2002).

Ashton saw the Commonwealth Government's view of the project as a product to be delivered within very tight constraints. He laments their inability to understand architecture as distinct from a purely functional aspect when he compares the difficulties faced with an alliance system charged with delivering a cultural building compared with an alliance systems previously used to commission an oil drilling platform.

> It's much easier to put risk and reward on an oil rig than it is on a cultural building because nobody cares what the oil rig looks like. All they care about is, 'Is it safe and is it built on time? (Ashton [interviewed by author] 2003).

John Mitchell cites an example that illustrates that the magnitude of the uncertainties of costings can be drastically reduced by the use of a coherently constructed and analysed data model.

> Kajima[194] have calculated from the clash detections and the failures of coordination found already before they are on site, that they have saved 175,000 pounds. They paid for the cost of building the model three or four times already so their investment is incredibly profitable. (Mitchell [interviewed by author] 2003).

John Mitchell's statement is supported by another example of the financial benefits of data modelling.

> Kajima UK used ArchiCAD on a project in Cambridge and saved 250,000 Pounds in detecting clashes in advance of construction. http://www.graphisoft.com/community/envisions/04.07.html.

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[194] Kajima is the 2nd biggest building company in the world. *See* http://www.kajimausa.com/

Due to the nature of the AEC sector, design information needs to be disseminated to many different recipients who traditionally require only a small percentage of the information given to formulate costings. As this experience is repeated by others involved in the project, the potential for misunderstandings increases with the number of parties involved. Also, due to the complex nature of the NMA and the Acton Peninsula Alliance's philosophy of ongoing rather than static documentation, there were many unknowns. These two factors in combination with what Peters *et al.* describe as a claim industry would normally create an environment which gave rise to numerous claims for additional funds. Due to the structure of the Acton Peninsula Alliance's risk/reward mechanism which financially linked the parties, the claims industry was effectively nullified. Also by use of a 3D CAD model the unknowns and misunderstandings which usually contribute to the uncertainty in costings of a project can be dynamically explained and rectified in a much shorter time span than would normally occur through the requests for information regime. This is supported by John Mitchell's statement *"The information model as an auditing tool is a very powerful risk management device*" (Mitchell [interviewed by author] 2003).

5.3.3 The Cost/Time Control Matrix

This sub-section deals with the interplay of factors and their influence over the choices made between the cost, the quality and the effect on the timeframe. One example highlighting this is when Casey recalls a mutual agreement to lay more expensive flooring than was originally envisaged. This is an indicative example of how areas of the budget were adjusted by consensus to address these issues; in this case a quality issue. The alliance innovation of quality pools was seen by Raggatt as just a different way of giving a contingency. When asked about the quality pools he characterised them as a traditional contingency sum.

> The 7.2 [million] could be over and above because the profit incentive or what I always just regard as a contingency, really. I think what they did to us was give the contingency sum and say if you can save all of that you can keep it (Raggatt [interviewed by author] 2002).

McDougall continues the theme by highlighting the distinction between the alliance procurement process and the budget/time constraints. "*The budget constraint is actually not a product of alliancing at all because the Government always had the opportunity to add more money*" (McDougall [interviewed by author] 2003).

Henry explains the Commonwealth Government's position once the budget had been fixed.

> So they looked at all the ways how they could actually make this project achieve, the project they had already decided upon doing in the time, and alliancing was the only thing that came up as not a certainty but the best possibility (Henry [interviewed by author] 2003).

Raggatt gives his view of the interplay between the project constraints.

> The only freedom is money and if there is no money there is no freedom really and you just… you are back to delivering making endless decisions to modify things to make them more and more achievable within cost and time whilst maintaining, you know, the architect's vision and we did that pretty well with the museum. It doesn't look like a project that had its arms and legs cut off (Raggatt [interviewed by author] 2002).

He continues,

> An alliance might try its best but if there is nowhere to move such as more money or more time - the same thing, more money and time. They are the same thing and there is a requirement that is in terms of penalties to deliver that project on time and budget (Raggatt [interviewed by author] 2002).

The perception from Jim Service, an early advisor to the museum, quantified the savings to the government made by using the alliance structure.

> That previous chairman [Jim Service] who was a construction expert that would say we got this building $20 to 30 million cheaper than had we gone down the traditional contract method (Casey [interviewed by author] 2003).

The Commonwealth Government were cognisant that they had to employ a procurement method which would deliver a better outcome than the traditional methods. As the Auditor-General reported,

> The government recognised that the time of a little over four years to complete construction was extremely tight. Using a traditional tendering and construction approach, previous projects of this scale have taken six years to complete (Auditor-General 2000 p.11).

The alliance process encouraged a timely completion. The architect's previous experience indicates, as McDougall attests, that the parameters would be too tight if pursued under a traditional contracting/procurement method.

> The timing was too short, I think there was no doubt about that and in fact the relationship between the timing and the delivery system, the alliancing is that there was no way that would have been delivered under a traditional system (McDougall [interviewed by author] 2003).

There persists a view that with a State or Commonwealth Government as the client, that the budgetary constraints are ambit rather than an appropriately calculated figure[195]. This belief is fuelled by a history of government projects fully funded despite exceeding their original estimates e.g. Melbourne Federation Square and the Sydney Opera House. This misconception was articulated by Morton "*They thought we were only kidding there was no more money*" (Morton [interviewed by author] 2003).

He continues by explaining what impact a fixed budget had upon the architects, "*They really did have to give up some of their ideas and find equally good solutions within the budget*" (Morton [interviewed by author] 2003).

Speaking before the completion of Federation Square, Raggatt describes the time and financial decisions made at the museum as almost arbitrary and hence able to be changed if the Commonwealth Government chose to.

> I know it is political imperatives that gave us Federation Square done in Melbourne and it is going to be about two years late. At the end of the day the project came in March of the Federation year, it could have come in at the end of the year as long as it got into the Federation year. I would have thought that was OK but anyway someone set the date. As usual someone sets a date that has nothing to do with anything other than it is a date and someone sets an amount of money, which equally has nothing to do with anything other than someone thinks that's a good number and we get the job of delivering something for it, obviously (Raggatt [interviewed by author] 2002).

The combination of cost and size promoted a more cooperative environment as the cost and size were predetermined and unable to be varied. Casey describes how the direct relationship between the alliance partners' decisions would impact upon their bottom line due to the nature of the risk/reward mechanism.

> We definitely were a bit short on money so but the situation where you pay people direct cost definitely drove the right behaviour

[195] The financial resources of a private company are limited by accounting practices which are subject to government regulation. Hence for a company to expend more than it receives in revenue, it would by definition become insolvent and would be required to cease trading. Government expenditure by comparison is not regulated by commercial practices and can be increased if necessary by adjustments to the tax rate.

> because in terms of if they increased their direct costs their profits would suffer and eat into the profits (Casey [interviewed by author] 2003).

The alliance system used at the NMA encouraged a more inclusive type of decision making ethos. However, the GMB project which was also delivered successfully within the project constraints employed differing devices to similar ends. One of the more prominent points of difference was the way the 3D CAD model was used throughout the project. FOG&A's principal driver for using a building information model was for cost control rather than aesthetics because it could be used to generate dimensionally accurate building elements, and there were nearby industries that employed computer generated fabricating technologies. Randy Jefferson, one of Gehry's senior staff, asserts that the choice of CATIA as the CAD system was a pragmatic choice driven by CATIA's ability to document building elements to high levels of accuracy and thereby drastically reducing wastage and on-site reworking. Therefore the use of CATIA was seen primarily as a cost control device by FOG&A (Jefferson in Friedman 1999). This view is supported by Gehry in an interview with Zaera-Polo of Foreign Office Architects when he summarised how his architecture has become affordable by advances in computer technologies.

> Flat pieces cost one dollar, single curvature pieces cost two dollars; double curvature pieces cost ten dollars. The good thing about the computer is that it allows you to keep a close control over the geometry and the budget (Frank Gehry in Zaera-Polo 1995).

One example of a tangible direct benefit of using a building information model has been FOG&A's use to model the most cost effective layout of panels without compromising the non-Euclidean forms. Bruce Lindsey[196], author of the book 'Digital Gehry', discusses how the CATIA system was used to generate a coloured 3-Dimensional graphics that indicate the number of different axes on which cladding panels were curved (Lindsey 2001 p.38). This analysis was subsequently used to divide the cladding into smaller panels with fewer axial curvatures. This is indicative of FOG&A's systematic approach to using computer modelling as a cost control device.

The GMB was constructed with a similar budget to other contemporary museums. However, FOG&A's made a decision to employ advanced computer techniques to help them not only realise Gehry's original vision but

[196] Bruce Lindsey is Professor and Head in the School of Architecture at Auburn University, USA.

more importantly to deliver this vision at an acceptable price. This is supported by John Mitchell when he asserts,

> Using the object model approach they are getting down to 5% accurate and that sort of accuracy means they can be more confident about cost and they have more capacity to make profit (Mitchell [interviewed by author] 2003).

Jefferson states when considering the main benefits of object oriented CAD at the GMB,

> In Bilbao we set up a series of rules, but the rules weren't derived because of limitations of the computer; they were derived to control costs. Going into the project, we knew that we had an extremely tough budget. It's easy for a budget to slip from $300 to $400 a square foot. So we began Bilbao with some very important ground rules as to how we were going to develop and maintain control of the budget (Jefferson in Friedman 1999 p.177).

Coosje VanBruggen, artist and author of 'Frank O Gehry Guggenheim Museum Bilbao' supports this when she states *"The Guggenheim Museum Bilbao would not have stayed within the construction budget allotted by the Basque Administration had it not been for CATIA"* (VanBruggen 1999). Gehry expands upon VanBruggen's statement.

> With the computer now we are able to quantify the materials to a great degree of accuracy. In the case of Bilbao the steel for the steel construction was documented to seven decimal points of accuracy. That is every piece of steel, every joint,…(Blackwood 2000).

He continues to qualify the advantages to the steel suppliers and fabricators.

> Each contractor they were within one percent of each other….They did but they were within one and they were eighteen percent under budget for steel and when they finished the steel only two pieces, like this long [visual cue], had to be remade. It is so accurate. It is a revolution this computer…(Blackwood 2000).

The ethos of a CAD system which has had time to evolve in an environment which understands the benefits of long term relationships is articulated by Cocke.

> The interesting thing here is that the building industry, architects, engineers, contractors, and fabricators is far larger than the aerospace and automotive combined. But those industries operate on long term contracts where they can demand that each of their sub-contractors get on a common platform. Every subcontractor, no

> matter how small, is looking at 20 years' worth of contracts, so the investment in technology makes perfect sense (Cocke 2000 p.54).

The NMA had both contractual motivation and the goodwill of the people on site and their understanding of the nature of the work to be done. FOG&A relied on high tolerance prefabricated elements to minimise or eliminate remedial in-situ operations; hence the reliance on the on-site workforce was substantially reduced from normal expectations. This difference of the local workforce can be seen in the contrasting levels of finish between in-situ to pre-fabricated work (Figure 66, p.250) at the GMB.

5.3.4 Perception from Government

This sub-section deals with how the government's representatives saw the government's agenda in relation to the NMA project. The Commonwealth Government, unlike most clients, had two parallel agendas for the NMA project, one more strictly defined than the other. The primary agenda was to provide a functional museum for the Australian public. The secondary agenda was that they also needed to champion notions of equity and fairness in their dealings.

The political imperative to have the building opened on time and on budget was such that the exact method of procurement using the alliancing system seemed the most appropriate to avoid adversarial Design & Construct issues. These issues have been a matter for government consideration for a number of years.

> The complex and intermittent nature of major projects in Australia provide limited opportunities for acquiring project management skills. Recent initiatives involving government and the private sector seek to overcome information deficiencies about tendering and contract processes. Other than improving the management of its own projects, the Commission does not consider there is an additional role for government in improving project management skills (Australian Government Publishing Services Canberra 1991 p.7).

Morton reiterates the government's position when he asserts he saw no role for the government in developing systems to benefit architecture, when asked about whether the government actively encouraged or underwrote any new architectural innovations.

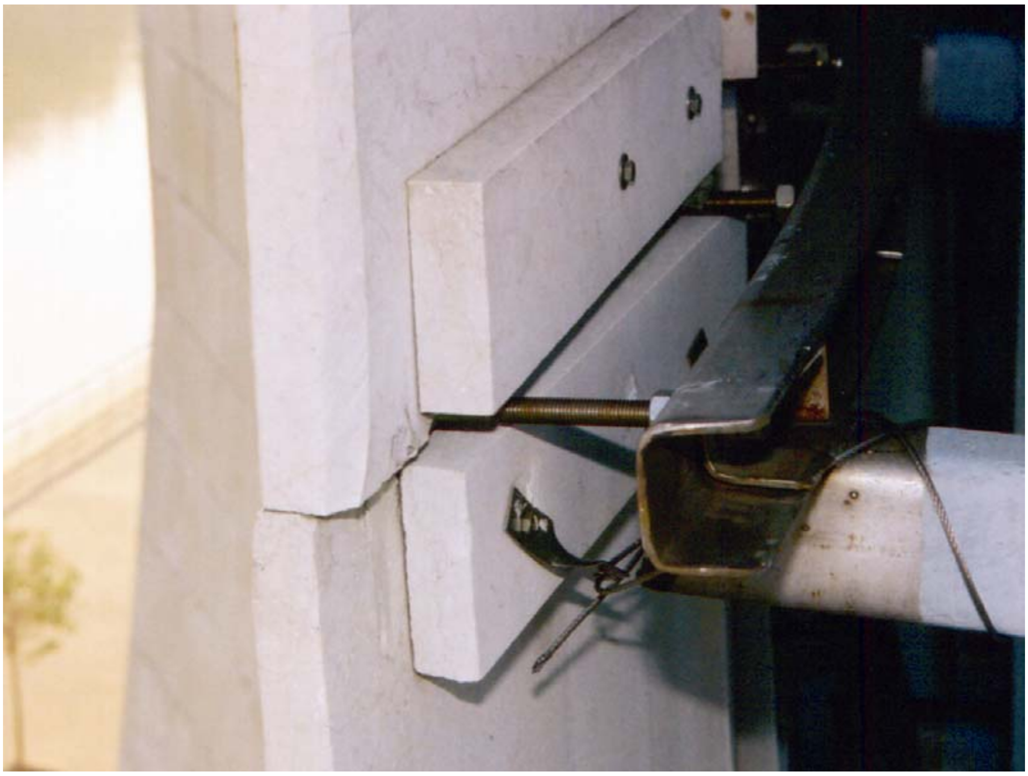

Figure 66 GMB, Cladding Detail.

> No, not as such. I don't think if you are asking did the Commonwealth go into this process looking to use it as a test bed for new architectural development, no (Morton [interviewed by author] 2003).

When asked whether the lines of demarcation were blurred, and the government's attitude to pushing the limits of the design, he continues,

> I don't think so in this case. I think it was very much, the design was very much the province of the architects and how the changes were maintained and how the changes were fit in the integrity to maintain the integrity of the design… was an alliance decision as we went through the project but certainly the Commonwealth wasn't pushing the boundaries in terms of the design (Morton [interviewed by author] 2003).

The government did try to encourage smaller architectural practices to be involved in the process, as Casey remarks *"Being a gift to the nation for Centenary Federation was to try and work out a way to attract smaller architectural firms*" (Casey [interviewed by author] 2003). The aim of incorporating smaller and younger design orientated practices she saw as the most appropriate way to create a larger cross section of proposed designs and a diversity of architectural practices.

However Henry tempers Casey's optimism about the variations in designs and how the more complex examples may not be in line with the expectations of the Commonwealth Government when he refers to the government's initial reaction to the successful ARM scheme.

> If you think of the architecture of the exterior by the look of the place - there was the functional aspect itself. It really came a second place to the architectural design as opposed to the functional design. It was a lot easier getting the functionality out of it. The funding was there to build a museum, not a sculpture (Henry [interviewed by author] 2003).

He continues to surmise that there were issues from the government's view with the AEC sector which required a rethink of how the project would be procured, "*You have got to have a problem before you start looking for a better way of doing it. If it is done OK then they probably don't look.*" (Henry [interviewed by author] 2003).

Morton continues, "*There was a high level of dissatisfaction of what was happening in the construction industry*" (Morton [interviewed by author] 2003). However, regardless of this scepticism he continues to say that the complexity of the design was of less concern than the industry's ability to deliver it within the prescribed constraints.

> I wasn't involved in the project at the start but I think in terms of the unusual design, I think that would have been viewed as a positive rather than negative because what people were looking for was a really distinct and different type of building, which was supposed to be the flagship of the centenary of Federation celebrations. And so just another boring Canberra box would have been particularly unwelcomed and I think, the competition was certainly designed to promote interesting ideas (Morton [interviewed by author] 2003).

The government perception about the AEC sector's track record of publicly funded projects was an expectation that there would be problems. This was compared to the normal feedback received from the industry as Morton continues, "*[T]he industry just laughed when we announced we were going to build this sort of building with this sort of money and in this sort of time*" (Morton [interviewed by author] 2003). He continues, "*Nobody was impressed: you are mad, you are being taken for a ride, you are never going to get it done*" (Morton [interviewed by author] 2003). Even after the successful completion of the project there is still a view that it was a risky venture as Henry continues, "*I am still getting people telling me it was a big risk*" (Henry [interviewed by author] 2003). The government's representatives were aware that the Commonwealth's choice of a department which had never commissioned a major building work before placed them in an unfamiliar environment where they may not have been considered the appropriate commissioning body. Casey accepts that ARM saw the government's representatives as not as informed as they may have been; "*I know they thought that we were uneducated clients*" (Casey [interviewed by author] 2003). Casey's assertion that they were uneducated clients can considered in light of Peters *et al.*'s assertion that clients with lower levels of self confidence in their construction expertise will tend to refrain from making enforced design changes.

> One can look at the procurement continuum through the lens of influence and trust. At one extreme the client may trust the design influence exercised through the contractor more than being exercised through an independent design team under the direction of the client. At the other extreme the client wishes to retain influence and control over the projects aesthetics and functionality. If clients have high levels of self-confidence in their exercise to effectively exert this influence they will tend to exercise direct authority over the design team. If they have low levels of self-confidence in their expertise they may devolve this authority to the client representative. In this view the traditional approach rest on its trust that the design is sufficiently well developed and the competence of the other design team to fully consider issues of constructability is so advanced that the 'lowest tendered price' will end up being the least expensive and functionally acceptable alternative (Peters *et al.* 2002 p.353).

The perception from government was from one point of view ambivalent, both involved and detached. The initial impetus for a non-traditional procurement system whilst being suggested from an industry representative (James Service, AO), was embraced and implemented by the commissioning body (DCITA) and the alliance partners, with both demonstrating a philosophical engagement with this new system. This was in spite of legal advice that the alliance process as advanced was legally untested and hence functionally unpredictable. However, the DCITA did detach itself from many rudimentary decision requiring elements of the project.

5.3.5 Perceived Potential Legal Complications

This sub-section deals with the alliance partners' concerns over the legal implications resulting from the alliance structure. Traditional contracting or procurement methods come with the expectation of differences of opinions between parties. However, the differences of opinion, although sometimes large, are quantifiable due to the party's previous experience. McDougall gives his point of view of this pattern of behaviour.

> I think there is a huge risk in traditional deliveries - any project like, it's a $150 million project of which about $100 million of it was the building side of it. So a $100 million building project in standard delivery is a legal nightmare so you… but the difference is they are known issues because for forty years we have delivered projects like that in traditional lump sum contracts and the legal precedence can relate to that. So there is a series of practice notes and practices and advisors and so on who have experience (McDougall [interviewed by author] 2003).

He continues by outlining the benefits of the alliance structure against the traditional model,

> I think the alliance process allows, firstly it allowed a greater - what's the word? - It alleviated the overlay of legal structure that traditional delivery methods have. I think architectural practice in the last thirty years, let's say the last forty years has drifted away from the process of documentation, documenting intent and directing delivery as a single fluid process that isn't interrupted by points of adversarial hurdles (McDougall [interviewed by author] 2003).

This underlines the need for the contractual system to work in concert with the documentation system to avoid nugatory and gratuitous generation of information purely for contractual reasons.

A similar view of the same generic issues present at the GMB project was outlined by James Glymph of FOG&A when he describes his view of the architect-client-builder relationship. He recognised that the legal relationships between parties have not kept pace with innovations in building procurement. The current status is now being challenged, as Glymph points out,

> The American legal system, the insurance system, and the tradition of the architect-client-contractor relationship are based on a bunch of phoney assumptions. After the architect designs the building and does the drawings, he rises from the floor five feet and becomes the holier-than-thou arbiter between the client and the contractor. That's the assumption of the old system. What really happens is that the contractor goes to the owner and says, "If you straighten this wall out, I can save you a million dollars," and the client says Wow! And sometimes he does it. The contractors, because of their relationship to the money, become parental in the equation, and the architect becomes the child – the creative one (Glymph in Friedman 1999 p.54).

Due to the speed of change and action in the contemporary workplace, traditional relationships are undergoing frequent re-evaluation. As the system of law is traditionally based on recorded precedent (case law), there is necessarily a period of time before any specific legal issues can be resolved and hence generate generic legal guidance between parties. Due to the lack of statutory and/or common (case) law and the complex set of financial inter-relationships there is much interest in a potential legal liability. However due to the prohibition of legal action between parties (referred to as a no blame cause) less time is consumed considering the legal implications of particular actions than would normally be the case under a traditional procurement system.

5.4 The Changing Role of the Architect

This section deals with the external and internal influences which impact upon the skill set of the architect. The role of the architect as project manager can be seen from a certain perspective to be moving towards that of a motion picture producer. The motion picture industry has a long established practice of producers contracting directors, actors, and writers and creating the right environment for those professions to interact in the most productive way. McDougall outlines this when asked about similarities between the motion picture industry and the AEC sector.

> I think the movie industry is intriguing in that way. I don't actually know a lot about the movie industry but you would have to say, I am always amazed that actors ad lib. You don't think that it is all, they make it up and the director then responds to their… the way that they make it go. So it seems like the conception of the original idea of the film is changed by the interaction of the actor and the director and so there is a sort of a strange… I will select the people I want to work with because it is that sort of concept and alliancing has the capacity to do that (McDougall [interviewed by author] 2003).

This interplay between those involved with motion pictures draws an interesting parallel with the experience of the alliance partners on the NMA project. At the NMA the inclusion of the major trades and professions into an alliance motivated those with detailed knowledge of a specific area to actively share their knowledge with others. Stephen Ashton describes one of the advantages of the shifting areas of involvement.

> We are getting involved in lots of issues that we wouldn't otherwise be involved in. Yeah, we are at the table where all the main decisions are made so you are not like that in other forms of delivery. You know

> if you are just working for the builder and the builder for the developer you are not at the meetings between the builder and developer where they say they've got a problem unless they think you can help them, which is not very often usually. So it does change the role. So it's got to be a good thing from that point of view (Ashton [interviewed by author] 2003).

He takes a very pragmatic approach to the continuing and central role of the architect when he asserts "*our role is still to come up with ideas and present them and get them built*" (Ashton [interviewed by author] 2003).

Wright describes what he sees as a changing in the architect's skill set, particularly the technological and design acumen. He sees the marked difference in the acceptance of the most appropriate contemporary skills between architects by generation.

> We have a lot of meetings here with the people on-site and the architects and the younger architects are quite good at it. It's the old ones that are struggling with it a bit because they are bringing a bit of baggage (Wright [interviewed by author] 2003).

Due to the inclusive nature of the Acton Peninsula Alliance, solutions to design problems were not specifically the role of the architects. This inclusive design process allowed for solutions from outside the usual pool of people, as Casey recalls when stating the effect the alliance had upon where design solutions came from in times of design paralysis, "W*e stalemated so people had to come up with great ideas, and that is what it did*" (Casey [interviewed by author] 2003).

Ken Bool, one of ARM's project's architects on the NMA project, described a new project he was working on "*I am currently doing a job at the War Memorial [Melbourne] and it feels like regressing after the museum [NMA]*" ([interviewed by author] 2002). This sentiment was shared by Wright, the project manager for the NMA project who articulated what techniques implemented at the NMA project had made the transition to his preferred way of working after the NMA project, "*that's happening now because I learnt how to do it on the museum*" (Wright [interviewed by author] 2003).

The move to a greater role for non-designers under a relationship-based agreement means more latitude for non-designers to have an effect over the design. This can be more prevalent in areas where the documentation is loose, ambivalent or more performance based than prescriptive, as it is in everybody's interest to have the most workable solution to a design problem. Kieran and Timberlake suggest that solutions may come from non-designers.

"*The process of making is no longer entirely linear, producers engage in design, and designers engage in production*" (Kieran and Timberlake 2004 p.7). When asked about the impact of 3D CAD modelling on the role of the architect Ashton replied,

> Probably has strengthened our position in regard to the rest of the industry… is starting to realise there is a technological edge to be had by understanding 3D modelling and probably architects are the ones with the most experience with that at the moment, and therefore that a thing that people expect you to be able to do now and look to you for a bit of leadership in that area (Ashton [interviewed by author] 2003).

This view is supported by John Mitchell's assertion that architects are the obvious choice to assume the role of information or model management.

> [You] have a model and it's a database you need a person on the project team who is what I call the model manager and this is becoming quite clear in other users. The model manager is a person who knows how to use the model properly and he has to be an architect, why because he has to understand the nature of a building (Mitchell [interviewed by author] 2003).

He continues by elucidating why architects are the obvious choice for managing design information.

> It is quite interesting that in the information modelling, in the team of people who have been building the IFC model there is a thing called an information model, modelling information and you are building an information model, right. Turns out that a lot of architects are very interested and technically qualified in that, so if you look at the proportion of architects in that team in the development of the model there is an enormous over-representation of architects. Architects like to build concepts, if you have to come to a solution for the clients request you have to actually build a concept and it is in your mind largely at the beginning and they are good at articulating a concept (Mitchell [interviewed by author] 2003).

He continues that not only should architects become the manager of building information but also this information could be used by the architect to perform the role of a quantity surveyor, when he asserts,

> The quantities of an object's geometry are an attribute of the geometry, there is no calculation required it is just a function of the model and so what has happened is the builders see this, big builders again are getting into this, instead of being a quantifier you are actually using your knowledge of building (Mitchell [interviewed by author] 2003).

A difference between the NMA and the GMB is that the subcontractors at the GMB were more used to handling 3D design information. Gehry's view is that design information can be generated collaboratively but for a less inclusive and more collaborative process as he states,

> One thing that comes to mind when you think about that is it is collaborative. It is a group of people working toward the greater whole greater than the sum of its parts. That is a model we have seen in government, we have seen it in that so why not in architecture, why can't that be possible. And why can't it be possible with rugged individualists, with the model of Frank Lloyd Wright, the model of Corbusier, with the model of the rugged individualist still making their mark, making their best work without compromise in the context of this collaborative effort. So I have explored that (Blackwood 2000).

The shift to a more cooperative and inclusive way to work positions architects closer to the source of the resources and the central means of production. The work systems used by architects are in part credited for the successes or otherwise of any work of architecture. The Acton Peninsula Alliance procurement method (Peters *et al.* 2002) used at the NMA and FOG&A's use of Requests for Proposals (Tombesi 2002) make the lines of demarcation between the architect and the non-architect less distinct. This may change the traditional notions of professionalism which will in turn impact on re-framing the building-design-construction relationship in light of design specialisation (Tombesi 1997).

One vision of how the role of the architect is changing is offered by Godfrey, as an architect of information, when he talks about his colleagues, technologically forward looking architects when he asserts "*We actually want to design the frame of reference*" (Godfrey [interviewed by author] 2003). He sees some forward looking architects as understanding their role as being significantly more important as the definers of parameters for others to work within. He gives a specific instance of a colleague of his as,

> A brilliant architect who can design wonderful buildings but he is seeing his job as a designer is to ensure the city of Melbourne emerges with high levels of urban design quality through a different process (Godfrey [interviewed by author] 2003).

Due to the complexities of the GMB an innovative approach was taken which involved the builders at an earlier stage than is usual. This early collaboration gave FOG&A expert knowledge of the constructability of the GMB which did not exist within his firm at the time. The most significant aspect of what became known as the 'design-assist' concept was that it harnessed the most appropriate knowledge at the most effective time. Tombesi when considering the success of FOG&A's *design-assist* system asserts

> The work developed by the office [FOG&A] in the last ten years has defined a distinctive niche to which only a relatively select group of trade specialists has had access. Even within a competitive bidding environment, the type of projects and the use of specific technical and formal solutions have resulted in a limited construction market with limited players. This condition has obviously created relations of consolidated trust, mutual understanding and technical cooperation which go beyond the scope of work defined by hard documents. Even if proved, the financial success of FOG&A's working relationship with many trade specialists could well depend on this unusual and privileged relationship rather than on the structure of the documentation (Tombesi 2002 p.84).

John Mitchell reinforces Tombesi's and Ashton's notion of the architects as the managers of knowledge, but in the case of FOG&A's experience, this knowledge has more of a dynamic quality between the architects and other design professionals.

> This will change a lot because we are going to give you the model, we should be paid more for giving you a much better information database but your job has been reduced because you don't have to do the creation of the data, you just have to exploit it (Mitchell [interviewed by author] 2003).

He goes on to say *"They are still the best people to interpret the requirement of a client, the functional and other performance requirements, and interpret that in a design solution."* (Mitchell [interviewed by author] 2003).

This new role for the architect as a manager of design information has definite implications for the process of how architecture is designed and documented. These implications necessarily impact upon the division of design, design development and documentation. Whilst these requirements of an architectural project will remain, the traditional means of documentation would be substantially altered. Documentation using a building information model could most accurately be described as the generation of required data as a function of the data model. In short, the documentation is best understood as simply a by-product of the building information model. The implications of this change for the process of producing architecture to documentation stage is decreasing the reliance and time expenditure on preparing physical documents for other users. John Mitchell extends this idea by asserting that not only was the previous documentation regime inefficient but moreover it has distracted architects' attention from more useful professional skills.

> So I argue now the opportunity comes back to the architect to retrieve some of this professional capability they have given away and some of the professional skills they haven't adopted but they should have. Because what is happening is the object model technology without doubt is the proper design environment. In the past David Sutherland[197] in Melbourne makes a beautiful analysis, we have a lost generation of architects who are using 2D CAD because 2D focuses on documentation, it doesn't focus on design and that is what architects are best at, design. Documentation he argues should be a by-product of the model (Mitchell [interviewed by author] 2003).

He advanced the proposition that there is a greater level of cohesiveness due to favourable access and goodwill over documentation. Greg Lynn[198], himself well-known as an architect exploring digital modelling, sees Gehry's contribution to contemporary architecture as changing notions of conceptualising the enclosures of space and to advancing the practice of architecture through innovative techniques and connections between industries.

> The Lewis house is a seminal piece of architecture, first because of the aesthetics. It introduces a new kind of set of forms and vocabulary and it really stretches the kind of collage language into new realms. If you had to put a point on what that is, it is one of the first projects that use surfaces to make space rather than volumes. Usually architects draw with points and lines and volumes whereas an automobile designer thinks in terms of flexible surfaces like cloth. In terms of innovation in digital architecture the Lewis house was really the first place you started to see people trying to fabricate these elements you associate with the aeronautics industry or the car industry. Just in terms of construction the slumped glass, the doubly curved metal panels, the doubly curved structural elements and beams, all of that work it was really the first time it was ever proposed and it was the first time it ever started to get worked out (Greg Lynn in Kipnis 2003).

Over time, architecture and building have become two separate disciplines. With the exception of movements like the Bauhaus and its attempt to link traditional handcrafts with architecture, the architectural profession has largely accepted that the position of the architect as designer-builder has been replaced with the position of the architect as a designer. Architects have created their own niche in response to, or to differentiate themselves from, others who are engaged in similar activities. Magali Sarfatti Larson[199] asserts,

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[197] David Sutherland is the CAD manager for Fender Katsalidis.

[198] Greg Lynn is the principal of Greg Lynn FORM and has taught throughout the United States and Europe. Professor of Spatial Conception and Exploration at the ETH (Swiss Federal Institute of Technology) in Zurich and as an Adjunct Assistant Professor at Columbia University, USA.

[199] Magali Sarfatti Larson is Professor Emeritus, Temple University, USA.

> In capitalist societies, architecture emerged as a profession that possesses artistic, technical, and social dimensions. The emphasis placed on each varied in different times and places. However, the existence of engineering as a separate profession precluded almost everywhere a strictly technical concentration. In the face of engineering's more established position, it was strategically easier for architects to base their professional claims on the aesthetics of construction than on technology mastery or scientific methods. Thus, the image and identity of modern architecture remained centred on the subordination of technology to design (Larson 1993 p.4).

Accepting Larson's assertion, it follows that the role of an architect is most appropriately understood as a designer, rather than expert in the knowledge of building. Consequently, a predisposition towards visually complex architecture may be a response to an increasing concern with the visual. The corollary to this assertion implies that engineers have based their legitimacy more on technical mastery than aesthetics. Only works that exhibit both aesthetic interest and technical accomplishment reveals what an interweaving of these two areas can do in realising complex works of architecture.

In this section I have argued that at the NMA the software used (both animation and architectural) was known to the architects and as such no outside expertise was required for its use. The most significant aspect of technology transfer at the NMA was the knowledge transfer of how the software could be used from the architects to the engineers. The willingness to undertake technological transfer played a role in facilitating successful relationships between parties who did not initially share compatible technologies.

The role of the architect necessarily changes in response to the technologies and social dynamics of the age. One understanding of the contemporary architect may be one who examines technology tools to ascertain the most appropriate technical devices to realise their particular architecture. Just as in previous eras, the role included assessing the appropriateness of the way they communicate their designs and the method for dealing with the myriad of individuals and entities needed to complete a contemporary project.

6 Conclusions

In this chapter conclusions are drawn about the intertwining of computer technologies and relationship-based procurement. These interactions are explored through the research questions, which are:

1. What relationships were facilitated by the procurement method used at the National Museum of Australia?
2. What connections exist between procurement methods and the computer technologies that were used on that project?
3. What lessons are to be drawn from this experience for contemporary architectural practice in Australia?

The themes that emerged from addressing these research questions are as follows:

- The procurement method created an environment which promoted the use of architectural computing through both professional and personal relationships, as can be seen in:
    - a procurement method structured to facilitate/encourage a cooperative and informed environment, where all involved, were aware of, and shared a common purpose.
    - independent oversight panels to diffuse/negate some potential adversarial issues.
    - the pro-active engagement of the individuals most influential in the project.
- The synergy between computing technologies and relationship-based procurement had a positive influence on managing the constraints of time, cost and quality, and the way architects communicate with others, including:
    - the use of computer generated graphical representations to convey the conceptual framework to the wider workforce, building a genuine informed and involved ethos within the team.
    - the negation of the traditional *requests for information* regime by the use of an inclusive procurement system, facilitating additional design information delivered electronically.
    - the immediate and collaborative problem resolution via real-time 3D CAD simulations between architects and fabricators.
- The impact of advances in computer technologies and relationship-based procurement expanded the skill set of the architect, via:

- the increased availability and understanding of design information made possible by a wider use of computer technologies.
- the architect's engagement with a more collaborative rather than prescriptive role, and
- a receptive environment which allowed a CAD package to be used primarily for its form making.

This thesis has shown that although superficially the National Museum of Australia and the Guggenheim Museum Bilbao projects appear similar there are fundamental differences between them. The GMB in comparison to the NMA exploited an existing industrial infrastructure with which it shared commonalities in production methods.

It has further shown that both the NMA and GMB are best understood as projects that stayed within their constraints of time, cost, and quality by using different non-traditional and innovative approaches to personal and professional relationships. In the case of the NMA, the major factor influencing the constraints was the relationship-based procurement method. However, in the case of the GMB the major factor influencing the constraints was the application of ubiquitous and highly sophisticated computer technologies.

Both ARM's and FOG&A's approaches were essentially pragmatic and this pragmatism was coherent with the infrastructure that supported it. For ARM the technology they used could be more experimental as the other alliance partners did not share, or expect, a common data format other than conventional 2D orthographic projections. Consequently, this unconventional approach meant that at times ad hoc arrangements were made to satisfy a requirement for information in a form acceptable to third parties.

Conversely, FOG&A were bounded by the expectation of a deliverable format for secondary users. They supplied data in a format interoperable with fabricators and others, which enabled them to be able to maintain a level of efficiency necessary to complete the project within its constraints. Comparatively, the GMB was more reliant on computer technologies than the NMA.

This thesis has shown that the successful use of computer technologies at the NMA is best characterised as a human art rather than technological inevitability. The successful use of computer technologies in architecture relies on both a level of technical literacy and a common frame of reference. This common underpinning can be established by both contractual and non-contractual means.

The interpersonal or human aspect of the NMA is exemplified in the collaborative rather than adversarial nature of the Acton Peninsula Alliance. This fostered in the Alliance partners an inclusive ethos which made them less protective of their professional niches. The project manager Peter Wright characterises the ethos with the example of the absence of traditional adversarial contractual activity (p.197). The absence of what could best be described as contractual disputes allowed the project to be completed without any major delays.

The famous quote by Lord Ernest Rutherford (Nobel Laureate for chemistry 1908) "*We haven't got the money, so we've got to think*" (Rutherford 1962 p.102) encapsulates the alliance partners' approach and behaviour throughout the NMA project, including their approach to computer technologies, as the Commonwealth Government had made it clear that there would be no increases to the NMA project's modest budget. Hence the NMA project could not deliver the resources for ARM to invest in leading edge technology. ARM's existing infrastructure budget, including mainstream software applications, was already absorbed under their general expenditure. Alternative technology such as CATIA would have required a sizeable increase in ARM's computer infrastructure budget as well as the accompanying productivity issues of retraining.

ARM modelled the NMA using computer technologies which were commercially available. However, these technologies were applied in an unorthodox and hybrid fashion. It is in the innovative combination of these various technologies that the essence of ARM's approach to architecture as a dynamic craft is illustrated. The significance of the NMA project for the future of architecture in Australia is illustrated in the combination of the innovative use of computer technologies and the use of a procurement system that did not penalise this hybrid use of these technologies. ARM's decision to use multiple modelling and documentation packages is commensurate with their desire to maintain an ongoing dialogue with the project.

Contrary to common opinion that FOG&A pushed the boundaries of existing architectural computing, it is more appropriate to consider this project with regard to their adaptation of a more applicable CAD system from outside architecture for their needs and the complexities of the project. As ARM formed non-traditional relationships to deliver the NMA project, FOG&A formed alliances with aviation fabricators to deliver the GMB. These alliances were underpinned by the interoperability of the design information. BOCAD, a complementary software package to CATIA used by the aerospace industry in the Basque country, was used to generate not only a materials list but exact coordinates to CAM machines from FOG&A's CATIA model (Lindsey 2001). CATIA supported a total solution utilising higher levels of pre-fabrication than are normally found in architectural projects.

FOG&A also benefited substantially from the research and development undertaken for the unbuilt Lewis House project (Kipnis 2003). These opportunities were provided beyond those traditionally allowed under normal commercial arrangements. The ensuing research and development inspired by Gehry's dissatisfaction with the staircase at the Vitra Design Museum, Weil am Rhein, significantly changed the way his practice perceived what was possible (Blackwood 2000).

The GMB project also used the skills of others to advance the final project but under a different system which called for input at an early stage of the project. This input was under the control of FOG&A (Tombesi 2002). This more effective use of people with complementary knowledge outside their office played a role in realising new knowledge used by FOG&A's team.

The GMB could legitimately be described as an inspired example of technology transfer. The legacy of this technology transfer determined that the format of design data would be heavily influenced by the original context of the aerospace industry. In its original context the technology had an associated means of production which included long term contracting and economies of scale in production. Given the particular technological circumstances which underpinned the GMB project, this geometrically complex building could be seen as a foreseeable consequence of technological advances developed by the aviation and automotive industries. These industries use aerodynamic performance and fabrication as part of their design criteria. These criteria for functionality and aerodynamic forms facilitated a financially viable use of Gehry's preferred non-Euclidean forms. Gehry has consistently maintained in numerous interviews, that the complexity of his architecture was only possible because of CATIA's facility to take his highly idiosyncratic complex forms and provide accurate design information for pre-fabrication and construction (Zaera-Polo 1995; Friedman 1999; Ivy 1999; Blackwood 2000).

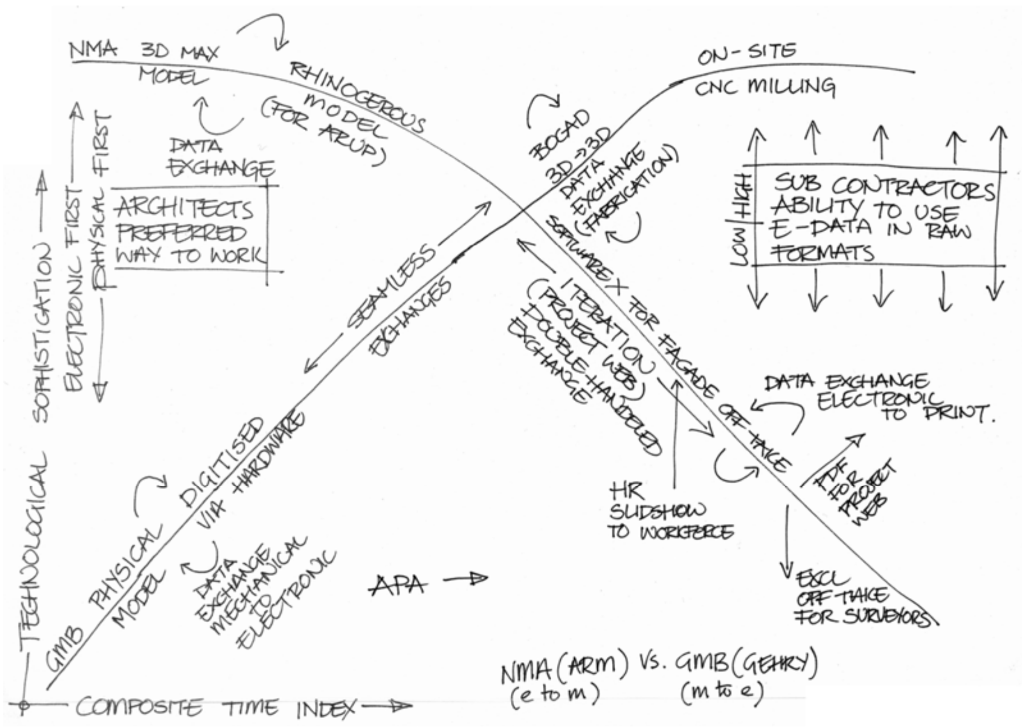

Figure 67 Graphical Representation of Project Workflow.

The seamless transfer of digital data maintained the integrity of Gehry's design intentions. This was done in a similar way to the early stages of the Acton Peninsula alliance. However, the architectural computing used at the NMA was less seamless, less convergent and less ubiquitous than at the GMB. ARM's work on the NMA project showed one paradigm of ingenuity.

It used situationally appropriate technologies to satisfy particular needs. As such they defined one possible template of how to use complex 3D modelling software and a variety of secondary techniques to produce contractually adequate and visually informing design data. ARM's idiosyncratic approach to meeting the challenges of design documentation and dissemination through various techniques is in sharp contrast to FOG&A's approach (see Figure 67, p.265). Accordingly, these very different approaches to the use of technology have changed their skill set. This redefined how the architects saw their particular contribution and relevance within the project team requiring them to depart from traditional architectural practices.

FOG&A has been credited with championing the computer in architecture (Novitski 1992; Stein 1997; Steele 2001; Mitchell 2003), however the use of CATIA was employed for design, development and cost control rather than preliminary design. The majority of cerebral input into the design is embodied in Gehry's initial sketches and physical models for the GMB (VanBruggen

1999; Blackwood 2000). As Gehry asserts, "*I think my best skill as an architect is the achievement of hand-to-eye coordination; I am able to transfer a sketch into a model into the building"* (Gehry 2005).

The delivery system used at the GMB required that the design data was completed before any physical work was undertaken. The design evolution in terms of form was substantially completed as a series of physical models. The structural and other technical details were developed after the final physical model was digitised. Hence, the design of the GMB project could be considered as *done* in some sense from the moment the final physical model was completed. This seeming inevitability could be seen as a consequence of a procedure that delivered a single, coherent and seamless data model. FOG&A's choice of CATIA essentially ensured that a sophisticated 3D database could be seamlessly applied throughout the life of the project and beyond.

The process which delivered the GMB is completely explainable when seen as an example of technology transfer. However, when considered without knowledge of aviation design and procurement, the GMB seems revolutionary. The evolution of CATIA which was the underpinning technology of the GMB project, evolved within the aerospace and automotive industries. This is often not accurately considered when assessing the impact of the GMB. FOG&A were not responsible for the development of CATIA; however, they were responsible for the application and development of CATIA in architecture. The GMB is FOG&A's most significant contribution to the deliverability of complex architecture.

Given the appropriate software, the staff to use it and a set of off-site fabricators able to read the CAD files, the construction of the forms at the GMB seems less remarkable. Conversely, the NMA would require a far more diverse if not detailed set of skills. ARM's use of technology produced a building of significant complexity but used technology in a less structured way.

There has been, and persists, a perception that building trades do not embrace change as Rudyard Kipling wrote in A Truthful Song[200] "*I tell this tale, which is strictly true, Just by way of convincing you, how very little, since things were made, things have altered in the building trade*" (Kipling 1995 p.135). However, the increasing presence of computers in architectural practice combined with the increasing popularity of non-traditional

[200] A Truthful Song was chapter 8 of a collection of poems called Rewards and Fairies, published in 1910.

procurement systems has significantly changed the way architects work and relate to others.
There is no doubt that FOG&A's use of CATIA at the GMB was a seminal moment in the application of near seamless technology in an architecture project. ARM's use of multiple techniques and formats could be seen as inelegant by comparison. This characterisation is an over-simplification. What some characterised as inelegant, can also be seen as a hybridised use of computer technologies to successfully articulate cerebral notions and design intents, as McDougall points out (ABC 2000).

Gehry has repeatedly stated that he considers technology as a tool, not a *raison d'être*. *"Drawing is a tool. So is the model. Everything is a tool. The building is the only thing that means anything – the finished building*" (Gehry in VanBruggen 1999 p.40). Similarly, Raggatt credits the computer with enabling ARM to document forms which before the use of computers would have been undocumentable. Both Raggatt's and Gehry's comments are indicative of ARM's and FOG&A's approaches to architecture. Whilst the philosophical view of computer technologies as a tool is the same, the application of that tool is a major differentiating factor.

The artistic or cerebral intent of architecture can only successfully be realised with an understanding of the means of production, which now includes digital production. Due to the particular technological underpinning at the GMB there was an understanding of the process of prefabrication, whilst the NMA relied on a closer working relationship with the on-site workforce. The means of production and the finished quality are inter-reliant. The engagement of the workforce is legible in the varying qualities of finishes at each of the projects. The impact of control of the design and the finished quality at the projects can be summarised as:

a) ARM's approach required a *devolution* of some degree of design control to others, allowing more iterations and a more cohesive project team which in turn led to a high level of quality in the in-situ work.

b) FOG&A's approach allowed greater architectural *control over* design due to their control of the CAD database, but this high level of design which was responsible for remarkable structural work did not extend over the quality of the in-situ work.

The GMB shows that even with a CAD system considered by many as the most advanced system currently available, the quality of the finished product is in places below what reasonably could be expected for a project of such architectural significance. This anomaly can be seen in the stains on the Boat Gallery Riverside façade and the poorly fitting limestone panels (Figure 66 p.250).

The evolving role of the architect as seen in the NMA and the GMB has substantial impact upon the types of control architects can exercise over their projects. The computer technologies increased the realisable geometries available to the architect. If employed with an understanding of a holistic view of the project, works of complex architecture can be realised within contemporary commercial budgets. The use of an inclusive procurement system increases the level of design influence from outside the design professions. If the outside influence is controlled by the architect as in Gehry's use of RfPs (Tombesi 2002), there is a greater level of acceptance and ownership of design. Whereas if the external design interventions come at a later stage of design, they are received less favourably.

In an environment where the amount of design specialisations is increasing, it is becoming harder for an individual architect to have more than a cursory understanding of the many areas of design specialisation. Hence complementary knowledge and the architects' understanding of their roles are crucial if architecture such as the NMA and GMB are to be produced in the future.

The NMA was a complex architectural project which satisfied all its contractual requirements and hence by that measure must be considered successful in financial terms. The main contributors to this success were the mixture of an implementation of a non-traditional procurement method and computer technologies. Although the GMB utilised technology at the leading edge it was a far simpler process insofar as there were less interventions into the data model due to the levels of prefabrication and subject to less external negotiation than at the NMA. However, ARM made compromises (due to the involvement of the design integrity panel) in design matters which contributed to the overall success of the NMA project. Whilst these compromises were considered minor by some, Howard Raggatt, the design architect makes the point that whilst the project was completed in line with the alliance agreement it could have been a more impressive architectural work. He says with pride in the outcome (relative to the resources allocated to it) '*it doesn't look like a project that has had its arms and legs cut off*" (Raggatt [interviewed by author] 2002). This comment is in sharp contrast to Gehry's view of the GMB when he states with pride about his uncompromised vision, '*this building is just like my drawings*' (Blackwood 2000).

6.1 Future Research

There are four possible areas for future research which build upon the contribution made by this thesis. They could be broadly characterised as:

a) How the new dynamics reconcile with the classical notion of the master builder in the digital age;
b) How the perception of architecture as art or commerce has been reframed by computer technologies and/or a non-traditional procurement method;
c) How the bifurcation that saw two streams of CAD development into 'animation modelling/graphic design' and 'product design and manufacture' seem to have converged at the GMB.

The notion that craft changes with the times, and how it has changed due to the digital revolution is well expounded by McCullough (1996). The master builder in the digital age as advanced by Snoonian (2002), Glymph (in Friedman 1999) and Kolarevic (2003a) must necessarily take account of the technological and procurement environment. Also the link between architectural craft and industry that was made by Sebestyen (1998) could be revisited in light of the evolving notion of architectural craft in the digital age. The definition of 'architect' must now be widened to accommodate the emerging computer technologies and the notion of craft to fit the new digital 'master builder'. This thesis has provided a case study approach to a high profile work of architecture and provided conclusions accordingly. Further studies could consider other building types or a wider sample set to assess if the contentions made in this thesis can be observed in a different environment and using a wider but less detailed case study approach.

An alternate line of enquiry may be to consider the notion that art traditionally requires originality and uniqueness to be considered successful. It follows therefore that the notion of an artist requires a quality of innovativeness to successfully realise new and unique art. Conversely, it could equally be argued that commerce requires economies of scale and an understanding of process if it is to be viable. Therefore at a given point in time, the spectrum between commerce and art as manifested in architecture contains both potentials. Successful architecture could be seen as a series of new and unique challenges met, or as constraints overcome. Hence a study concerning the interweaving of aesthetic considerations and the realities of commerce combining to determine the outcomes of particular works of architecture would extend and build upon the research undertaken in this thesis.

The bifurcation of the two streams of CAD is well documented in the literature that looks at the two areas of interest. However, little work has been done to explain why the two paths have not crossed before the GMB project. In light of the Gallaher report on the US construction industry (Gallaher *et al.* 2004) and its contention that over USD $15 billion per annum are lost in inadequate interoperability in US Federal buildings alone, there is an obvious need for a framework for the implementation of cross-disciplinary and cross platform information exchange. An obvious advantage would be the organic redistribution of design and vital activity versus documentation and perfunctory activities. An analysis of the deficiencies of data analysis and storage, the productivity gains, and a redesignation of design, development, documentation and perfunctory documentation verification would promote such a framework.

6.2 Epilogue

Looking back on all I have read, seen, and heard I am left with the impression that the GMB was a building *waiting to happen*. The confluence of inclusive procurement incorporating a more extensive knowledge base and one of the first uses of a coherent 3D object oriented data model would produce a remarkable and ground-breaking building. I believe this sense of inevitability is fuelled by the advances in aviation and automotive design realised in architecture through the phenomenon of technology transfer. Therefore it seems that a system which can handle complex non-Euclidean geometries and generate secondary information from these geometries was waiting for an architect who could realise their full potential within architecture. Gehry’s work on the project allowed him an opportunity to apply this research with an appropriate project brief. I believe this is the GMB’s lasting legacy to architecture which will endure longer than the impact of the design.

The NMA was not a building waiting to happen in the same technological sense as the GMB. However, the use of the non-traditional procurement method has advanced the case for relationship-based procurement within Australian architecture. So whilst LeCuyer (1997), Ivy (1999), Steele (2001), Mitchell (2003) and many others have advanced the theory that the GMB shows that architecture is coming of age, it could equally be argued that this often considered pivotal moment in architectural computing owes a great deal to the connection between industries. In a similar way, the success of the NMA owes less to the technology used than it does to the use of a non-traditional relationship-based procurement method developed outside of architecture. I believe that the system of goodwill and appropriate forms of conveying design intent is the NMA's contribution to architectural practice in Australia.

The approaches used on the NMA and the GMB represent a marked difference in the way technology can be utilised for a similar outcome. The GMB used a near seamless transfer of design data from its inception to its production. Conversely, the information stream that was responsible for the NMA had experienced many changes including many transformations between 3D to 2D to suit the members of the alliance and other subcontractors. The selective use and ad hoc arrangements of software packages to satisfy the requirements of differing stages of the project was also a major point of difference between the projects. Hence, the on time, and on budget NMA had something more than a sophisticated flow of electronic information from one technically proficient party to another. As technology becomes convergent and ubiquitous, the NMA shows how CAD systems less sophisticated than CATIA if used with a complementary procurement system can be used with remarkable results. This is in my view one of the legacies of the NMA project.

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Atkin, Brian	Vice-President, The University of Nottingham (Malaysia Campus). Head of the School of Chemical, Environmental and Mining Engineering at The University of Nottingham, England.
Austin, Valerie	Graduate co-ordinator for Interior Design and Exhibition Design at the National School for Design, Swinburne University of Technology, Victoria, Australia.
Barnett, Rod	Landscape architect and lecturer at the landscape architecture program at UNITEC Institute of Technology, Auckland, New Zealand.
Balendra, Jaya	Arts producer for ABC television.
Blackwood, Michael	Architecture documentary film director and producer.
Bollinger, Elizabeth	Professor of Architecture at the University of Houston, Texas, USA.
Brayer, Marie-Ange	Author and Director of the Centre for Regional Contemporary Art (FRAC) in Orleans, France.
Brewer, John	Professor of Sociology at the University of Aberdeen. He is an author of qualitative research methodology and ethnography.
Bull, Catherine	Elizabeth Murdoch Professor of Landscape Architecture, University of Melbourne, and Board Member of the National Capital Authority, 1992-97.
Cachola Schmal, Peter	Architect, critic and curator of German Architecture the Museum (DAM), Frankfurt, Germany.

Author	Biography
Casey Dawn	Inaugural director of the NMA and general manager of DCITA pre NMA.
Chu, Karl	Architect, theoretician and founder of X Kavya research studio, California, USA.
Cocke, Andrew	Practicing architect and critic. He has authored numerous articles on FOG&A.
Corbin, Juliet	Key figure in the Grounded Theory research.
Coyne, Richard	Professor of Architectural Computing at the School of Arts, Culture and Environment (ACE), University of Edinburgh, UK.
Day, Norman	Practising architect and critic.
Derrida, Jacques	French deconstructionist philosopher (1930–2004) whose work had an impact on continental philosophy and on literary theory,
Devine, Miranda	Journalist for The Sydney Morning Herald, Australia.
Droege, Peter	Professor of Architecture and coordinator of the Urban Design program in the Faculty of Architecture, University of Sydney, Australia.
Eisenman, Peter	Principal architect of Eisenman Architects, New York and lecturer at Yale and Princeton Universities.
Fischer, Martin	Associate Professor, Civil & Environmental Engineering, and Computer Science, Stanford University, USA. Director of CIFE since 2001. He is an author of 4D modelling tools in design and construction.
Frampton, Kenneth	Ware Professor at the Graduate School of Architecture and Planning, Columbia University, New York, USA. Author of numerous texts on architectural history.
Gallaher, Michael	U.S. Department of Commerce Technology Administration National Institute of Standards, USA.
Galofaro, Luca	Author of publications regarding the use of CAD. Lecturer at University of Pennsylvania and was previously an associate of Eisenman Architects, New York.
Gann, David	Head of Innovation and Entrepreneurship, Imperial College, London, holding the Chair in Technology and Innovation Management, and advisor to several government and industry organisations,

Author	Biography
Garbutt, Michael	Author, critic and artist. He presented a number of contemporary architectural ‘postcards’ for Australian free-to-air television.
Gardiner-Garden, John	Australian parliamentary librarian.
Gehry, Frank	Architect and artist. Principle of Gehry Partners.
Gibson, Grant	Journalist and former editor of ‘Blueprint’ magazine.
Gillham, Bill	Lecturer in educational psychology at the University of Nottingham, UK.
Glymph, James	CEO and principal of Gehry Technologies. He introduced CAD technology to the office and has guided the integration of this technology into the firm's design process.
Goad, Philip	Professor of architecture at the University of Melbourne. Visiting scholar at Columbia University, Bartlett School of Architecture (London) and UCLA (Los Angeles).
Godfrey, Ian	Architect, previously a partner of Sweetman, Godfrey and Ord, and founding member of the IAI in Australia.
Guerin, Scott	Lead exhibition designer for the NMA for Anway and Co.
Henry, Bruce	Technical manager for the NMA project.
Hunter, Albert	Professor of Sociology at Northwestern, USA. Published author of books and articles, including co-author of Multimethod Research.
Ito, Toyo	Honorary Visiting Professor at the University of North London, UK and Columbia University, USA as well as being a principal of Toyo Ito & Associates, Architects, Japan.
Iyengar, Sridhar	Director, Advanced Technology, Unisys Object Technology Labs, Unisys Corporation, USA.
Jefferson, Randy	Principal of FOG&A, and Project Manager for the GMB.
Jencks, Charles	Architectural theorist, historian and author.
Jenner, Ross	Lecturer in architecture at the University of Auckland, New Zealand.
Jodidio, Philip	Art historian and author.

Author	Biography
Jones, Wes	Principal of Jones, Partners: Architecture. Visiting Professor at School of Architecture Harvard, Princeton, IIT, Columbia, UCLA and the Ohio State University, and Southern California Institute of Architecture.
Kalay, Yehuda	Professor of Architecture at Berkeley University and author.
Kam, Calvin	Assistant Professor at the School of Engineering in Stanford University and the Program Manager of the US National 3D-4D-BIM Program with the Office of the Chief Architect for the United States General Services Administration.
Keniger, Michael	A previous Queensland architect of the year (1998), and the Inaugural Queensland Government Architect, previously Professor of Architecture and now Deputy Vice Chancellor, Queensland University. Member of the Independent Quality Review Panel and the Design Integrity Panel for the NMA
Khemlani, Lachmi	Architect specializing in intelligent building modelling, and the founder of Arcwiz (www.arcwiz.com), author on CAD, BIM, and AEC technology in industry publications, and is the founder and editor of AECbytes (www.aecbytes.com).
Kieran, Stephen Timberlake, James	Stephen Kieran and James Timberlake founded Kieran Timberlake Associates in 1984. Both have written about the effect of manufacturing innovations on architecture whilst practising as architects in Philadelphia. Advocate the transferring of efficiencies from other industries to architecture.
Kipnis, Jeffrey	Curator of Architecture at the Wexner Center for the Arts at Ohio University. USA documentary film maker.
Kohane, Peter	Senior Lecturer in the Faculty of the Built Environment at the University of NSW, Australia.
Kolarevic, Branko	Associate Professor of architecture, founder and director of the Digital Design Research Lab (DDRL) University of Pennsylvania, and author/editor.
Koolhaas, Rem	Principal architect of the Office for Metropolitan Architecture. He is also "Professor in Practice of Architecture and Urban Design" at Harvard University's Graduate School of Design, USA.

Author	Biography
Kumaraswamy, Mohan	Lecturer in Construction Engineering and Management at the University of Hong Kong, China.
Laiserin, Jerry	Architect and industry analyst, and an advocate for "building smarter".
Larson, Magali Sarfatti	Professor Emeritus, Temple University, USA
LeCorbusier (Charles Edoard Jeanneret)	Influential architect, theorist and proponent of the modernist movement.
Le Cuyer, Annette	Associate Professor of Architecture at the University of Michigan. Architect and author and has written extensively for architectural publications.
Lindsey, Bruce	Professor and Head of the School of Architecture at Auburn University, USA.
Lynn, Greg	Principal of Greg Lynn_FORM. Professor of Spatial Conception and Exploration at the ETH (Swiss Federal Institute of Technology) in Zurich and previously Adjunct Assistant Professor at Columbia University, USA.
Manne, Robert	Professor of Politics at La Trobe University, Melbourne, Australia.
McArthur, John	Senior Lecturer in architecture at the University of Queensland.
McCracken, Grant	Author of texts on interview techniques and Founding Director of the Institute of Contemporary Culture at the Royal Ontario Museum, Canada.
McCullough, Malcolm	Associate Professor of Architecture and Design at the University of Michigan, USA.
McDougall, Ian	Architect and Partner ARM, past president of the Victorian Chapter of the RAIA. Adjunct Professor of Architecture at RMIT.
Markham, Michael	Architect and Co partner in FIELD consultants. Winner RAIA Victorian Architecture Medal 2000.
Migayrou, Frederic	Chief curator of architecture and design at the Pompidou Centre in Paris, France.
Mitchell, John	Architect, formerly of Mitchell Walker Wright and founding member of the Australasian chapter of the IAI and current chair.

Author	Biography
Mitchell, William	Professor of Architecture and Media Arts and Sciences at MIT, Boston, USA. Director of the Media Lab's Smart Cities research group and author. *See* http://web.media.mit.edu/~wjm/.
Morton, Craddock	General Manager of the DCITA at the time of the construction of the NMA and the second Director of the NMA.
Negroponte, Nicholas	Co-founder and Chairman Emeritus of the MIT Media Laboratory. Author of 'Being Digital'.
Ostwald, Michael	Professor of Architecture at Newcastle University, Australia.
Paroissien, Leon	Editor of Visual Arts and Culture and a member of the Design Integrity and Quality Panels for the construction of the NMA.
Patton, Michael Quinn	Former President of the American Evaluation Association and author of texts on qualitative research methodologies.
Pawley, Martin	Architect and critic and architectural columnist for several British broadsheets and editor of 'World Architecture'.
Perlman, Ian	Architect and author.
Radford, Antony	Professor of Architecture at The University of Adelaide and author of texts on the use and implications of CAD in architectural practice.
Raggatt, Howard	Architect and Partner ARM. Design architect for the NMA. Adjunct Professor of Architecture at RMIT.
Reed, Dimity	Architect, adjunct Professor of Urban Design at RMIT, and author.
Sanders, Ken	Associate Partner and Manager of Information Services at Zimmer Gunnel Frasca Partnership. 1995 Chair of the AIA's National Computer Aided Practice.
Sebestyen, Gyula	Former President and Secretary General of the CIB, "Conseil International du Bâtiment" (in English: International Council for Building).
Sexton, Jennifer	Journalist and commentator for 'The Age' newspaper, Melbourne, Australia.
Shiel, Simon	Project architect (ARM) for the NMA.

Author	Biography
Spuybroek, Lars	Principal of NOX Architecture and Professor at Delph University, Netherlands and author.
Steele, James	Associate Professor, the University of Southern California School of Architecture, USA.
Stein, Karen	Architect, editorial director of Phaidon Press, and journalist with Architectural Record.
Strauss, Anselm	Sociologist, who worked the field of medical sociology. Known as co-founder of grounded theory.
Sudjic, Deyan	Visiting professor at the Royal College of Art, and architecture critic for the Observer, UK.
Taylor, Jennifer	Adjunct Professor of Architecture at the Queensland of Technology and author of books on Australian Architecture.
Tombesi, Paolo	Associate Professor in Architectural Design and Practice, University of Melbourne and author on design specialisation and the economics of architecture.
Tschumi, Bernard	Architect, and former Dean of Columbia University's Graduate School of Architecture, Planning and Preservation, New York, USA.
VanBruggen, Coosje	Practising artist, critic and author.
Walker, Derek	Professor at the School of Property, Construction and Project Management RMIT University. Co-author of the Acton Peninsula Report.
Ward, Peter	Lecturer in Building at the University of Newcastle, Australia.
Weirick, James	Professor of Landscape Architecture at the University of New South Wales, Australia.
Weller, Richard	Director of the landscape architects 'Room 4.1.3'. Senior Lecturer in history, theory and design at the School of Architecture and Fine Arts at the University of Western Australia.
Windschuttle, Keith	Former history lecturer in social policy at University New South Wales. Guest lecturer on history at several American universities. Sits on the board of the Australian Broadcasting Commission.
Wright, Peter	Project manager for the NMA and Managing Director of Construction Control Australia.

Author	Biography
Yin, Robert	COSMOS Corporation Principal Investigator and program evaluation, USA.
Zellner, Peter	Lecturer in Design at RMIT, author and curator.
Zils, John	Lead engineer on the GMB project.
Zulaika, Joseba	Professor and Director of the Centre for Basque Studies, Bilbao, and author.

Image Reference List

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List of Abbreviations

ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AI	Artificial Intelligence
APA	Acton Peninsula Alliance
ARM	Ashton, Raggatt & McDougall
ARM&RPH	Ashton, Raggatt & McDougall & Robert Peck von Trethowan Hartel
AUD	Australian Dollar
BIM	Building Information Modelling
CAD	Computer Aided Design
CAM	Computer Aided Manufacture
CIFE	Centre for Integrated Facility Engineering (Stanford University, USA)
CNC	Computer Numerically Controlled (Machines)
CRCCI	Cooperative Research Centre for Construction Innovation
DCITA	Department of Communications, Information Technology and the Arts, Commonwealth of Australia.
DDRL	Digital Design Research Laboratory (University of Pennsylvania, USA)
DXF	Drawing Interchange Files
FOG&A	Frank O. Gehry & Associates
GMB	Guggenheim Museum Bilbao
GOAD	Garden of Australian Dreams
GOFA	Gallery of First Australians
IAI	International Alliance for Interoperability
IGES	Initial Graphics Exchange Specification
JPEG	Joint Photographic Experts Group
LOM	Laminated Object Manufacture
MIT	Massachusetts Institute of Technology (Boston, USA)
NMA	National Museum of Australia
QUT	Queensland University of Technology
R&D	Research and Development
RAIA	Royal Australian Institute of Architects
RFP	Request for Proposals
RMIT	Royal Melbourne Institute of Technology (Melbourne, Australia)
SIAL	Spatial Information Architecture Laboratory (at RMIT)
SOH	Sydney Opera House

Appendix A: EIA9 Paper, Istanbul 2003

Swift, J. P. (2003) The National Museum of Australia: a study in generative design. in *E-activities in design and design education, 9th Europia International Conference,* pp. 185-191 Europia Productions, Istanbul, Turkey ISSN/ISBN: 2-909285-22-7.

NOTE: This publication is included on pages 301 – 306 in the print copy of the thesis held in the University of Adelaide Library.

Proceedings of the 37th Australian & New Zealand Architectural Science Association (ANZAScA) Conference
Faculty of Architecture, University of Sydney, 2003. ISBN – 1 86487 132 6

Appendix B: ANZAScA Paper, Sydney 2003

Swift, J. P. (2003) Expressing technology in the contemporary cultural cathedral, case studies in Bilbao and Canberra. in *The diversity of architectural science, Proceedings of the 37th Australian and New Zealand Architectural Science Association (ANZAScA) Conference* pp. 726-734. Faculty of Architecture, University of Sydney, Sydney, Australia ISSN/ISBN: 1-86487-132-6.

NOTE: This publication is included on pages 307 – 318 in the print copy of the thesis held in the University of Adelaide Library.

Appendix C: Code of Ethics

An Investigation into the use of digital tools in re-framing architectural relationships
John Paul Swift – PhD Researcher in Architectural Practice
Code governing case study research in the
School of Architecture, Landscape Architecture, and Urban Design
The University of Adelaide
At <<DATE>> <<MONTH>> <<YEAR>>

1. The nature and purpose of the case study is to investigate aspects of architectural practice, which will be discussed and recorded with <<INTERVIEWEE>>.
2. The researcher will attempt to share and discuss emerging ideas and hypotheses with <<INTERVIEWEE>> whose interests and concerns will be incorporated where possible.
3. <<INTERVIEWEE>> will have access to data collected by the researcher relating to <<INTERVIEWEE>> and control over release of such data to others from time to time.
4. The researcher will have the right to discuss the data with his supervisory panel at the University of Adelaide (and elsewhere) and present the material for his thesis.
    a. The researcher in his part will undertake not to release the data beyond the confines of the School or the thesis discussion or reports.
    b. Where validity and reliability checks are required, the researcher may present material to selected colleagues for comment.
5. <<INTERVIEWEE>> will have the right of reply to any research report and have her replies incorporated before any decision about its release beyond the confines of the School and thesis is made. Wherever practical, the replies will be incorporated into the thesis before final submission.
6. Strict anonymity will be maintained, when information is given in confidence, this confidentiality will be respected, when requested.
7. All forms of data will be kept under the control of the researcher only unless <<INTERVIEWEE>> agrees to release the data relating to <<INTERVIEWEE>> into the public domain.
8. In the event of a difference of interpretation, <<INTERVIEWEE>> may contact either/both members of the supervisory panel (Professor Antony Radford and Dr Susan Shannon, School of Architecture, Landscape Architecture and Urban Design) without reference to the researcher.
9. Where an issue of commercial-in-confidence sensitivity is approached, data may be embargoed until an alternative course of action can be negotiated.
10. In the event <<INTERVIEWEE>> no longer remains engaged in this study at <<INTERVIEWEE>>'s request, the researcher will be able to use any data collected and approved by <<INTERVIEWEE>> to that date.

Supervisory Panel:
Professor Antony Radford, Tel: +61 8 8303 5475, email: Antony.Radford@adelaide.edu.au
Dr Susan Shannon, Tel: +61 8 8303 5490, email: Susan.Shannon@adelaide.edu.au
School of Architecture, Landscape Architecture and Urban Design, Adelaide University SA 5005
Researcher:
Mr John Swift, Tel:+61 8 8172 2340 , email: jpswift@adelaide.edu.au
School of Architecture, Landscape Architecture and Urban Design, Adelaide University SA 5005

Appendix D: Follow Up Letter

Mr John Swift
Department of Architecture, Landscape Architecture and Design
University of Adelaide
South Australia 5000

«FIRSTNAME_» «LASTNAME»
«COMPANY»
«ADDRESS1»
«ADDRESS2»

Re: PhD Research

Dear «FIRSTNAME_»

Thankyou for allowing me an interview on «DATE» for the purpose of progressing my PhD research.

I enclose a transcript of the interview.

I will ring in a week to check that you are satisfied that the enclosed transcript accurately reflects the conversation we had, and to ask what changes you would like incorporated.

Thank you again for your continuing time and support.

Yours sincerely,

John Paul Swift
PhD Candidate

Appendix E: Acknowledgement Letter

Mr John Swift
Department of Architecture, Landscape Architecture and Design
University of Adelaide
South Australia 5000

«FIRSTNAME» «LASTNAME»
«COMPANY»
«ADDRESS1»
«ADDRESS2»

14 March 2004

Re: PhD Research

Dear «FIRSTNAME»

I am now in the writing up phase of my research and I would like to take this opportunity to thank you for your generosity in making your time available to me. If you have any questions about the use of the data (interview transcript) please do not hesitate to contact me at the above address.

Also, if it convenient for you I would like to verify/validate some of the data in a follow-up interview at your offices some time towards the end of this year.

Yours sincerely,

John Paul Swift
PhD Candidate

Appendix F: Draft Thesis Follow up Letter

Mr John Swift
Department of Architecture, Landscape Architecture and Design
University of Adelaide
South Australia 5000

«FIRSTNAME» «LASTNAME»
«COMPANY»
«ADDRESS1»
«ADDRESS2»

19 October 2005

Re: PhD Research

Dear «FIRSTNAME»

I write to follow up my letter dated 25 August 2005. Accompanying that letter was a draft of the introduction and conclusion sections of my thesis. Accordingly as my research is now in its final stages I would like to consider any comments you have concerning those sections of the draft thesis. If you do have any comments I would be pleased to receive them before I continue with the final stages of my research. I will in due course forward to you a copy of the final thesis as outlined in the code of ethics for your final comments (if any).

Regards

John Paul Swift
PhD Candidate

Appendix G: Equipment List

Equipment	Manufacturer	Model
Camcorder	Sony	DCR-TRV11E
SLR Still Digital	Canon	350D
SLR 35mm	Canon	EOS 3000N
SLR Lens	Tamron	AO3 (28-200mm)
SLR Flash	Canon	Speedlite 300EZ
Minidisc Audio Recorder	Sharp	MD-MT15
Microphone	Sony	ECM-MS907
Compact Still Digital	Nikon	Coolpix SQ