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VIRTUAL ARCHITECTURAL WORKSPACES

DIGITALLY MEDIATED COLLABORATION IN THE ARCHITECTURAL DESIGN PROCESS

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ABSTRACT

Digital technology is a fast-growing, ubiquitous field that has a strong impact on every area of our life and has become an inseparable part of the design process both in academia and practice. In today’s world of globalization, buildings are being designed in distributed settings with a diverse number of specialists across geographical locations. This leads to an increasingly complex design process that is inherently collaborative due to the large number and diversity of professionals who are involved. The goal of the study is to investigate how the present scenario of digital mediation facilitates collaboration during the design process in architectural practice.

Since digital mediation for collaboration in design is an emerging phenomenon, an exploratory investigation using mostly qualitative methods of social science research techniques is undertaken. The objective of the study is to understand the phenomenon of digitally mediated collaboration in two distinct contexts: the academic setting and the realm of professional practice. Observations and field study of a Participatory Design Studio between Pennsylvania State University and Carleton University, where student teams worked remotely on their designs was carried out. The next step was to study exemplary conditions or case studies of architectural firms, who are designing projects that require them to employ digital tools for the purpose of design communication over distributed locations.

The study examined the nature of collaboration in various stages of the design process and based on this, identified the type of digital tools and media required for design collaboration. Some of the issues related to digital mediation in design such as design idea exchange and representation, teamwork ability in distributed settings and technical issues of bandwidth and interoperability were revealed. The study compared and contrasts between the tools, technology and mode of design in academia and practice and hence, helped to generate a set of guidelines that enable optimum practices for remote design collaboration.
# TABLE OF CONTENTS

LIST OF FIGURES .................................................................................................................. vii

LIST OF TABLES .................................................................................................................... ix

ACKNOWLEDGEMENTS .......................................................................................................... x

Chapter 1  INTRODUCTION ......................................................................................................... 1
  1.1 RESEARCH CONTEXT ...................................................................................................... 2
    1.1.1 Thesis Problem ....................................................................................................... 2
    1.1.2 Goals and Objectives ............................................................................................ 2
  1.2 METHOD OF INQUIRY .................................................................................................... 3
    1.2.1 Field Study of the Participatory Design Studio ..................................................... 4
    1.2.2 Case Study and Interview of selected Architectural Firms .................................... 4
    1.2.3 Limitations .......................................................................................................... 5
    1.2.4 Analysis and Conclusions .................................................................................... 6

Chapter 2  DIGITALLY MEDIATED COLLABORATION IN THE DESIGN PROCESS .............. 7
  2.1 MEDIATION IN DESIGN ................................................................................................. 9
    2.1.1 Outlook towards Digital mediation in architecture .............................................. 10
    2.1.2 Role of Mediation ............................................................................................... 12
    2.1.3 Digital Mediation in Design .............................................................................. 13
    2.1.4 Digital Technology in Design Process ............................................................. 13
    2.1.5 Design process as a complex problem .............................................................. 15
  2.2 COLLABORATION IN DESIGN ....................................................................................... 17
    2.2.1 Collaboration in the Architectural Design process ............................................. 17
    2.2.2 Types of Collaboration ....................................................................................... 19
    2.2.3 Digital Communication ...................................................................................... 20
    2.2.4 Theories on Computer Mediated Communication ............................................. 23
  2.3 DIGITALLY MEDIATED DESIGN COLLABORATION ...................................................... 26
    2.3.1 The Current Context of Architectural Practice .................................................. 26
    2.3.2 Evolution of Collaboration in Architectural Design Practice ............................. 26
    2.3.3 Scenarios of Architectural Design Collaboration .............................................. 28
    2.3.4 Extent of Use of Digitally Mediated Technology in Design Firms .................. 31
    2.3.5 Emerging Digital Technologies in Design Practice .......................................... 32
    2.3.6 Emerging Digital Tools ..................................................................................... 36
    2.3.7 Emerging trends in Design Research ................................................................. 36

Chapter 3  PARTICIPATORY DESIGN STUDIO BETWEEN PENNSYLVANIA STATE UNIVERSITY AND CARLETON UNIVERSITY ............................................................................. 38
  3.1 VIRTUAL DESIGN STUDIOS ........................................................................................... 38
5.1 FINDINGS........................................................................................................................................105
  5.1.1 Issues of Digitally Mediated Collaboration...........................................................................105
  5.1.2 Limitations .........................................................................................................................106
  5.1.3 Guidelines for future PDS ..............................................................................................107
5.2 FUTURE DIRECTIONS.................................................................................................................109
  5.2.1 Changing Trends in Architectural Praxis ...........................................................................110

BIBLIOGRAPHY....................................................................................................................................113

Appendix A  PDS Student Group Projects....................................................................................121
Appendix B  Journal format .........................................................................................................127
Appendix C  Survey Questionnaire ............................................................................................130
Appendix D  Recruitment email for firms ....................................................................................133
Figure 2-1: Integrating role of digital model (source: Mitchell and McCullough, 1995). ............16
Figure 2-2: Design process (source: Kirk and Specklemeyer, 1988). ........................................17
Figure 2-3: Model of collaborative design (source: Kalay, 2004). ............................................18
Figure 2-4: Close-coupled and loosely-coupled design (source: Kvan, 2000). .........................20
Figure 2-5: Time/Space matrix for groupware. .......................................................................21
Figure 2-6: Media Richness Theory diagram (source: Daft and Lengel, 1984). .........................24
Figure 2-7: Design collaboration (source: Maher et al, 2000). ...............................................29
Figure 2-8: Degree of collaboration in AEC industry (source: Ferris, 2006). ............................32
Figure 2-9: Design collaboration (source: Maher et al, 2000). ...............................................33
Figure 2-10: Integration of traditional and digital media (source: Mitchell and McCullough, 1995). ............................................................................................................................35
Figure 3-1: Project 1-Design of Vertical Lift Museum.................................................................44
Figure 3-2: Project 2-Renovation of School of Architecture.....................................................45
Figure 3-3: IEL, CIMS and the digital scene. ............................................................................47
Figure 3-4: Project 1 – Access Grid. .......................................................................................48
Figure 3-5: Project 2- PDS dashboard. ....................................................................................49
Figure 3-6: Screen shots of the projects during IEL session.....................................................51
Figure 3-7: IEL schematic (source: Heilman, 2006). .................................................................54
Figure 3-8: System Architecture for PDS (source: Jemtrud, 2006). .......................................58
Figure 3-9: PDS dashboard log-in page (source: Jemtrud, 2006). ..........................................59
Figure 3-10: PDS dashboard activity (source: Jemtrud, 2006). ..........................................59
Figure 3-11: Configuration at CIMS (source: Muramoto, 2006). .............................................60
Figure 3-12: PDS dashboard architecture (source: Jemtrud, 2006). .....................................62
Figure 3-13: Screen shot of ftp site.................................................................63

Figure 3-14: Design stages (based on Kalay’s diagram with findings of field study). ..............65

Figure 4-1: Wall panels of Loblolly House. .............................................................81

Figure 4-2: Studio and conference area at KTA. ......................................................83

Figure 4-3: Teleconference room in the Kieran Timberlake office. ................................83

Figure 4-4: Porter House residential complex facade. ..........................................86

Figure 4-5: Studio and teleconference room..............................................................87

Figure 4-6: The Korean Presbyterian Church, Queens, NY. ........................................90

Figure 4-7: Greg Lynn’s studio and the physical prototype of blobwall .......................91
LIST OF TABLES

Table 2-1: Four types of digitally mediated design ................................................................. 22
Table 2-2: Scenarios for design collaboration in firms ............................................................ 29
Table 2-3: Popular digital design and collaboration tools used for design collaboration (based on websites and brochures) ............................................................... 36
Table 3-1: Literature related to VDS ...................................................................................... 40
Table 3-2: Tools used in Penn State and Carleton ................................................................. 53
Table 3-3: Multimedia applications used for data exchange ................................................... 63
Table 3-4: Table of student teams based on journal ............................................................... 64
Table 3-5: Issues of digitally mediated collaboration based on journal ................................ 66
Table 3-6: Positive and negative aspects of PDS ................................................................. 68
Table 4-1: Firms selected as case studies .............................................................................. 72
Table 4-2: Interview question guidelines .............................................................................. 75
Table 4-3: Technical specifications of each firm .................................................................... 77
Table 4-5: Interview replies by SHoP .................................................................................... 88
Table 4-6: Interview replies by FORM .................................................................................. 92
Table 4-7: Interview replies by GA ....................................................................................... 94
Table 4-8: Findings based on firm interviews ....................................................................... 97
Table 4-9: Medium of collaboration in various phases of design ......................................... 100
Table 5-1: Issues of digitally mediated design collaboration ................................................. 105
Table 5-2: Comparison between academic and practical setting ............................................ 106
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INTRODUCTION

Digital technology is a fast-growing, ubiquitous field that has a strong impact on every area of our life and has become an inseparable part of the design process both in academia and practice. Due to advances in technology; “the pace of innovations in architecture has accelerated leading in turn to new technological discoveries” (Duffy 1997).

Globalization and the advent of information technology have led to a phenomenon of distributed collaboration where ideas and expertise of designers is able to cross spatio-temporal boundaries. Widely used in the context of design today, collaboration has almost become a catchphrase of our age. The international competition for the World Trade Center in 2002 exemplifies this phenomenon, where majority of responses came from collaborative teams including the United Architects. Founded on the principles of collegiality, it consisted of Foreign Office Architect (FOA), Greg Lynn FORM, UN Studio, Reiser + Umemoto’s RUR Architects, Imaginary Forces and Kevin Kennon Architect. Kennon (2007) describes that no single vision dominated but rather different ideas coalesced around a synthetic process that incorporated the best ideas.

Though attributed only to contemporary digital technology, similar instances of collaboration have taken place in history as well. Described as “probably the most significant exchange of theoretical ideas on architecture in this century” (Whyte, 1985) the “Crystal Chain” initiated by Bruno Taut around November 1919 was a correspondence between 14 members brought together by him. This alliance of radical artists and architects including Walter Gropius, Adolf Behne and Heinrich Tessenow, communicated via chain letters using pseudonyms and exchanging visionary sketches to inspire each
other to be imaginary architects. Nowadays however, digital technology is able to facilitate and provide opportunities for the need for collaboration much more effectively the world over.

1.1 RESEARCH CONTEXT

In today’s world of globalization, buildings are being designed in distributed settings with a diverse number of specialists across geographical locations. This leads to an increasingly complex design process that is inherently collaborative due to the large number and diversity of professionals who are involved. Digital tools are increasingly being used in every aspect related to the design process from computer-aided design to collaboration between the specialists. Therefore, it is very important to study the role of digital tools and technology in transforming the architectural design practice. Defining digital mediation as the medium used for the purpose of designing, it is creating new paradigms for the way buildings are designed and are creating a huge impact in each phase of the design process. Digital mediation could encompass hardware, software and all other related technological infrastructure that is utilized for the purpose of design. The study explores how digital tools mediate the architectural design process and design collaboration.

1.1.1 Thesis Problem

To investigate how the present scenario of digital mediation facilitates collaboration during the design process in architectural practice.
1.1.2 Goals and Objectives

The goal of the study is to explore the role of digital mediation in design collaboration by examining the nature of collaboration between different design participants along with the tools and technology needed and used in various stages of the architectural design process. This would be carried out through an exploratory study with the following objectives:

1. Understanding digital mediation in the design process and collaboration for architectural design.
2. Identifying the digital tools used as mediums for design collaboration and how they are used during various stages of the design process.
3. Analyzing the effect of digitally mediated collaboration on the design process and the feasible digital tools required for each design stage.
4. Bridging a gap between academia and practice by studying the digital tools used in both realms and by integrating that knowledge to create a guideline for effective digital mediation for collaborative design.

1.2 METHOD OF INQUIRY

Since digital mediation for collaboration in design is an emerging phenomenon, an exploratory investigation was undertaken using mostly qualitative methods of social science research techniques. The research began with a set of broad questions related to digitally mediated design collaboration along with a review of relevant literature on the various subjects related to the topic. The study is divided into two parts: the first part evaluates the tools and technology used in academia, through the participatory design studio (PDS) conducted between Penn State and Carleton University; and the second part examines the tools and technology used in practice.

Qualitative methods of direct observation such as the field study were adopted for the first part of the research in the participatory design studio conducted in spring 2007. In the second part, case
studies of a small sample of exemplary firms were undertaken by conducting semi-structured interviews to gain deeper understanding of the phenomenon. The purpose of this research study is to provide observation & conclusions by developing a set of guidelines that explain the observed events of digitally mediated collaboration.

1.2.1 Field Study of the Participatory Design Studio

Many architectural schools have conducted virtual design studios (VDS) of some form since early 1990’s. A field study was carried out in the participatory design studio (PDS) conducted with third year architecture students between Pennsylvania State University and the Carleton University during the spring 2007 semester. This study on the collaborative design studio was carried out to help reveal insights into the nature of collaboration in the design process. The goal of the study was to identify the digital tools used for collaborative design; how the tools are used and at what stages of the design process are they required.

1.2.2 Case Study and Interview of selected Architectural Firms

To offer new paradigms for the future of collaborative architectural workspaces, it is imperative to study firms that are pioneers in the use of digital tools for collaboration during the design process. This would help in informing the research and experiments conducted in architectural schools better, hence, bridging the gap between the two realms in the field of remote design collaboration. Interview of firms would serve to understand the prevalent views and concerns on the impact of digital tools in architectural practice. Since the goal of the study was to identify firms that are exemplary conditions in the use of digital media for the purpose of collaborative design, the following firms were considered.
Greg Lynn FORM, CA is a forerunner in exploring the possibilities in digital fabrication. The firm is experienced in working in collaborative partnerships on a number of projects; Kieran Timberlake Associates, PA - an architecture firm noted for its research, innovative design and planning services; SHoP, NY - a firm that explores new fabrication technology and is riding the crest of architecture’s digital wave and finally Garofalo Architects, IL – a firm that actively pursues architectural design to include forms of collaboration by employing electronic media.

1.2.3 Limitations

The study compares the tools and technology used for digitally mediated collaboration in two distinct settings, the participatory design studio in a university setting and few selected digital design firms. One of the goals of the study is to bridge a gap between the knowledge of these tools used in the two settings. However, in this exploratory study, a few disparities between the two settings have been recognized. In an educational design studio, due to pedagogical and time considerations, greater emphasis is placed on the conceptual design phase only. However, in the practical setting, the design projects are designed with intent to be built, and hence go through each phase of design. Here, more emphasis is laid on later design stages such as design development and construction and more specialists are involved in the design process. Another significant contrast between the two settings is the difference in the level of experience in design and use of tools and technology, age of designers and the way of designing. Third year students in a design studio, while learning to design practice very differently from practitioners who have completed real life projects in established firms. Even the way tools are used to design is distinct in both settings.
1.2.4 Analysis and Conclusions

The goal of the field study and case studies would be to identify issues for digital mediation in design collaboration. Tools based on the needs of architectural design practice during the various stages of the design process and the media affordances available would be analyzed both in the universities where relatively high bandwidth and visualization technologies are available, (such as in the IEL in the department of architecture at Penn State) and in the cutting edge firms visited for interviews (such as Greg Lynn FORM, Kieran Timberlake Architects, SHoP and Garofalo architects).
Digitally mediated collaboration in the architectural design process is extremely multi-disciplinary in nature, including the diverse fields of architectural design, theory of design collaboration, digital technology, communication, networks, human-computer interaction and the AEC industry. The intent has been to gain overall perspective of the related fields and a general understanding of the relationship of various issues and subject matter to architectural design. To understand the effect of digital mediation on the complex nature of the design process, the technological impact of digital infrastructure was studied. This included the evolution of Computer Aided Design (CAD) along with the hardware and software used during the design process. The review explores the broader phenomenon of the effect of technology to better understand the overall context of the emerging trends of architectural practice such as distributed design, specialization and digital fabrication, and Building Information Modeling (BIM). The phenomenon is also studied through a socio-theoretical lens by reviewing literature and theories of fields related to technology such as Human Computer Interaction (HCI), Computer Supported Cooperative Work (CSCW), Computer Mediated Communication (CMC) and the emergence of network and information societies. The literature review is divided into three parts:

Mediation in Architecture

The first part of the literature review deals with mediation in architecture. It looks at the role of mediation in the design process, laying emphasis on digital mediation by placing “digital mediation” on a larger horizon. Then it explores the two ways in which digital mediation effects architectural design, firstly during the design process and secondly through design collaboration. In The first sub-section,
design process is defined with respect to the evolution of the digital tools and technology developed for it. Following this in the second sub-section design communication is described along with the theories related to communication technology, after which their effect on design is discussed briefly.

*Collaboration in Architecture*

The second part of the literature review examines collaboration in architecture. It necessitates the need for collaboration during the design process and in the realm of architectural practice. It then defines collaborative design along with the types of collaboration and its different interpretations. Subsequently it defines the various scenarios of design collaboration possible in the context of architectural practice. This sub-section includes phenomena such as mega firms, global outsourcing, and specialty firms leading to the discussion of digital mediation in design collaboration in the next part.

*Digital Mediation and Collaboration in Architecture*

Finally the third part of the literature review combines digital mediation and collaboration where the notion of distributed design collaboration is introduced along with its implications. After that, the extent of digital collaboration in design firms is carried out followed by a critical evaluation of various outlooks towards the latest developments in digitally mediated collaboration. Current and new tools and technologies are reported along with their projected capabilities and finally it assesses the emerging trends in architectural practice. To conclude, gaps in the research are identified directing to future research. As a lot of topics related to the issues discussed above are covered, this literature review is by no means comprehensive.
2.1 MEDIATION IN DESIGN

Digital technology is paving a way for transformation of the way architecture is practiced.

Castells (2000) claims that:

We have entered a new technological paradigm, which represents a greater change in the history of technology than the technologies associated with the Industrial Revolution, or with the previous Information Revolution (printing). The characteristic of this technological paradigm is the use of knowledge-based, information technologies to enhance and accelerate the production of knowledge and information, in a self-expanding virtuous circle.

Nonetheless there is great concern on how this emerging digital technology is changing and affecting the design process. Many critics speculate on the consequences of the speed of advancements and their applicability in the field of design. They somewhat resist the notion of technological mediation in architectural design. Rather than seek opportunities that the new medium can afford, they lament the loss of certain metaphorical or poetic quality of design that are overshadowed by the use of technology (Perez-Gomez, 1983). Just as the Industrial Revolution had a great impact on architecture by virtue of mass-production, advances in engineering technology, and developed socio-economic conditions, leading to transformation of the design process with introduction of movements such as Art Nouveau, Arts and Crafts and the Bauhaus idea of design as functionalism, similarly digital mediation as part of the information revolution will also bring about a makeover of the design process.

Tracing back in history, the architectural design process has always been perpetuated through some form of mediation. Pre-Renaissance, when paper first began to be used as a mode to represent design ideas; it was regarded as a novel tool for building, compared to the constructive architecture and notion of the master builder during and prior to gothic period. The design process evolved and new techniques to communicate ideas with the aid of descriptive geometry and art of perspective drawing developed. For the first time, it enabled architects to design away from the actual built site, to be easily transported there later for construction. Drawings on paper being much more portable than before and
became the principal means of recording design ideas. This had a great influence on design thinking and imagination as language and conventions could be used to communicate design ideas and intent. Though taken for granted today, sketches and scaled drawings communicated the design idea at the built site. While collaboration of design usually took place around the drawing board or in conference rooms traditionally, the means of communication that bring together design teams now comprise of electronic file transfer, videoconferencing, and other groupware. With such contrasting mediums of communication, there are varied social reactions to the use of emerging digital technology in design.

2.1.1 Outlook towards Digital mediation in architecture

The paradigmatic shift in architectural design where the digital technologies are almost becoming ubiquitous, has led to conflicting viewpoints to these changing trends. The notion of digital mediation is either blindly accepted or completely rejected. In the midst of this constant flux, many writings express the dilemma facing architecture. While Perez-Gomez laments on the loss of rich interpretation of sketches due to use of computer visualizations (Frascari 2007), authors such as Groat (1993), Gutman (1992) and Willis (1999) write about the resistance to diversity and change and other problems prevalent in architectural practice since increase of specialization, globalization and introduction of new technology and so on.

On the other hand Celento (2007), Seletsky (2005) and Yoo et al. (2008) feel that the AEC industry is going through a transformation. They feel that the current architectural production methodology (and all associated deliverables) is about to be completely turned on its head where architects will now have to adjust their understanding of collaboration as one occurring synchronously (in real time) within a team creating and assembling an interrelated set of building components, versus occurring asynchronously (at staggered times) with a team creating and assembling a loosely
interrelated set of drawing. This is a radically different notion of collaboration as understood and commonly played out in professional practice and academia. Moreover, they feel that the architect’s refusal to embrace technological innovation invites their extinctions. To avoid obsolescence, architects need to increase demand for their skills by embracing and critically engaging in emerging technologies that both stimulate and satiate consumer desires. This is being undertaken to some extent by Bill Massie, Thom Faulders, Forsythe + macAllen, Evan Douglin, SHoP, John Nastasi and many others (Celento, 2007).

In addition, there are some basic issues raised by collaborative design in architecture. On the one hand, there is participation of multiple individuals of various design perspectives and expertise, who may act on heterogeneous design worlds to undertake domain-specific design tasks. On the other hand, there is the goal of developing a single integrated design that satisfies the design requirements elicited by all design participants (Peng, 2001). How collaboration works in the present context is continuously evolving and has still not been completely resolved.

The architect’s ideal has traditionally been to control the entire design and building process, though he was not necessarily both designer and builder. Controlling the design process requires the architect to collaborate with the different people involved in the various stages of the design process. According to the American Institute of Architects, as many as 25 professions operate within the design process (Cuff, 1992). Currently the 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 of the architect’s medieval predecessors (Kolarevic, 2003). Apart from the realm practice, many innovations are taking place in the field of research related to digital collaboration across all disciplines. Therefore, it is important to pay heed to the path being paved through design research.
2.1.2 Role of Mediation

Because architectural design has always been embodied through mediation of some kind, be it the conventional medium of paper or the present ubiquitous use of computers it has always been affected by either the reductive quality or amplificatory effects of the technology used. For instance, the sketch has been deemed extremely important due to its ambiguity that allows rich interpretation and greatly influences design thinking and imagination (Frascari, 2007). As a consequence, Mitchell (2001) observes that architects drew what they could build, and built what they could draw. And so, Frascari (2007) feels that the design process has evolved around the mediation of drawing (mostly on the medium of paper) and has become an inseparable part of the “facture” or making of architecture. Though used extensively in the field of design today, digital technology has not yet been able to capture this essence and for this reason has failed to make a considerable impact on the process of design. This may be due to the fact that digital technology and design media is still in its infancy compared to the traditional tools of design with which we have had vast experience (Mitchell and McCullough, 1995).

It is essential to understand the relationship and impact of digital mediation in architectural design. In Existential Technics, Ihde argues that mediation of any kind is non-neutral and the tools and technology engaged in a situation inherently transform it. Conversely, to be completely focused on the work, it is imperative for the tools to become transparent and only then will they be truly instrumental to achieve the desired objective (Ihde, 1983). Therefore, looking at the case of digitally mediated design collaboration, due to adoption of a newer technology, it is evident that the context of design process itself would have to undergo a paradigm shift or at the very least some kind of change. Yet equally as time goes by and familiarity with the digital medium increases, it will eventually reach a point where it will become an innate part of the design process and hence become transparent and no longer be
envisioned as a medium in the course of design. For instance, knowing the production capabilities and availability of particular digitally-driven fabrication equipment would enable architects to design specifically for the capabilities of those machines (Kolarevic 2003).

2.1.3 Digital Mediation in Design

There are broadly two ways in which digital technology mediates in the field of the collaborative architectural design process – first in the development of the design and second in the collaboration of design ideas. Digital mediation in design has been realized through computer programs, software and related tools (such as CAD) that have since their implementation, attempted to aid in the design process. The other digital mediation through networked telecommunications has facilitated collaboration and data exchange especially in distributed settings. To understand how digital technologies have been utilized, it is necessary to know how and when digital tools such as computers, design software and programs, and network technology were introduced to the design process.

2.1.4 Digital Technology in Design Process

Digital technology began to be applied in the design process along with the development and introduction of computer technology. Extensive research was done around the late 1960’s to employ computers as tools for design. While, Ivan Sutherland’s Sketchpad in 1963 was the first interactive graphic design tool, it became a precursor in the field of computer-aided design and paved the way for development of many software and computer languages related to design. Consequently, efforts were made to program computers to design on their own as humans would by analyzing the problem and proposing appropriate solutions. In 1969, Simon (1969) wrote on the logic of design and discovered
how it was argumentative and full of paradoxes. This was also an intense time for development in operations research (OR) and artificial intelligence (AI), and both were applied to solve architectural design issues as an attempt to “handover” the process of designing to the computer.

2.1.4 Digital Tools in Architecture

Computation in the realm of architectural practice has been a hard problem to figure out due to the countless factors involved. For instance, the design process in a professional setting takes place through various stages that are identified as program development, schematic design, preliminary design, design development, contract drawings, shop drawings, and construction (Laseau, 1980). Each stage above requires different type of tools and digital mediation. Though digital technology has been employed successfully in some of the latter stages of the process, especially from design development up to construction, it has had ‘little qualitative impact’, especially on the early design phase. For early history of computer-aided tools in architecture, refer to Radford’s (1987) CADD Made Easy and for recent developments, refer Kalay’s (2004) Architecture’s New Media. The first generation of computer programs were meant to aid design intelligently, but they soon gave way to Computer Aided Drafting (CAD) and became drafting tools, to make architectural drawing production more efficient by simply automating the process of traditional drafting, modeling and communicating. Hence, the notion of digital mediation affecting the early phase of the design process, and thereby transforming it is still not achieved.
2.1.5 Design process as a complex problem

To effectively implement computers as aids to design, there was a need to understand the logic and structure of design problems. Many authors and researchers henceforth defined design as an increasingly complex and hard to define problem. Simon (1969) categorized problems of planning and design as ill defined. Ill-defined problems are those, which have little structure in terms of their operational parameters: goals, legal operations, alternatives to be considered, and evaluative functions. One of the paradigms of architectural design process became problem solving that included the concept of satisficing, (Simon, 1969) where solutions are created for specific goals and constraints. Similarly, Alexander (1965) described the design process in his seminal essay; The City is not a Tree as having solutions that are parameter-based. While Rittel (1973) defined the design or planning problem as “wicked” since it is an activity aimed at achieving certain desired goals without undesired side or after effects, according to Archea (1987), design is the “search for most appropriate effects that can be attained in a unique context.”

Following the 80’s, many authors like Rowe (1987) in Design Thinking, Akin (1986) in Psychology of Design and Goel (1995) in Sketches of Thought, attempted to define the design process through theories of information processing or as a cognitive process where one has to externalize the mental models of thought. There were exchange of ideas between the design theorists and computational theorists. For computation of design, some of the design methods considered were trial and error search, constraint satisfaction, rule-based design and precedent based methods. These methods and definitions were taken into consideration for developing digital tools for the design process.
2.1.5.1 Need for Collaboration in the Design Process

Most contemporary problems in architecture require a self-conscious process. Architects have to decide how design should come about, when to examine the allied bodies of knowledge, and how to bring such knowledge to bear on design. They have to decompose the design process explicitly into smaller phases to make possible the contributions of a large number of participants, such as engineers, planners, landscape designers, and users or client groups. The integration of each participant in this complex process is essential. Professionals and other interest groups can participate in design meaningfully, if they are informed about the relevant decisions and alternatives during the course of the process (Akin, 1986). For instance, collaborative decision making, design cognition and knowledge-based creative design (Gero and Maher, 1993), protocol analysis of problem solving in design and many other design related research has been undertaken since the 1960’s with the emergence of cognitive psychology (Eastman, 2001).

Figure 2-1: Integrating role of digital model (source: Mitchell and McCullough, 1995).

It is apparent then that the design process cannot take place without some form of communication. Not only with people of other fields, architects also need to communicate and
collaborate amongst each other to exchange ideas. Architects communicate with each other through drawing and talking as parallel ways to design. Schön calls this the *language of designing* (Schön, 1983). The purpose of design collaboration is to share expertise, ideas, resources or responsibilities. Design communication is central to design development in the process. The effectiveness of design communication becomes critical for designers in sharing design information, in decision-making and coordinating design tasks (Chiu, 2002). The digital model can help by becoming the communication process for various design tasks, people and processes as shown in figure 2-1.

### 2.2 COLLABORATION IN DESIGN

#### 2.2.1 Collaboration in the Architectural Design process

![Figure 2-2: Design process (source: Kirk and Specklemeyer, 1988).](image)

Around the late 80’s, the concept of collaboration became an integral part of the design process. Figure 2-2 above shows a change in definition of design process as defined by Kirk et al (1988) in *Creative Decision Making*, that shows the various phases of the design process between the given context and the final product, whereas Kalay (2004) in *Architecture’s New Media* defines the
process by explicitly showing communication playing a vital role in linking the various phases of the design process in figure 2-3. He states that design is a social act and buildings are much too complex to be designed individually. Complexities require joint effort of a team of specialist. Therefore building is a sum total of: coordination; communication- means of sharing information among individuals.

There are various participants who play a key role in this design process. Architects, throughout history have been seen as problem solvers and communicators of design knowledge. The decision-making process has however, progressed from one based on the judgments of a single designer to the complexity of modern design. The gradual addition of economic, technological, and social variables to the design equation has meant that the design process has become fragmented into myriad subspecialties, each controlled by systems experts (Kirk & Specklemeyer, 1988).

Participants bring their own expertise, perspectives and objectives to a task. Within the multi-faceted world of design, team members can be trained with different sets of references and vocabularies that enrich the design process but make communication difficult (Cheng and Kvan, 2000). In creative collaboration, such as design, the teams are formed to find a solution to the problem of creating something new. They are required to have shared understanding and joint-decision making.
skills (Kalay, 2004). The participants operate under much different conditions from other collaborations.

As collaboration became an integral and over-used word in relation to the design process, there have been many attempts to define what collaborative design entails. Collaborative design consists of parallel expert actions, each of short duration, bracketed by joint activity of negotiation and evaluation (Kvan, 2000). Thus the design activity itself is discrete, individual and parallel, not intimately linked. The participants act as individual experts addressing design issues from their perspectives. A collaborative design project consists of a team of design partners who are engaged during the period of the project in a particular design task. The group forms a short-lived community with the goal to create a design (Achten, 2001). Their expertise may change during a design session as their understanding is supplemented and they learn from their environment.

In an AEC context, Kalay (2004) defines collaboration as: “the agreement amongst specialists to share their abilities in a particular process, to achieve the larger objectives of the project as a whole, as defined by a client, a community or a society at large.”

2.2.2 Types of Collaboration

Collaboration among different participants in the design of a building involves both synchronous and asynchronous communication. It involves the ability of the different participants to work on their part of the project using their own particular ways of working yet being able to communicate with other participants to bring about a common objective (Rosenman, 2006).

Since, various people are involved in the act of designing at different stages of the design process, there are different degrees in which they collaborate with each other. In a continuous close-coupled design, participants work closely, understanding the rationale of each other’s moves. In loosely
coupled design, participants contribute what they can in different domains of expertise at moments when they have knowledge appropriate to the solution (figure 2-4).

There can be further categorization of design collaboration as follows:

- Mutual collaboration, in which participants are busy working with each other.
- Exclusive collaboration, in which participants work on separate parts of problems negotiating and asking advice from others occasionally.
- Dictator collaboration, where participants decide who is in charge and that person leads the process (Kvan, 2000).

### 2.2.3 Digital Communication

Apart from being a tool for design, digital technology has also played a vital role in design communications. This has been possible due to advances in the network technology since the dawn of computers. Computers were first seen as potential communication devices as early as the late sixties, when experiments were carried out in computer-aided communication (Licklider et al, 1968). Barney (2004) in *Network Society* describes how the post-industrial society witnessed an information revolution 50 years ago. However, because this technology has been able to boom so rapidly, the
infrastructure today has grown and led to greatly advanced telecommunication capabilities. Hence, the effect of digital technology on communication has been much far and wide. Rapid technological advances in the field of communication have created what Darin (2004) terms a “network society,” a phenomenon that demonstrates the extent of permeation of Information Technology (IT) in everyday life.

Communication technology has evolved from the telegraph, telephone, radio, and television to the latest Internet. The first extensive computer network, the ARPANET, begun in 1969, was intended to let researchers log on to remote computers and share scarce resources such as large programs, databases, or special hardware (Sproull and Kiesler, 1991). With the invention of networking technology, it became feasible to send data and messages to other computers. Today terms such as computer-mediated communications (CMC) are used to encompass the most popular computer-based communication technologies and applications: networks, electronic mail, electronic bulletin board and electronic conferencing. The groupware matrix in figure 2-5 shows the spectrum of tools used for different time/ space configurations. These tools have been widely accepted since the mid-nineties and their use keeps on growing.

Figure 2-5: Time/Space matrix for groupware.
This great leap of progress in technologies and rapid development of information exchange has mostly been attributed to the quantity and rate or speed of data exchanged, which is dependant on the bandwidth. This has been considered to be the most important critical element in the evolution of IT. As Mitchell states in the *City of Bits*, if the value of real estate in the traditional urban fabric is determined by location, location, location, then the value of the network connection is determined by the bandwidth (Mitchell, 1996). The infrastructure technology part of network communications, which is bandwidth or the rate of data exchange, has increased from a modest 56 kbs/s from a dial up modem to almost 10-100 Mbs/s through Ethernet and wireless connections to the latest of up to 10 Gbs/s through the gigabit connection. As trends in advances in network technology show, this may not be the ultimate speed of connection, and this would definitely continue to grow in the future. Table 2-1 shows the various scenarios of digitally mediated design, where remote locations can be connected via Internet.

<table>
<thead>
<tr>
<th>Table 2-1: Four types of digitally mediated design.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Synchronous</strong></td>
</tr>
<tr>
<td><strong>Same Location</strong></td>
</tr>
<tr>
<td><strong>Remote Location</strong></td>
</tr>
</tbody>
</table>

At present, many endeavors are being undertaken to improve the infrastructure of network technology. Atkins (2003) report on *Cyberinfrastructure* emphasizes that vast opportunities exist for creating new environments of collaboration by improving upon the infrastructural capabilities of IT. This report however, also warns that there are real dangers of disappointing results and wasted investment for a variety of reasons including under funding in amount and duration, lack of understanding of technological futures, excessively redundant activities between research fields and industry, lack of
appreciation of social/cultural barriers, lack of appropriate organizational structures and inadequate
related educational activities. Another relevant US project initiative called the National Lambda Rail
(http://www.nlr.net/) was incorporated in 2003 for the high demands of scientific research community
and universities. The systems works on optical electronic systems, with a maximum capacity of 40 and
32 wavelengths per fiber pair respectively. Each wavelength can support transmission at 10 billion bits
per second (10 Gbps). This network has also been utilized in the research study for the Participatory
Design Studio (PDS) conducted in Penn State and Carleton University is a part of the next chapter of
this thesis.

2.2.4 Theories on Computer Mediated Communication

To understand the effect of use of network technology on the architectural design process, it is
important to briefly overview the research, theories and speculations in the fields of communication
media and Human-Computer Interaction (HCI). First of all Mc Luhan’s well known quote “The medium
is the message” applies validly to all the media of print, television, computers and now the Internet
because it is the “medium that shapes and controls the scale and form of human association and
action.” Each medium, independent of the content it mediates, has its own intrinsic effects, which are
its unique message. The message of any medium or technology is the change of scale or pace or
pattern that it introduces into human affairs (McLuhan, 1967). This is also pertinent in the revolution
witnessed today in distributed design collaboration as well as in the form of generative design,
parametric modeling etc. in the design process.

The field of computer supported collaborative work (CSCW), which is a branch of HCI, is also
relevant for digitally mediated design as it deals with how computers and information technology
support human activities through a social and behavioral lens. Some of the theories of interest are
distributed cognition that looks at collaborative problem solving, (Perry, 2003) and Clark’s Common Ground Theory that formalizes the notion of collaborative activity as “joint action” and deals with language use and its understanding as a means of collaborative activity between humans through CMC (Monk, 2003). This theory if considered in conjunction with Schön’s language of designing could be a crucial tool for analyzing networked collaboration in design and the importance of shared understanding, especially in the context of architecture which involves great amount of visualization and specialists from diverse fields.

Yet another relevant theory is known as Media Richness Theory (MRT) that comes primarily from the literature on CMC and is most often associated with business communication. As shown in figure 2-6, it deals with the affordances of each media. MRT can be used to analyze communication media choices and to help reduce ambiguity of communication through the appropriate selection of communication media for the required task (Daft and Lengel, 1984). In the context of design, this can be related to using tools that say best support visualization needs.
2.2.4.1 Effect of IT on Society at large

Because there has been a great cultural impact due to the IT revolution, there are many points of view on the effect this technology has on society. There has been a lot of emerging literature on the manner in which this technology is shaping the future society and mode of life and work. Castells (1996) claims that the contemporary “network society” has redefined and afforded new ways in which collaboration can take place. It has created new paradigms for remote or distributed collaboration, which in turn impacts the design process and opens up myriad possibilities for the theory and practice of architecture.

Many authors have tried to presage whether and how people use IT in the context of work. For instance Sproull and Kiesler (1991) state that though communication technology can overcome temporal and geographical barriers to exchange of information, the hard problem is to predict how technology will interact with ongoing routine practices and policies and imagining how this will lead to long-term changes. Taylor (2001) expresses in The Moment of Complexity, that in midst of extensive and rapid changes, it is difficult to assume a critical perspective from which to access the significance of what is occurring. The emerging complexity invites a variety of interpretations and prognostications. A network culture is emerging and critics of new technology predict that the proliferating innovations will completely change the world, as we know it. However, some other claim that as technology is undergoing rapid development, our daily activities may not catch up and we maybe going through a “cultural lag”. Even though technology has the ability to reunite skill and intellect, according to McCullough (2004), people will always be more interesting than technology. A similar trend can be seen in the field of architectural design, which is discussed in the next section of this chapter.
2.3 DIGITALLY MEDIATED DESIGN COLLABORATION

2.3.1 The Current Context of Architectural Practice

The traditional view of the architect as a lone hero and ultimate creator of “good” architecture has been gradually abandoned, in favor of greater attention to the importance of collaboration in assuring excellence in design (Cuff, 1992). In today’s world of globalization, it is possible for various designers from all over the world to contribute in making a building in any other corner of the world. With advances in communication technology, people who are not necessarily at the same geographical location can in fact design in collaboration with each other. Many architectural firms have also become global and have branches worldwide; hence the need to collaborate arises within their organization.

Buildings today have become far more complex and need to be completed in far less time, but we are still to a great extent relying on drawings and written instructions to communicate. In addition, the amount and complexity of information have grown as well as the number of people who need information and have information to share (Peri, 2000).

2.3.2 Evolution of Collaboration in Architectural Design Practice

Since early writings of architecture to Renaissance and finally to the emergence of Modernism, the architect has been treated as the master builder. He is known to coordinate teams of specialists and people working under him or for the project, but there are rarely accounts of more than one architect or designer in a project. The question that arises is when did architects start to work together? Modernism epitomized and lay in the shadows of great architects celebrated for their individuality. A Howard Roarkian image is forever imprinted in our minds with relation to architects. Even though the word
collaboration hasn’t always been explicitly used in relation to architecture, the underlying principles of architecture have always implied some form of working together.

An architect as a professional, has mostly been perceived as a lone practitioner post Renaissance with famous architects such as Michelangelo, and more so with Le Corbusier and Wright during Modernism. Some of the earliest instances of collaborative design where two or more architects have worked together on a design took place around the late nineteenth century. One of the cases of architectural partnerships in America were witnessed in Chicago with a famous example of Dankmar Adler and Louis Sullivan, who collaborated on the famous Auditorium building in 1886 each bringing their own expertise of acoustics and architectural design respectively. Collaboration in architectural practice took off mostly in the fifties as a phenomenon of the prosperous postwar decade when teamwork was canonized. This is the period when Mies van der Rohe worked with Philip Johnson on the Seagram building as a collaborative project with crucial intervention of Phyllis Lambert, from the moment of commission; MoMA exhibited SOM, which was established in 1933 and Walter Gropius went into partnership forming The Architects Collaborative (TAC) in 1945 (Colomina, 1999). The TAC was a unique and extraordinarily successful experiment in genuinely collaborative practice in a time when individualism was a widely accepted characteristic of modern architecture (Von, 1966).

There have been many changes in ways of working post-industrial revolution and more so after the IT revolution including in the field of architecture. The need for collaboration in the design process and architectural practice has deemed it necessary to reexamine the changing role of the architect in the design field. Wade (1977) states that design is too complex and requires too much information to permit an individual to work in isolation. The architect cannot possibly take into consideration every facet of the design. Diverse fields influence architecture; ranging from art, sociology, ecology, mathematics, engineering, technology and many more. There is so much
information, specialized knowledge and research that go into any design. Cuff (1992) talks about the responsibility of the architect in *The Story of Practice*.

Ever since the first century BC, when Vitruvius spelled out the tremendous range of knowledge an architect needs, the burdens of such an unwieldy bundle of expertise has weighed upon the profession. In order to coordinate the input of the many collaborators, an architect is expected to be knowledgeable in all the fields brought to bear upon a design project. Even consultants are not the proprietors of their domain.

Gropius wrote on teamwork (Von, 1966) saying:

The conception of the architect as a self-sufficient operator who can with the help of a good staff and competent engineer solve any problem is an isolationist. It runs counter with the concept of Total Architecture, which is concerned with the whole of our environmental development and demands collaboration on the broadest basis.

Gropius also states that the most important aspect of collaboration is communication. There should be continuous mutual exchange among the participants of the team, of their ideas and their professional actions taken.

### 2.3.3 Scenarios of Architectural Design Collaboration

Architectural design requires the collaboration between various specialists (Figure 2-7). To understand the present context of architectural design collaboration, it was important to imagine various types of scenarios (Table 2-2). These could comprise of mega firms that house various specializations within their firms or branches; collaboration between *starchitects* and architects of record, where the concept designers are distinct from the executive architects; distributed collaboration between architects and consultants who may be geographically dispersed and even outsourcing to developing countries globally for design production.
However, for the purpose of this thesis, the most pertinent scenario of collaboration considered is that between different designers who are remotely located and come together during the initial stages of design to create buildings through digital mediation.

Table 2.2: Scenarios for design collaboration in firms.

<table>
<thead>
<tr>
<th>Scenario of collaboration</th>
<th>Examples of firms</th>
<th>Design Team</th>
<th>Time/Space</th>
<th>Type of Collaboration</th>
<th>Means of Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mega Firms (AE firms) Multi-speciality</td>
<td>SOM</td>
<td>Designers Specialists</td>
<td>Synchronous Co-located</td>
<td>Exclusive Dictator Mutual</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>Mega Firms-branches</td>
<td>Burt Hill</td>
<td>Designers Specialists</td>
<td>Synchronous, asynchronous, distributed</td>
<td>Exclusive Dictator Mutual</td>
<td>Remote</td>
</tr>
<tr>
<td>Design Firm + Consultant</td>
<td>Gehry and Arup</td>
<td>Designers Specialists</td>
<td>Synchronous, Asynchronous, Distributed Co-located</td>
<td>Exclusive</td>
<td>Remote</td>
</tr>
<tr>
<td>Design Firm + Architect of Record</td>
<td>Disney + Antoine Predock</td>
<td>Concept Designer Project Manager</td>
<td>Asynchronous, Distributed</td>
<td>Dictator Exclusive</td>
<td>Face-to-face Document exchange</td>
</tr>
<tr>
<td>Global Outsourcing</td>
<td>Cadforce</td>
<td>Designers Draftsmen</td>
<td>Asynchronous Distributed</td>
<td>Dictator</td>
<td>Document exchange</td>
</tr>
<tr>
<td>Separate Design Firms</td>
<td>United Architects</td>
<td>Designers</td>
<td>Synchronous, asynchronous, distributed</td>
<td>Mutual</td>
<td>Remote</td>
</tr>
</tbody>
</table>
Some firms are often distinguished by size as this implies a number of associated features such as large-scale projects, complex clients like corporations and government organizations, generally over 50 persons, sophisticated operations, specialization, a wider range of services, higher pay, formalized management, and a hierarchical organization of responsibility and power (Cuff 1992). These firms typically branch out and disperse geographically, sometimes even multi-nationally. In terms of economic health, they are more productive, more profitable and can employ architectural designers, business developers, marketing directors, project managers, construction managers, accountants, interior designers, public relations personnel, office managers, secretaries, engineers, landscape architects and so on, hence becoming self-sufficient.

There is a dilemma that exists and generates tensions between those architects who are committed to a managerial conception of their role and those architects who wish to focus on their self-image as artists. Gutman (1992) feels that architecture easily lends itself to these kinds of internal tensions because of its unique status among the professions: it is the only profession that straddles the worlds of the fine arts and the service industries.

The design-production split occurs due to specialization of firms. A fundamental shift has been occurring in the profession where the valuable contributions made by each expert are well recognized by architects. Thom Mayne of Morphosis explains that on large projects, before schematics have been completed, his firm was receiving regular input from a parking consultant, lift consultant, cost estimator, fire consultant and all engineers (mechanical, electrical and structural). Both architects and clients have become accustomed to this crowd of specialized contribution (Cuff, 1992).

Most of the contemporary famous architects design worldwide and collaborate with the best consultants available globally. For instance Frank Gehry’s digitally driven design firm Gehry Technologies (GT), collaborates extensively with one of the world’s biggest structural engineering firm in UK, Arup. Apart form developing the software, Digital Project based on Dassault system’s CATIA in
2002, they have developed with Arup what they call “The Virtual Building.” Produced by Arup and GT, it is a combination of philosophy and technology that will not only influence the tools we use in the future, but the way in which they conceive, finance, design, construct, operate and ultimately decommission construction projects.

Another scenario of design collaboration can be understood through the phenomenon of outsourcing that is occurring due to globalization. According to Tombesi and Wilkins (2005), this creates a 24/7 global office setting, where the design production happens continuously in a cycle. Rather than developing complete designs; architects in these outsourcing shops tend to handle tasks such as turning schematic drawings into blueprints (Engardio, 2007).

2.3.4 Extent of Use of Digitally Mediated Technology in Design Firms

An Adobe Systems’ sponsored survey conducted in 2006 revealed that collaboration is vital to the AEC industry as 94% of participants said they collaborate with other designers on project information. Top collaboration tools are e-mail (92%), fax (69%), and audio conference (67%). New tools such as web conferencing (15%), instant messaging (14%) and video conferencing (14%) are less common. Most collaboration takes place within a single office, but 74% respondents claim that they collaborate outside the office location (Ferris, 2006).

The following graphs (figure 2-8 and 2-9) illustrate the extent of collaboration in the AEC industry through the standpoint of location and file formats used most frequently for data exchange. These tables signify the extensive use of digital tools for the purpose of data exchange. Another trend due to digital meditation that is becoming increasingly popular is BIM which is solely based on information exchange.
Figure 2-8: Degree of collaboration in AEC industry (source: Ferris, 2006).
Figure 2.9: Design collaboration (source: Maher et al., 2000).
2.3.5 Emerging Digital Technologies in Design Practice

The 2008 BIM Handbook states that Building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering and construction (AEC) industries as it constructs a virtual model of the building digitally and this computer-generated model contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the building. However, this technology is primarily based on business interests, most benefits related to cost, efficiency and estimation (Eastman et al, 2008).

One of the surveys on top criteria for choosing BIM revealed that it was considered most helpful for producing construction documents. Multi-disciplinary capabilities, though deemed important were not significantly high contributors for choosing BIM. Along with that, scalable solutions that support collaboration and distributed work processes were preferred (Khemlani, 2007). This signifies that BIM though an extremely important application of digital mediation for architectural information exchange does not effect the initial stages of the design process much and caters more towards the realm of construction and later stages of the design process.

However, some feel that the present digital age has radically reconfigured the relationship between conception and production, creating a direct link between what can be conceived and what can be constructed (Kolarevic, 2003). It is now possible with contemporary techniques to build relationship between culture, techniques and architectural production enabling to complete the feedback loop. It allows for processes where software breeds form, integrates manufacturing and creates spatio-temporal organization of spaces (Rahim, 2002).

Many experimental architects today, (like FOA, Preston Scott Cohen, Kolatan MacDonald and Greg Lynn) use the digital medium in ways that allow these architects to design innovatively. Newer paradigms of practice are emerging by adopting manufacturing methodologies such as rapid
prototyping, CAM and borrowing from the tools and techniques generally used in the fields of automotive, aerospace, animation and even video-game industries. Also, in the present-day architectural design process, digital media is increasingly being used not only as a representational tool for visualization but as a generative tool for the derivation of form and its transformation – known as the digital morphogenesis. The intention of these digitally-based generative techniques is to shift emphasis from “making of form” to the “finding of form” (Kolarevic, 2003). Another popular function increasingly served by digital mediation in the design process is that of communication. The figure 2-10 below shows the integration of traditional and digital media in the design process to create a building.

![Diagram of traditional and digital media integration](source: Mitchell and McCullough, 1995).

**Figure 2-10**: Integration of traditional and digital media (source: Mitchell and McCullough, 1995).
2.3.6 Emerging Digital Tools

The following table 2-3, shows a list of some of the digital tools commonly used throughout the design process today along with the company or person that owns them and the year on which they were introduced.

<table>
<thead>
<tr>
<th>Name of tool</th>
<th>Type</th>
<th>Year Introduced</th>
<th>Company/ Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>3DS max</td>
<td>Visualization and Animation</td>
<td>1995</td>
<td>AutoDesk</td>
</tr>
<tr>
<td>Maya</td>
<td>Visualization and Animation</td>
<td>1998</td>
<td>AutoDesk</td>
</tr>
<tr>
<td>AutoCAD</td>
<td>CAD</td>
<td>1982</td>
<td>AutoDesk</td>
</tr>
<tr>
<td>Form Z</td>
<td>3D Modeling</td>
<td>1991</td>
<td>Auto.Des.Sys-</td>
</tr>
<tr>
<td>Solid Works</td>
<td>3D CAD</td>
<td>1995</td>
<td>Dassault (solidworks)</td>
</tr>
<tr>
<td>Revit</td>
<td>CAD BIM</td>
<td>1998</td>
<td>AutoDesk</td>
</tr>
<tr>
<td>CATIA</td>
<td>CAD/CAM/CAE</td>
<td>1981</td>
<td>Dassault</td>
</tr>
<tr>
<td>ArchiCAD</td>
<td>BIM CAD</td>
<td>1987</td>
<td>Graphisoft</td>
</tr>
<tr>
<td>Vector Works</td>
<td>CAD 2D 3D</td>
<td>1999</td>
<td>Nemetschek North America</td>
</tr>
<tr>
<td>Rhinoceros</td>
<td>3D modeling</td>
<td>1997</td>
<td>Robert McNeel &amp; Associates</td>
</tr>
<tr>
<td>Digital Project</td>
<td>BIM</td>
<td>2002</td>
<td>Gehry Technologies</td>
</tr>
<tr>
<td>Sketch Up</td>
<td>3D modeling</td>
<td>2000</td>
<td>Google</td>
</tr>
<tr>
<td>Generative Components</td>
<td>3D modeling</td>
<td>2004</td>
<td>Bentley Systems</td>
</tr>
<tr>
<td>Collaboration Tools</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access Grid</td>
<td>Network Communication</td>
<td>2001</td>
<td>Argonne National Laboratory</td>
</tr>
<tr>
<td>Open Canvas</td>
<td>Image editing</td>
<td>2000</td>
<td>Portal Graphics</td>
</tr>
<tr>
<td>DCV</td>
<td>Collaborative infrastructure</td>
<td>2006</td>
<td>IBM</td>
</tr>
<tr>
<td>National LambdaRail</td>
<td>Networking Infrastructure</td>
<td>2003</td>
<td>National Lambda Rail</td>
</tr>
</tbody>
</table>

2.3.7 Emerging trends in Design Research

Some of the implications of the network society have been virtual collaborative work environments (CWE) that are computer-based, distributed, virtual space or set of places. They offer graphically realized, potentially infinite, digital landscapes where individuals can share information through interaction with each other and through individual and collaborative interaction with data representation (Churchill et. al, 2001). Remote collaboration can create a virtual environment that allows information from various specialists to be viewed simultaneously (Peri, 2000). According to
Maher (2006), recent developments in virtual environments and availability of high bandwidth networks have the potential to bring significant changes in the way design professionals collaborate and design.

Advent in information technology has led to developments in visualization and communication technologies that challenge location-dependant partnerships and open up possibilities for rich modes of creative activity and collaboration (Muramoto and Jemtrud, 2007). The use of computer-mediated communication (CMC) has established various distributed design environments that have enabled institutions across the world to form Virtual Design Studios (VDS) by exploiting new computing technologies (Chiu, 2002). However, there is a lack of understanding of how remote collaboration occurs in the world of architectural practice due to the differences prevalent between the academic and practical setting such as the design processes involved, objectives and goals for design and also the infrastructure and digital tools available in each setting.

By necessity, new media and 3D visualization technologies play an all-important role in scenarios of work that are distributed and involve numerous collaborators and participants. Heterogeneous collaborative work environments (CWE) require sophisticated digital tools, protocols, and infrastructure as yet not developed nor integrated. Digital assets must be acquired on and off site, manipulated and created, and deployed across networks, within immersive environments, and output to print, display and fabrication technologies (Jemtrud, 2004). One of the examples is the phenomenon of virtual design studios (VDS) that are discussed in detail later in chapter 3.
PARTICIPATORY DESIGN STUDIO BETWEEN PENNSYLVANIA STATE UNIVERSITY AND CARLETON UNIVERSITY

The first part of the study describes the phenomenon of distributed design in an academic setting. This chapter begins with a brief historical outline of the Virtual Design Studios (VDS) in the early 1990’s. It then talks about the research project conducted in spring 2007 in the Immersive Environments Lab (IEL) in collaboration with Carleton University through a networked realm. This is followed by a description of the studio projects- design of the vertical lift museum (VLM) at Penn State and renovation of the school of architecture (SoA) at Carleton University. The next part explains the methods of data collection for the field study that is carried out during the studio. The technology and tools used for digital mediation during the two studio projects is discussed in detail. The chapter is concluded with the observations and findings.

3.1 VIRTUAL DESIGN STUDIOS

3.1.1 Evolution of VDS

The notion of technologically mediated collaboration has been around since the mid 1990’s as communication technologies evolved and became available to the masses. William Mitchell coined the term “Virtual Design Studio” in 1992. The first Virtual Design Studio (VDS) was conducted in 1994 between 4 universities in North America (Washington University, St. Louis; MIT; University of British Columbia, Vancouver; Cornell); one in Europe (ETSAB, Barcelona) and one in South East Asia
(University of Hong Kong). The languages spoken by the students were English, Spanish, and Cantonese. The project was the redesign of Li-Long courtyard housing in Shanghai. Tongji University in Shanghai was responsible for the documentation of existing site conditions. The tools that were used comprised of CAD, Internet and teleconferencing. A “pinup” account was setup in UBC and an ftp server was used to transfer various files (scanned images, CAD files, text files, tiff, emails, DXF and ASCII). The local mirror of the pin-up and hard copies were available in all institutions (Cheng et al. 1994).

For real-time collaboration, interactive whiteboard, image sharing program and a 6-way video conference call were used, but these were slow for successful synchronous collaboration. Some of the problems faced were co-ordination issues between the 6 institutions along with limited duration of two weeks for the studio and inconsistent presentation skills between the institutions (Wojtowicz and Cheng, 1994). Following this, many tools were developed for distributed design collaboration such as a shared whiteboard program called SYCODE developed by Jabi (1995) that dealt with the issues of early design phase- client debriefing, data collection, architectural program formulation and schematic design generation.

As the concept of VDS became prevalent, various terms were coined to express the same phenomenon. This included collaborative design, participatory design, multi-disciplinary design, virtual design, co-operative design, concurrent engineering and many more. Another VDS experiment was carried out in 1998 between the University of Hong Kong, University of Seattle and the Swiss Federal Institute of Technology. This studio involved continuous work in 8-hour cycles and was termed as the global design studio. It was focused on relation-based design through 5 phases, where the students developed the design of other students after each phase. The projects were stored in a MSQL database on a server in Zurich (Kolarevic et al., 1998 and Hirschberg et al., 1999). Experiments on VDS became
widespread henceforth, with many universities researching on various aspects of distributed design collaboration. Table 3-1 lists literature related to VDS through the early nineties.

**Table 3-1:** Literature related to VDS.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wojtowicz, J. et al.</td>
<td>1992</td>
<td>Design as Digital Correspondence</td>
</tr>
<tr>
<td>Cheng, N. et al</td>
<td>1994</td>
<td>Place, Time and the Virtual Design Studio</td>
</tr>
<tr>
<td>Bradford, J. W. et al</td>
<td>1994</td>
<td>Virtual Design Studios</td>
</tr>
<tr>
<td>Wojtowicz, J.</td>
<td>1995</td>
<td>Virtual Design Studio</td>
</tr>
<tr>
<td>Kolarevic, B.</td>
<td>1998</td>
<td>CAD @HKU</td>
</tr>
<tr>
<td>Kolarevic, B. et al</td>
<td>1998</td>
<td>An Experiment in Design Collaboration</td>
</tr>
<tr>
<td>Donath, D. et al</td>
<td>1998</td>
<td>Virtual Design Studio 1998- a Place2Wait</td>
</tr>
<tr>
<td>Hirschberg, U. et al</td>
<td>1999</td>
<td>The 24 Hour Design Cycle An Experiment in Design Collaboration Over the Internet</td>
</tr>
<tr>
<td>Dave, B. &amp; Danahy, J.</td>
<td>1998</td>
<td>Virtual Study Abroad and Exchange Studio</td>
</tr>
<tr>
<td>Kvan, T.</td>
<td>2000</td>
<td>Collaborative design: what is it?</td>
</tr>
<tr>
<td>Proctor, G.</td>
<td>2000</td>
<td>Reflections on the VDS, Pedagogy, Methods</td>
</tr>
<tr>
<td>Cheng, N. &amp; Kvan, T.</td>
<td>2000</td>
<td>Design Collaboration Strategies</td>
</tr>
<tr>
<td>Mitchell, W. J.</td>
<td>2004</td>
<td>Challenges and Opportunities for Remote Collaborative Design</td>
</tr>
<tr>
<td>Maher, M. L. et al</td>
<td>2000</td>
<td>Understanding Virtual Design Studios</td>
</tr>
<tr>
<td>Maver, T. &amp; Petric, J.</td>
<td>2001</td>
<td>Media in Mediation Prospects for Computer Assisted Design Participation</td>
</tr>
<tr>
<td>Stellingwerff, M. &amp; Verbeke, J.</td>
<td>2001</td>
<td>A Future Focus on Collaborative Design</td>
</tr>
<tr>
<td>Achten, H. H.</td>
<td>2001</td>
<td>Future Scenario for a Collaborative Design Session</td>
</tr>
<tr>
<td>Klecker, J. &amp; Henrichsen, J.</td>
<td>2001</td>
<td>Can simulations in VE support architects and building designers in solving complex design problems</td>
</tr>
<tr>
<td>Schnabel, M.A. et al</td>
<td>2001</td>
<td>The First Virtual Environment Design Studio</td>
</tr>
<tr>
<td>Gul, L.F. &amp; Maher, M.L.</td>
<td>2006</td>
<td>The Impact of Virtual Environments on Design Collaboration</td>
</tr>
<tr>
<td>Maher, M.L. et al</td>
<td>2006</td>
<td>Studying Collaborative Design in Face to Face, Remote Sketching and 3D virtual world environments</td>
</tr>
<tr>
<td>Jemtrud, M. et al</td>
<td>2006</td>
<td>Intelligent Infrastructure Enabled Participatory Design Studio</td>
</tr>
<tr>
<td>Muramoto, K. et al</td>
<td>2007</td>
<td>Emerging Technologies in a Tele-Collaborative Design Studio Between Pennsylvania State University and Carleton University</td>
</tr>
<tr>
<td>Muramoto, K. et al</td>
<td>2008</td>
<td>Participation, Intersubjectivity, and Presence in a Digitally Mediated Workspace</td>
</tr>
</tbody>
</table>
3.1.2 Issues of VDS

Due to the lack of available collaboration technologies, early VDS had to rely heavily on asynchronous communications such as e-mail, message bulletin boards (“digital pinup boards”), ftp, and the still developing Internet. With insufficiently powerful and crudely coordinated tools, collaboration was primarily in an asynchronous, task-based working process that did not allow for full participation by members of the design teams (Mitchell, 1997). As a result, participation was reduced to “simply submitting and giving oneself over” (Vaitkus, 1991) to the process and other participants.

With the wider occurrence of the virtual design studio, there were many attempts to understand in-depth, the nature of collaboration by many persons involved in these research projects. Kvan (2000) wrote on the requirements of collaborative design and differentiated collaboration and cooperation. He claimed that while collaboration implies that the members of the design team share a common goal, cooperation, though similar in context, implies only that the design team works together. According to him, design collaboration requires a higher sense of working together in order to achieve a holistic creative result. He described three types of collaboration- mutual, exclusive and dictator (Kvan, 2000). A European workshop called ACCOLADE (ArChitectural COLlAborative DEsign) was also conducted with similar goals in mind around 2001 (Verbeke and Stellingwerf, 2001). Many authors such as Achten (2001), Klercker (2001), Maver and Petric (2001) along with over 25 researchers from 12 universities researched on the underlying principles in collaborative design for the future. They discussed the important qualities of collaboration, and the hindrances in simultaneous and multidisciplinary design process to figure out the aspects to be developed for future.

Since then, many virtual design studios have been incorporated as an integral part of the curriculum in some architectural schools in Australia. Schnabel and Kvan (2000) also conducted the first virtual design studio in Australia that was conducted solely in a virtual environment. From 2000
onwards, Maher (2006) carried out a lot of studies related to analyzing the tools required for VDS including usability studies and protocol analysis of tools. Virtual design studio has implications on the way design decisions are made and designs are documented. According to Maher et al (2000), very little is understood about the phenomenon of collaboration within a distributed computer-networked environment and there is need for appropriate computer representation for design development and documentation.

3.2 Penn State’s Participatory Design Studio (PDS)

During the spring 2007 semester, a collaborative design studio was conducted with third year architecture students between Pennsylvania State University and the Carleton University. This experimental tele-collaborative architectural studio was held in the Immersive Environments Lab (IEL) at Pennsylvania State University and The Carleton Immersive Media Studio (CIMS) at Carleton University. A total of 32 students (16 from each institution) participated in this studio. The studio comprised of two design projects that were given to the students during the semester. The first project was the design of a vertical lift museum at Penn State and the second project was the renovation of the school of architecture at Carleton University. Depending on the location of the project, the students were supposed to document the existing context and send it to their counterparts in the other university.

3.2.1 Research Project

The Participatory Design Studio (PDS) was implemented as a proof-of-concept design studio. This studio was a part of the research project to develop and access the education impact of rich environments in which multi-disciplinary design teams can work together despite being located at a
distance on complex problems. The goal of the project was to integrate immersive virtual environments, broadband data networks, high definition video communication systems, multimedia applications and rendering resources within a service oriented architecture (SOA) to provide a group collaboration environment and workflow that would be flexible, robust and relatively transparent to users. The objective was to develop infrastructure on distributed design studio.

This project was envisioned as an effort that would include two institutions and researchers from varied fields of interest such as architectural design, computer visualization, communications and departments of Computer Science. The research group comprised of Katsuhiko Muramoto and Michael Jemtrud who were responsible for the overall project organization and course development of the collaborative studio.

As a research assistant in a group with Professor Katsuhiko Muramoto, Professor Loukas Kalisperis, and Bimal Balakrishnan, I helped in collecting and analyzing data related to the tools and technology used in the collaborative design studio. Professor Michael Jemtrud and Danielle Wiley were responsible for conducting the studio at Carleton University.

3.2.2 Description of Studio projects

3.2.2.1 Vertical Lift Museum

During the first six weeks, the project entailed designing a small helicopter museum called the Vertical Lift Museum (VLM) for the department of Aerospace Engineering at Penn State (figure 3-1). The students were organized into groups of 4, with two students from each school, to jointly design for the project. The eight groups worked in collaboration using Access Grid middleware, primarily for presentations and discussions during studio hours.
Since the proposed project was located at the Pennsylvania State University, the students took responsibility of documenting the existing conditions of the building and its existing context. The conveyed information consisted of the history of the Aerospace department, precedents of museums, site photographs, and program description with adjacency and occupancy diagram along with the 3D digital model of the building. The Form-Z digital models, pictures of existing conditions, conventional architectural drawings in PDF format (site plans, building plans, elevations and sections) and video documentation were transferred to the Carleton University students via ftp sites.

3.2.2.2 School of Architecture – Renovation

The second project for duration of eight weeks was the renovation and expansion of the school of architecture at the Carleton University (figure 3-2). This time the project was hosted by the Carleton University students, who conveyed the existing conditions of a complex building site to their remote
partners at Penn State. For this project, groups were combined and reorganized, resulting in a variety of group size of four, six, seven and eight students.

The student groups worked with the infrastructure developed by the Carleton University research group called the PDS dashboard, based on a Network Enabled Platform (NEP) which utilized the high bandwidth connection provided by National Lambda Rail along with Canada’s CA*Net4 and UCLP technologies. These are discussed in detail in the next section.

3.3 DATA COLLECTION

The goal for the PDS was to identify the digital tools used for collaborative design, to understand how the tools were used and at what stage of the design process were they required. A field study approach was adopted for primary data collection.
The research involved methods based on ethnographic field study, where the researcher becomes part of the group under study and observes subject’s behaviors (participant observation) to gain insight into what, how, and why their patterns of behavior occur (Agnew, 1997). Data collection comprised of observation of the setting and technical infrastructure used, journals of the design process maintained by students, video recordings and screen captures of collaborative sessions, focus group study at the end of the semester and finally a survey and questionnaire of the students.

3.3.1 Observation

The primary mode of data collection was through observation, description and interpretation of the events that take place in the studio. As a research assistant in the studio, I observed the students while they were in the IEL. Notes were taken during each studio session to see how the tools were being used to discuss design. Along with this, I also helped to set up Access Grid and access presentations from the server for the student’s sessions. This helped in observing and understanding the entire setup and user interface used in the IEL and gaining familiarity with Access Grid and PDS service dashboard by operating these tools for the students collaborating during studio.

3.3.1.1 Staging of the Participatory Design Studio

The two projects conducted during the duration of the studio utilized an ensemble of resources as proof-of-concept configurations of the various tools available which kept evolving as the studio progressed. The following describes the setting/staging used in the two projects. The staging of the digital environment consisted of three primary “scenes”: the IEL, the CIMS lab, and the third digital “scene” (Muramoto, 2007). The third scene was created through the dynamic interaction between the
students and the two distinct technological interfaces. According to Muramoto et al (2007), within this third scene, unique modes of communication, embodiment and subjectivity might emerge. Also this physical scene requires a robust physical substrate, which is porous, and allows transgression or passing of data sets and assets along with bodily gestures, expressions and ideas across the digital collaborative environment.

3.3.1.2 Access Grid- Project 1

The first project comprised of videoconferencing between Carleton University and Penn State and was supplemented by conventional architecture studios held individually in both institutions. The technology used for the tele-collaborative meetings was the Access Grid, which is an ensemble of resources, visualization environments and grid middleware that is used to support group-to-group interactions across the grid.
Scheduled videoconferences were held once a week for the first three weeks and twice a week for the rest of the project. After the initial meeting session via Access Grid conferences, students also communicated with their teammates using a plethora of tools for pair-to-pair communications, including AOL, MSN, email, and telephone and ftp sites.

The Access Grid conference was easy to operate and robust enough to serve for productive conversation and exchange of concepts and critiquing, thus contributing to the establishment of common ground for the projects. Most of the design collaboration on the projects, however, was task-based collaboration and happened asynchronously for the duration of the project.

3.3.1.3 PDS Dashboard- Project 2

The staging of the collaborative design environment for the SoA project focused on a Standard-Definition (SD) Video tele-conference platform; a high performance visualization solution for real-time application sharing (IBM’s “Deep Computing Visualization”, Remote Visual Networking (DCV-
RVN); and a web-based “dashboard” developed at CIMS (Eucalyptus) for more flexible configuration of rendering and modeling technologies.

During the IEL sessions, the students communicated their design intentions to their counterparts, using primarily pre-prepared PDF format with images from Form-Z models and scanned hand drawings, as well as some AutoCAD and other modeling software. The students transferred information related to the project between each other via emails and pre-established ftp sites.

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Figure 3-5: Project 2- PDS dashboard.

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3.3.2 Journal

Once the students were organized into groups with their counterparts in Carleton University, they were asked to assign pseudonyms for themselves. The students were required to maintain journals to record any type of communication that took place between them and their teammates during the entire semester. A structured format of the journal was provided to the students (refer appendix B),
which they filled with relevant data pertaining to their mode of collaboration. The journals tracked the extent of time, modality, team members who participated in a particular design session and the before and after representations of the design artifact. This included exchange of emails, online chatting and other forms of communication that could not be directly observed during studio hours. These journals were collected and classified chronologically for each student group after each week. A record of their email conversations and chat transcripts was also kept.

3.3.2.1 Videotaping

The final collaboration session when the students presented their design synchronously in both universities was video recorded. This session consisted of design presentations of the student’s proposal as well as the critiques sessions. The video recordings helped to analyze the impact of high bandwidth media on design communication and critique. The video analysis examined the user interface and effectiveness of ‘staging’ along with how tools were used, ease of use and feasibility of implementing those tools in a digitally mediated environment.

3.3.2.2 Screen shots

To study the usability of tools in detail, certain experiments of data collection were carried out throughout the semester. For instance, during certain studio sessions, screen activity (figure 3-6) was captured using software such as INTERACT. The mouse movements and the time spent were recorded for each team session in the IEL. The information recorded comprised of the duration of each session along with the frequency of mouse clicks and mouse movements.
3.3.3 Focus Group Study

At the end of the semester a focus group-study was conducted with the students at Penn State to gain insights on their experience of working in a remote collaborative studio setting. The discussion was based on student’s social presence in the tele-collaborative studio, computer skills and use. The focus group discussions helped to capture the nuances of the collaborative process and enable in-depth discussion and evaluation of the collaborative studio for future design exercises.
3.3.3.1 Survey and Questionnaire

At the beginning of the study, the students were asked for their consent to participate in the study and a survey (refer appendix C) was conducted to ascertain student’s demographics, use of design software and comfort level with computers and technology. This survey included questions like average estimated hours per week spent on the computer and on specific software generally used by the students such as Adobe Photoshop, Form.Z and MS Office. The students were also asked to rate their level of confidence and experience using an array of software for the purpose of image editing, drawing, drafting, CAD, and modeling.

Another survey was conducted at the end of the semester to ascertain students’ perception of presence and their experience from the collaborative studio. The questions asked in this questionnaire related to their level of comfort in working with the students at Carleton University. The goal of the questionnaire was to ascertain the sense of presence felt by the students in a digitally mediated geographically distributed environment. Questions included “To what extent did you have a sense of being in the same room as your Carleton teammates.” Muramoto et al (2007) also discuss the results of these questionnaires in detail.

3.4 TECHNOLOGICAL INFRASTRUCTURE

The approach for configuring different types of tools and technology used for the duration of the two projects was termed as staging. This implied the choreography of different technologies- high-bandwidth networks, various types of hardware settings, immersive virtual environments, along with visualization and collaboration tools including multimedia applications employed for the studios. This staging actuated a dynamic interplay between technological mediation and the embodied reality of
making in various spatial and temporal conditions (Muramoto et al. 2007). Various configurations of the hardware, middleware and software infrastructure along with different settings and combinations of technology were tried out throughout the semester. The technology components used for the studio are divided in four parts comprising of rich immersive environments, broadband network, middleware technologies and software, high performance visualization technologies and finally multimedia applications.

Table 3-2: Tools used in Penn State and Carleton.

<table>
<thead>
<tr>
<th>Tool</th>
<th>PSU</th>
<th>Carleton</th>
</tr>
</thead>
<tbody>
<tr>
<td>SETTING</td>
<td>IEL Lab</td>
<td>Conference Room</td>
</tr>
<tr>
<td>NETWORK</td>
<td>NLR, Access Grid</td>
<td>CANARIE CA*Net4, PDS</td>
</tr>
<tr>
<td>HARDWARE</td>
<td>3 Large screens, PC Desktop,</td>
<td>Plasma Screen, Laptop</td>
</tr>
<tr>
<td></td>
<td>Sony Video Camera Ambient microphones</td>
<td>Sony Video Camera</td>
</tr>
<tr>
<td>SOFTWARE</td>
<td>Form.Z, AutoCAD, MS PowerPoint, Adobe Photoshop</td>
<td>AutoCAD, Maya, MS PowerPoint, Adobe Photoshop</td>
</tr>
</tbody>
</table>

### 3.4.1 Immersive Environment Lab (IEL)

The IEL display system consists of three, six-by-eight foot, rear projection, and passive stereo display screens. These screens are joined at an angle of 135 degrees and provide a panoramic view and could also be used in an immersive three-screen virtual reality (VR) mode (Balakrishnan, 2004). The following figure 3-7, is the schematic diagram of IEL.
Figure 3-7: IEL schematic (source: Heilman, 2006).
3.4.2 Broadband and Network Technology

The IEL and CIMS labs were linked by broad bandwidth connection, 1 GB/s National Lambda Rail Packet Net (layer 3) and CA*net4 (Canadian Broadband layer 2 with 10 GB/s light path connectivity) in order to meet the large data transfer requirements of these emerging technologies.

3.4.2.1 National Lambda Rail (NLR)

The NLR is a major US research initiative towards a powerful networking infrastructure. The maximum capacity of this fiber optical electronic system is up to 10 GB/s. The NLR enables the simultaneous deployment of multiple networks for experimental and production purposes to provide powerful, flexible, and scalable networks that are critical to successful collaborative efforts across the country (http://www.nlr.net/). The NLR Layer 3 services were provided by Penn State on May 23, 2006 when Penn State's initial connection to NLR's Packet Net service was activated. This NLR service uses Penn State's fiber connection and is relayed to NLR's national network which also includes a growing number of universities (http://its.psu.edu/nlr/index.html).

3.4.2.2 CA*Net4

CA*net4 is an Internet network for research and education in Ottawa, Ontario. It serves as a testing ground for new optical-networking applications, technologies, and concepts. The major premise behind CA*net4 is object-oriented networking to support customer control of purchased wavelengths on the optical network. The network's optical architecture, developed by CANARIE design team, will eventually allow users to control and manage the routing, switching, and grooming of their own light paths across the network using an agent-based management system. A light path, as defined by the
CANARIE design team, could mean traditional single-frequency wavelengths, STS channels, or subchannel implementations (Richards, 2002). The light path is fixed in bandwidth and cannot be merged or modified between two points on the network. The CA*net4 can provide up to 10 GB/s wavelengths for the network.

### 3.4.3 Middleware Applications/ Software

#### 3.4.3.1 Access Grid

The middleware used for the first project was Access Grid (AG). The Access Grid is an ensemble of resources including multimedia large-format displays, presentation and interactive environments, and interfaces to Grid middleware and to visualization environments. These resources are used to support group-to-group interactions across the grid (http://www.accessgrid.org/). Access Grid technology, a product of Argonne National Laboratory, is a cutting edge video conferencing tool. AG is a collection of “resources that can be used to support human interaction.” These AG tools allow geographically distributed locations the ability to visualize distributed data, video conference, hold formal and informal meetings, and participate in courses being offered at other Access Grid sites. The approach of providing for group-to-group communication versus the current desktop-to-desktop communication currently used in collaborative projects was beneficial for the PDS.

#### 3.4.3.2 Eucalyptus - PDS Dashboard

For the second project, Eucalyptus – the first “in the wild” deployment of a Service Oriented Architecture was undertaken. The user controlled light path enabled participatory design studio (UCLP-
PDS or “Eucalyptus”) had been designed to allow users to assemble a dynamic set of light paths into a private end-to-end optical network – articulated private network (APN) that helped to establish secure, high-bandwidth, and low latency point-to-point connections across multiple sites. The UCLP web service was designed to include a variety of software and hardware tools that could be typically considered location dependent.

The emergence of service oriented architectures (SOA) and user-controlled light-paths (UCLP) herald the beginning of a new age where fully participatory multi-site design may become possible. While most service-oriented solutions are developed for gluing systems or data together, the PDS Eucalyptus has been developed to manage and configure the resources needed by users engaging in a participatory design session, such as a videoconference application, and a visualization server.

Harnessing the power of UCLP, Eucalyptus strives to provide a set of upper layer services for non-technical users to provision devices and applications running on high-speed broadband networks, in addition to conventional TCP/IP networks (Jemtrud et al, 2006).

3.4.3.3 PDS Dashboard and widgets

A service oriented architecture and graphical user interface (GUI) called the “PDS dashboard” was designed by Jemtrud et al (2000) to provide users with more control and participation by allowing for system flexibility and ease of use. This PDS dashboard was implemented as a web application. The functions provided by it are based on task-oriented and service/utility services.
In order to be transparent, the PDS SOA was designed in a way to hide the logical complexities of the tools used through the dashboard (figure 3-9 and 3-10) allowing users to simply select combinations...
of applications most suited to their task making the GUI flexible and customizable for group specific
projects.

3.4.4 Visualization Infrastructure

To Participatory Design Studio was supported by an ensemble of infrastructure to enable high
definition video conferencing (Figure 3-11). These high definition video communication systems
comprised of Sony video cameras, Clear One conference system and speakers along with Black Magic Multi Bridge and Pleora ether cast technologies. Apart from this, IBM’s Deep Computing Visualization (DCV) and Remote Visual Networking (RVN) were also utilized.

3.4.4.1 High Definition video communication systems

The IEL was equipped with a Sony EVI-D100 remote camera for recording the students and Clear One RAV 900 conferencing system with loudspeakers and 3 ambient microphones. Whereas the CIMS Lab had a high-definition Sony HDR-FX1 HD DV camcorder and UB1204FX HD DV camcorder along with UB1204FX Audio Mixer. The schematic diagram below depicts the connection of the network technologies and the hardware and middleware used in the second staging of the PDS project.

Figure 3-11: Configuration at CIMS (source: Muramoto, 2006).
3.4.4.2 Black Magic Multi Bridge

The Black Magic Multi Bridge comprises of a compact external chassis that was used to convert video and audio by connecting to the IEL hardware via PCI Express cable and plug in board. It allowed space for connection to the projectors for the three screens of the IEL and also to the Clear One RAV 900 conferencing system that was connected to three ambient microphones in the lab.

3.4.4.3 Pleora Technologies ‘Ether Cast’

Pleora Technologies is a leading global supplier of Gigabit Ethernet connectivity solutions. Pleora Technologies’ Ether Cast and iPORT products send video and/or imaging data in real-time over low-cost GigE connections with very high performance, while at the same time giving systems long-distance reach, scalable processing, flexible networking, and unmatched ease of use. Pleora is headquartered in various cities in Canada and will contribute video transport devices and expertise on its use to PDS.

3.4.4.4 IBM Deep Computing Visualization (DCV) Remote Visualization Network (RVN)

The PDS was designed to present IBM with new opportunities of customizing IBM solutions for the AEC field. The IBM DCV solution was used and refined in the context of the PDS such that new possibilities for the use of DCV could be tested and refined. IBM ported the Alias software, Maya and has contributed their Web Sphere Integration Developer (v6.0) and Web Sphere Process Server (v6.0) software to the PDS. They plan to port other commonly used software such as Form .Z in their platform as well. As an experiment, one of the IEL sessions was utilized to walkthrough a model of a student team’s School of Architecture project that had been generated in Maya.
IBM DCV provides a scalable, collaborative, middleware infrastructure to help support and enhance the graphics functions of OpenGL software applications. The IBM DCV version 1.4 offered improved capabilities and resource handling for both remote visual networking (RVN) and scalable visual networking (SVN). However, for the purpose of the PDS, only RVN was utilized. The DCV implementation proved to be economical and highly adaptable solution designed with a commitment to interoperability based on open standards.

IBM Deep Computing team contributed hardware, software and expertise in cluster technologies for high-performance visualization and network-based, real-time visualization. They helped deal with increasingly large distributed data sets by providing a flexible infrastructure to scale up and out without being price prohibitive. This aided in real time decision support with the student teams in the distributed locations of the studio between Carleton and Penn State (figure 3-12). The DCV allowed the increase of screen resolution and size while maintaining performance allowing better decisions based upon increased display content (http://www-03.ibm.com/systems/deepcomputing/visualization/index.html).

Figure 3-12: PDS dashboard architecture (source: Jemtrud, 2006).
3.4.5 Data Exchange

![Screen shot of ftp site.](image)

Figure 3-13: Screen shot of ftp site.

File transfer protocol (ftp) running on conventional TCP/IP settings was also used extensively to store and retrieve data and files during the course of studio (figure 3-13). The ftp site was accessible at all times by the students who uploaded and shared their work and presentations. The ftp server was located in Carleton University, and was password protected ensuring restricted access only to the students and researchers related to the project. The ftp site was called: ftp://arcs3106@cims.carleton.ca. Table 3-3 below shows the various tools used for data exchange through the duration of the studio.

Table 3-3: Multimedia applications used for data exchange.

<table>
<thead>
<tr>
<th>Type of software</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email</td>
<td>Text, data files</td>
</tr>
<tr>
<td>FTP site</td>
<td>Text, data files</td>
</tr>
<tr>
<td>Talk, Chat</td>
<td>Text</td>
</tr>
<tr>
<td>Video Conferencing</td>
<td>Video, Audio, Text, Images</td>
</tr>
</tbody>
</table>
3.4.5.1 Open Canvas

The second staging comprised a remote sketching program called Open Canvas that was used by one of the groups for synchronous design. It is an image editing and sketch program specifically designed for use with pressure-sensitive drawing tablets. This program was discovered and used by one of the student groups to discuss and develop their design ideas with their remote teams. Though no longer available in the current version 2, the last free version 1.1-b72 of Open Canvas did include network support, allowing collaboration in real-time over the internet, using different layers of the same drawing.

3.5 FINDINGS

3.5.1 Findings based on Journal

Research on the proof-of-concept design studio was focused on the impact of digital collaboration media on the design process. The communication between student groups (table 3-4) as well as the impact of each mediated communication session on the design process was captured primarily through journals. For group design projects, refer appendix A.

Table 3-4: Table of student teams based on journal.

<table>
<thead>
<tr>
<th>Alias name</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penn State</td>
<td>Orange Cord</td>
<td>C.H.M</td>
<td>OPT</td>
<td>JPMS</td>
<td>Team “Fly”</td>
<td>Xpollination</td>
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<tr>
<td></td>
<td>of Death</td>
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<td></td>
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<tr>
<td>Carleton</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Mode of</td>
<td>IEL Chat</td>
<td>IEL Email Chat</td>
<td>IEL Email Chat</td>
<td>Skype chat</td>
<td>IEL Chat</td>
<td>Open Canvas</td>
</tr>
<tr>
<td>communication</td>
<td>Chat</td>
<td>Chat</td>
<td>Chat</td>
<td>MSN Email Chat</td>
<td>Chat</td>
<td>Chat Email</td>
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<td></td>
<td>Email</td>
<td>Chat</td>
<td>Ptp</td>
<td>Chat</td>
<td>Email</td>
<td></td>
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</tbody>
</table>
The journal was referred to provide insights into decision-making through the digitally mediated design process. Based on the email exchanges and chat sessions recorded by students in their journals, many aspects of design collaboration outside of the IEL collaborative sessions were revealed. There were broadly two types of collaboration that took place: the first comprised of discussing and documenting design decisions and the other was managing the design process. This typically included scheduling the next meeting etc.

An important aspect that became evident through the chat records in journals was the different activities and changing nature of collaboration at different stages of the design process. This process could broadly be divided into three categories of design documentation, design decision-making and design production as shown in figure 3-14.

Figure 3-14: Design stages (based on Kalay’s diagram with findings of field study).

The first phase of the design documentation was important to familiarize the remote team with the context of the design project. There was need of data exchange and intense level of communication to clarify doubts and explain the nuances of the design site well. Despite this, some confusion always arose once design decisions were made. During the initial designing, there was a lot of crucial decision-making that took place. This was the point when most arguments, discussions and back and forth communication took place. Levels of anxiety and interaction were highest during this stage. The
students would mostly design in their local teams and then come together to discuss the development of ideas and work. There was asynchronous activity that was usually bridged by synchronous decision-making. To be able to progress with their designs, it was important to register change and development (Cherney and Weise, 1996) and have some level of agreement and consensus in the group activity (McGrath et al, 1996).

Table 3-5: Issues of digitally mediated collaboration based on journal.

<table>
<thead>
<tr>
<th>Lack of Sketching</th>
<th>Decision-making</th>
<th>Gestures and Idea exchange</th>
</tr>
</thead>
</table>
| Yes we should have sketches to explain to each other  
i wish I could just use the pen sketch tool on here, it would be so much easier | I think that we should each talk about the positive aspects of the opposite team's proposal, and then we find the right overlaps. We set ourselves down and really only work with the good things that we share in common | Can we arrange with you guys for a videoconference tomorrow? So that we can sketch things out together |
| skype would work right now if we were using a two way digital whiteboard | Well, it might be more useful to just compare differences and their intentional basis rather than criticisms on specific schemes | I think the problem here is just a lack of communication this past week |

However, during the last phase of design nearing final presentations, there was a shift in the nature of collaboration. It was apparent that there were discussions pertaining to dividing the work mid-project onwards. The students spent more time on scheduling and planning rather than on design. This was also the phase when the issues shifted from social to technical where data exchange and update became more important. At this point, frustrations arose due to knowledge of different software, lack of communication, inability to transfer files of large size and an occasional restricted access to ftp sites. Throughout the exchanges, an interesting aspect of digital collaboration was the need of initial socializing, also described by Condon (1993) for effective computer-mediated communication to compensate for the lack of special gestures and body language, prevalent in face-to-face discussions. It is also important to note that due to the visit of Carleton students after the first project, familiarity between the students had increased. This facilitated communication. However, there were still
frustrations and issues that arose and are illustrated by using quotes from the journal of students (Table 3-5).

### 3.5.2 Findings based on survey and questionnaire

This study to measure presence was conducted by Balakrishnan (Muramoto et al. 2007). The questionnaire also included measures of computer use for academic and leisure purposes, expertise with various software used for architectural design representation and presentation. Responses were collected from 26 students who participated in the collaborative studio of which 48% were females and their age ranged from 20 to 23 years (S.D = 1.01). The self-reported mean computer use for all course related purposes was 37.43 hours per week (S.D. = 16.95) and leisure related activities were 11.28 hours per week (S.D. = 5.3). Form.Z (mean use of 12.98 hrs per week) and Photoshop (mean use of 15.5 hrs per week) were the most commonly used software. At the time of the survey, the students had a little over 16 months (Mean = 16.36 S.D. = 9.84) of experience with 3-d modeling software and close to 3 years of experience with 2-dimensional graphics packages (Mean = 34.8, S.D. = 11.56).

### 3.5.3 Findings based on Focus Group study

Based on The focus-group study conducted at the end of semester, and other methods of data collection the following observations were made:

The PDS provided an ideal ‘collaborative work space.’ This was due to the fact that it was first and foremost interactive occurred in real-time, and in three-dimensions. It potentially allowed for an expansive repurposing of assets in the organizing, sharing, transferring, and displaying of content in a more fluid, comprehensive, efficient, and effective manner (Table 3-6).
The potential of the collaborative design is an argumentative process in which designers create an environment for a design dialogue (Simon, 1981) where the project is advanced in a team environment. Schematic implementation of the proof of concept supported a free-flowing, multi-user, participation scenario based around the presentation and manipulation of rich visual design media, and as a result project emerged through a series of interactions between the members of the design team negotiating for a shared understanding via the aforementioned digitally mediated environment.

According to Maher (2001) some of the common problems of a VDS are difficulty in understanding tools, limited accessibility, and difficulty in finding or delivering information, technical problems while using tool and scarce support on tool features. The PDS between Carleton and Penn State avoided these problems by providing a transparent platform for collaboration in the IEL. Since both Access Grid and PDS sessions were fairly easy to operate, students could focus more on the task at hand. Also with the setup of ftp sites for storage and retrieval of data, barring a few exceptions, students could exchange data and had access to their projects all the time.

<table>
<thead>
<tr>
<th>Positive Aspects</th>
<th>Negative Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive and flexible tool sets</td>
<td>Formal and rigid</td>
</tr>
<tr>
<td>Real-time 3D collaboration</td>
<td>Audio delay and quality of video during Access Grid</td>
</tr>
<tr>
<td>Rich visual design media</td>
<td>“Eye-shifting effect”</td>
</tr>
<tr>
<td>Multi-user</td>
<td>Ability to sketch simultaneously</td>
</tr>
</tbody>
</table>

The focus-group study at the end of semester also indicated that audio delay prevented team members from fully experiencing spontaneous idea exchange and generation. In addition, the digital media presentation tools such as PowerPoint leave much to be desired. It was helpful in explaining each other’s ideas, but did not allow participants to think and act together. As it is acknowledged in the previous studies on the differences between remote sketching and computer modeling software during
the design process (Maher, 2006), most of criticisms were that computer-based presentations tend to be formal and rigid, not allowing spontaneous exchange of ideas and interpretations necessary between participants, especially at the early stage of the design process.

Mitchell (1997) pointed out that previous videoconferencing tools often failed to facilitate distributed discussion and negotiation, and often lead to miscommunication between participants. As Kvan (2000) emphasizes, design collaboration requires a higher sense of working together in order to achieve a holistic creative result. Thus the quality of audio/video feed was crucial to the collaborative work sessions as they contribute greatly to the ways that people can relate to each other and build a foundation of shared understanding. Although we could not utilize high-definition (HD) video for this experiment, standard-definition (SD) video signal was more than sufficient for team members to observe each other’s expressions. Compared with AG that was limited to conversation only, students quickly took advantage of the quality of video feed by using physical models to explain their ideas and intentions and even quickly sketched their ideas on paper and showed it to partners during the conference. The increased high-quality interactivity at videoconference made it possible to discuss alternative approaches to their design and to explore their design issues more thoroughly. Their design adjustments became much easier and quicker as they became accustomed to the environment.

As with every new technology, a number of difficulties had to be overcome. Although many different settings were tried, the placement of camera interfered with establishing seamless communication between distributed teams. Since a camera is not placed inside the display screen (similar to iMac), an “eye-shifting” effect was experienced. This was particularly problematic with the IEL due to its screen size, although its large screen size changed the videoconferencing experience for the better.
3.5.4 Implications

Based on the findings from the content analysis of student journals, focus group study and surveys on presence, certain issues of digitally mediated collaboration can be identified. One of the key issues highlighted during the studio was that each stage of the design process necessitates various communication scenarios and hence, various requirements and different kinds of collaboration. The goal of the field study was to identify the essential tools to foster design collaboration and compare that in real-world setting. Taking the Participatory Design Studio as a significant point of reference, it is possible to apply the knowledge gained as a model for another context. Having learnt about the important issues that have emerged from this study, the next step would be to see how these could be relevant in architectural firms. Studying the phenomenon in both contexts will help create a better understanding for future direction and scope of research in this field.

Therefore, it will be vital to understand the role of digitally mediated collaboration from both perspectives, identify commonalities and discover gaps, thereby creating a holistic understanding of the trend. While this chapter focuses on the role for digital tools in design collaboration in the educational setting, the next chapter will explore the realm of professional practice.
DIGITALLY MEDIATED COLLABORATION IN ARCHITECTURAL PRACTICE

Based on the field study carried out in an academic setting, digital tools that mediate the design process and the nature of mediation were identified. It was also important to study however, the role digital mediation plays in the collaborative design process in the field of architectural practice. Hence, to bridge a gap of knowledge between academia and practice, it was essential to observe this phenomenon through architectural firms. Initially for sampling, based on the ENR 2006 survey of top 500 design firms, the top 150 architectural firms were chosen to send surveys. This survey would have comprised of a questionnaire that accessed the digital tools used by the firms to collaborate during design, the frequency of use and the collaborators in the building process.

However, to understand this emerging phenomenon, the method of survey may not have been effective as it was important to study these issues in depth and detail. Cases for study (firms) are selected because they are “information rich” and illuminate, that is, they offer useful manifestations of the phenomenon of interest, and sampling then is aimed at insight about the phenomenon, not empirical generalization from a sample to population (Patton, 2002). Therefore, it was decided to do purposeful sampling, studying relatively small number of special cases that have been successful in incorporating digitally mediated collaboration in their work.
4.1 CASE STUDIES

4.1.1 Criteria for Selection of Case Studies

To offer new paradigms for the future of collaborative workspaces, it is imperative to study the need for collaboration in firms and the medium through which they collaborate. Architecture firms (Table 4-1) were chosen such that they were pioneers or exemplary conditions in the use of digital tools for collaboration during the design process. An attempt was made to choose among firms that have incorporated digital tools with other design firms and specialists for collaborative design work.

Case studies contribute uniquely to our knowledge of individual, organizational, social and political phenomena. Case studies help understand complex social phenomena and in investigating a contemporary phenomenon within its real-life context (Yin, 2002).

Table 4-1: Firms selected as case studies.

<table>
<thead>
<tr>
<th>Garofalo Architects</th>
<th>Greg Lynn FORM</th>
<th>Kieran Timberlake Associates</th>
<th>SHoP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago, IL</td>
<td>Venice, CA</td>
<td>Philadelphia, PA</td>
<td>New York, NY</td>
</tr>
</tbody>
</table>

Exemplary conditions or case studies and interviews of architectural firms involved in the collaborative design process help to identify the extent of collaboration, medium of communication and
the number of specialists involved during the initial design phase. Based on the above mentioned criteria, a few firms were selected for their digital expertise as follows.

4.1.2 Process of selecting Firms as Case Study

Six firms were identified as case studies to understand the context of collaboration. Amongst these were:

- Asymptote in New York, a firm that leads development in architectural and interactive digital design and has designed virtual buildings that exist solely on the Internet.
- The second firm considered was Kieran Timberlake Associates in Philadelphia, PA which is noted for its research, innovative design and planning services.
- Thirdly, SHoP in New York was considered, as it is a firm that explores new fabrication technologies and is riding on the crest of architecture’s digital wave (Hawthorne, 2001).
- FORM in Los Angeles, CA was considered, as its founder Greg Lynn has been a forerunner in exploring possibilities in digital fabrication. His firm is experienced in working in collaborative partnerships on a number of projects including the Korean Presbyterian Church in Queens which he designed with Douglas Garofalo and Michael McInturf who were all located in different cities. The designers collaborating with him were hence considered as case studies as well. These were Michael McInturf Architects, OH and Garofalo Architects in Chicago.
- Michael McInturf Architects is a research based firm that has collaborated with a number of other architects and designers and
• Garofalo architects has actively pursued architectural design that includes collaboration and employs electronic media.

Each firm was contacted in December 2007 via email to ask if they would like to participate in the study. By January, firms had replied back with their intent to give an interview in their office. Kieran Timberlake was interviewed on February 7, Shop was interviewed on February 14 and Greg Lynn FORM was interviewed on February 27. Garofalo architects replied to interview questions via email during April. Asymptote and Michael McInturf architects were unable to participate in the interview, as they did not respond to give consent for the interview.

4.1.3 Interview Questions

The interview questions drafted for the firms were mostly open-ended, not fully structured and therefore more exploratory in nature to allow the firms interviewed to give their insights and perspectives on the topic. The purpose of the semi-structured interview was to determine how firms are deploying tools and technology in their firms. Four categories of questions relating were explored to frame the questions based on Who, When, How, and Why aspects of digitally mediated design collaboration as listed in table 4-2.

The first category of questions dealt with the question of WHO and was focused on people involved in the design collaboration process. These questions were further subdivided into two categories: the first one explored how many people were involved in the project within the firm or what did the design team comprise of. The second question asked who the various specialists were involved in a typical project. These could include designers outside the firm, engineers and fabricators etc. that would be integrated in the design process but not necessarily belong to the firm.
Table 4-2: Interview question guidelines.

<table>
<thead>
<tr>
<th>WHO (PEOPLE)</th>
<th>WHEN</th>
<th>HOW</th>
<th>WHY</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many people are typically involved in a project in the firm?</td>
<td>What is the degree of collaboration during the following phases of the design process: - Program requirement; - Conceptual; - Design Development, Construction document</td>
<td>What digital tools and technology is used in your firm?</td>
<td>How important do you think collaboration is in the field of architecture?</td>
</tr>
<tr>
<td>Who are the different specialists (designers, engineers, fabricators etc) that you collaborate with during a design project?</td>
<td>According to you, what stage of the design phase necessitates collaboration and why?</td>
<td>Do you feel the present trend of ubiquitous computing and communication technology will affect the design process?</td>
<td>What according to you is the most important aspect of design collaboration and why?</td>
</tr>
<tr>
<td>Do you think there is a need for synchronous distributed collaboration in design? How can this be achieved with the present tools?</td>
<td>When is it most critical to collaborate/communicate during the various design phases?</td>
<td>What digital tools and technology would you prefer to use design collaboration?</td>
<td>How important is collaboration in the current context</td>
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</tbody>
</table>
The second category of questions dealt with the question of *WHEN* and was focused on the important stages of the design process that require design collaboration. The first question in this category explored the degree of collaboration during the various phases of the design process (program development, conceptual phase, design development and construction documentation). The idea was to delve deeper into this question and seek what stage, according to the firms interviewed, necessitates design collaboration and the reasons for that. This would help understand the nature of collaboration required in each stage. Another important aspect in this category was to ask the firms when they thought was it most critical to collaborate or communicate during the various design phases.

The third category of questions dealt with the question of *HOW* and was focused on the tools and technology used in the firms. The questions in this category probed on the present tools in the firm and how they were used for various functions in the design process. These questions were also asked in conjunction while filling up a ‘Technical Specifications’ for each firm as shown in table 4-3. The firms were also asked to reflect on the effect of the present trend of ubiquitous computing and communication technology on the design process. Finally, they were asked to imagine what tools and technology they would prefer to use to design collaboratively or what would the *ideal design collaboration* situation comprise of in respect to the tools and technology used.

The fourth category of questions dealt with the question of *WHY* design collaboration is important. The first question put forward to the firms was how important they thought design collaboration was in the field of architecture. Then the question was led to what they thought was the most important aspect of design collaboration (concept idea development, information exchange, conveying changes) and why did they believe that. They were also encouraged to suggest other aspects they may think of as important in design collaboration. Finally, they were asked to reflect on the importance of collaboration in the current context of practice and what the future may hold.
An overview or rough guideline of these questions was reviewed by the interviewees in each firm briefly before the start of the interview. The interviews were recorded after permission and consent from the firms interviewed. These recordings were later transcribed for analysis. The questions were not necessarily asked in the order they appear above; rather they were often reworded and asked according to the replies received from each interviewee. As a result, each interview transcript differed in length and sequencing of content.

### 4.1.4 Technical Specifications

<table>
<thead>
<tr>
<th>Table 4-3: Technical specifications of each firm.</th>
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<tbody>
<tr>
<td><strong>Digital Tools Software</strong></td>
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<td><strong>Digital Tools Software</strong></td>
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<tr>
<td><strong>Work Stations</strong></td>
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<td><strong>Hardware</strong></td>
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<tr>
<td><strong>Collaboration Tools</strong></td>
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<td><strong>Collaboration medium</strong></td>
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<tr>
<td><strong>Typical Files (file format + programs) exchanged</strong></td>
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* Construction collaboration software  
** Collaboration freeware software
A handout was presented to the interviewees that included questions relating to the contact information of the firm and the firm profile to ascertain the number of principals, senior associates, designers, technical staff and others involved in the firm. A brief discussion was initiated to understand the structure and working of the firm and how digital tools were used in the design projects. This handout was an overview of questions with many options, which they could fill out as applicable at a glance.

Apart from the open-ended questions, some questions were asked regarding the digital tools and technology used in the firm. This was helpful in understanding how the firms collaborated with others. These questions included design software used and the file formats exchanged. Each firm was asked about the number and type of workstations and the network technology used to connect, both within the office and outside. If possible, firms were asked to show the hardware facilities, servers, printers and other hardware such as laser cutters and CNC machines available in their office. The technical staff and people involved with the upkeep of the tools, if available, were also inquired about the digital tools used and issues related to them. After completing all the interviews, the data on the technical specifications of each firm was compiled and compared with each other. Table 4-3 shows a list of the various digital tools available in each firm.

On comparison of the technical specifications of each firm, it was found that all the firms used AutoCAD and other generic software such as the Adobe Suite and MS Office. Other common software was Rhino, especially in the conceptual design phase of the project that was used by all firms. However among all the firms, SHoP seemed to experiment the most with all kinds of software ranging from Revit, SketchUp, Generative Components and other construction related software. They claimed that they tried to incorporate these tools as early in the design phase as possible. Kieran Timberlake Associates (KTA) also had in their software collection analysis tools such as Ecotect and was trying to
incorporate Gehry’s Digital Project in their projects. Greg Lynn and Garofalo’s firm (GA) both had software that tended to have animation capabilities such as 3Ds max and Maya.

Among the number of workstations in each firm, it was apparent that FORM and Garofalo Architects were much smaller and had only up to 15 workstations. KTA and SHoP had a large number of workstations ranging from 50-80, and SHoP had just acquired their workstations a couple of years back to keep up with the growing size of the firm. Only a few workstations in KTA had Macintosh based operating systems (OS), the rest of the computers, including in all the other firms were only windows based. All firms had large size plotters and printers to cater to all the need of projects designed in their office. Due to larger sizes, KTA and SHoP also had dedicated server rooms. However, SHOP and FORM both had state-of-the-art laser cutters, 3D printers and CNC machines.

For the purpose of collaboration, all firms extensively relied on emails and ftp sites. While FORM also relied heavily on IM, KTA have been experimenting with collaborative groupware such as Go-to-meeting and AutoDesk sharing tools. Even SHoP used software such as Buzzsaw and Navisworks that helps them to collaborate. Most of the file formats used for data exchange was common across all firms. From the most common file formats such as MS Office files, Adobe pdfs to dwgs, some firms also exchanged flash files.

The purpose of the interviews was to gain a deeper understanding on how the firms perceive digitally mediated collaboration. Each firm was first considered as a case study to understand their background and design philosophy. A project that emphasized collaborative digital design was also studied for each firm. Finally some issues related to collaboration were raised and discussed with each firm.
4.2 CASE STUDY 1

4.2.1 Kieran Timberlake Associates

The *design research* firm located in Philadelphia was established in 1984, and their projects include programming, planning and design of all types of new structures, their interiors, and renovation, reuse and conservation of existing structures. The firm is the recipient of the 2008 AIA Architecture Firm Award, and also the AIA 2008 Institute Honor reward, profession’s highest recognition of works that exemplifies excellence in architecture for the Loblolly House project. The partners of the firm, *Stephen Kieran and James Timberlake* are both involved in professional work and have academic affiliations. They have also written a book called *Refabricating Architecture* (2004), which examines how manufacturing methodologies are transforming the building industry. This book relates to the study by exploring how new technologies have the potential of transforming architectural practice. The firm comprises of two senior associates, four associates and various other project architects and interns. They also have a research team that includes at least four professionals. Kieran Timberlake Associates currently has 40-50 professionals working in their firm.
The Loblolly House (figure 4-1) designed for one of the partners of KTA, is built in a new method of assembly that incorporates the idea of elemental architecture. It is composed entirely of off-site fabricated elements and ready-made components that were assembled in less than six weeks from platform up by using only a wrench. The conception and detailing was based on four new elements of architecture, which were the scaffold, cartridge, block and equipment. The scaffold was an aluminum system with connectors for offsite fabricated floor and ceiling panels called “smart cartridges” along with fully integrated bathroom units and mechanical modules (Kieran and Timberlake, 2008).

Figure 4-1: Wall panels of Loblolly House.
4.2.2 Interview

The interview was conducted on February 11, 2008 at 2pm with 5 professionals of the firm-Jason E Smith, Associate of the firm, and four other project architects that included Marilia Rodriguez, George Ristow, Casey Boss, and Mark Davis. The interview took place in an informal client presentation cum conference room that was integrated to the entire studio office and partitioned by two walls that were presentation boards. The interview lasted for approximately 1 hour, 45 minutes (figure 4-2).

Since the interview involved many participants, it almost became a focus group interview, with intense discussions emerging between the interviewees, based on comments made to each other. This helped in revealing many underlying issues that related to architectural practice in the broader sense. These included the current state of the profession and complications introduced due to digital technology. For example, Mr. Smith who mostly led the discussion claimed that, “designing in a digital process has made everyone’s expectations higher as they expect things to be turned around quickly. The complexity is also related to contract relationships. Also having a Revit model that shows conflicts do not ensure that the consultant from the other side is aware of and has reviewed it.” This and other discussions that followed revealed that though digitally mediated collaboration was effective, the real issue was still face-to-face interaction and building trust between the people involved in the project. Figure 4-3 shows the teleconferencing room used for distributed design collaboration meetings held with consultants throughout the design process.
Based on the questions asked, the following table 4-4 shows the relevant issues that came up during the interview.
### Table 4-4: Interview replies by KTA.

<table>
<thead>
<tr>
<th>Who</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of people</strong></td>
<td><strong>7 to 8 people, before deadline-10</strong></td>
</tr>
</tbody>
</table>
| **Type of people** | **Typical roster- SE, MEP, LA, CE.**  
**Depending on projects-**  
**Specialty consultants- Lighting design, AV, acoustical, food** |

<table>
<thead>
<tr>
<th>When</th>
<th></th>
</tr>
</thead>
</table>
| **Degree of collaboration in each stage** | **Conceptual Design - Largely face-to-face.**  
**Schematic phase- consultants come on board at end**  
**Design Development- integrate actual systems of consultants; exchange dwg formats; Loblolly House,**  
**sculptural marquee- an exception communication with Fabricators** |
| **Which stage is most important** | **Need of Project**  
**e.g. Loblolly House**  
**Revit drawings- exported as 3D model to F- 2D assembly dwg formats.** |
| **When in stage is most important** | **Complex design- e.g. Loblolly house- pre-fabrication, curved fiber glass**  
"Iterations and changes are much more expedient"  
**Revit- Condense CD stage; "make time more efficient in documenting"**  
**CD- "change something in model, gets updated in schedule- improves accuracy"** |

<table>
<thead>
<tr>
<th>How</th>
<th></th>
</tr>
</thead>
</table>
| **What tools** | **Drawings in AutoCAD exchanged**  
**Revit is being used as preferred platform**  
**Rhino model- curved fiber glass reinforcement**  
**FTP logins on server for consultants**  
**email exchange of files-size is issue**  
**AutoDesk sharing program- Teleconferencing**  
**Go-to-Meeting Share Desktop screen- annual contract**  
**Digital Project CATIA- was adopted but didn’t help efficiency** |
| **Effect on design process** | **Made expectations higher of client and consultants.**  
**No effect on initial design decision but reduces time spent on making changes** |
| **Tools preferred** | **Revit- Criteria for selection of consultants is changing in accordance with tools used- comfortable working with 3D environments**  
**FTP (consultants have access problems) over AutoDesk as it is clunky**  
**Sharing screens- handing over mouse.**  
**Faster accurate VC system- Intelligent system- zoom into artifact being discussed can be marked with a digital pencil and is recorded as minutes of meeting.** |
| **Need for synchronous Distributed collaboration** | **Geographic distance can create difficulties in collaboration**  
**Looking at same board, drawing at the same time** |

<table>
<thead>
<tr>
<th>Why</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Important aspects of collaboration</strong></td>
<td><strong>Face-to-face to build trust. Never going to replace that</strong></td>
</tr>
</tbody>
</table>
| **Collaboration in current context** | **Tools exist but are clunky- need faster, accurate VC tools**  
**Construction world is still lagging behind - though expect architects to turn things in faster**  
**Complexity of contractual relationships (barrier)- trying to establish straighter line between architect and designer** |
| **Need for synchronous Distributed collaboration** | **Geographic distance can create difficulties in collaboration**  
**Looking at same board, drawing at the same time** |
Though Kieran Timberlake Associates have pioneered in the design of pre-fabricated architecture with the Loblolly House and the recent SmartWrap design, they still work mostly on university projects. The firm deals with a lot of university renovation, redesign and expansion projects that requires them to deal with contractual issues. They feel that apart from digital technology, people skills are very important to successfully collaborate.

4.3 CASE STUDY 2

4.3.1 SHoP

The firm was established in 1996 by five partners- Christopher and William Sharples, Coren Sharples, Kimberly Holden and Greg Pasquarelli. The firm is considered avant garde in their design ideology and participates with fabricators. They believe in "Using technology to build practice, seeing practice as technology". They have been famous for the PS1 Dunescape model, the winning entry for the 2000 young architects displayed in the Museum of Modern Art. They have also won numerous awards, such as the Housing Design Award in 2005 for the Porter House in New York. The firm now has up to 80 professionals including 5 partners, director of design and project architects working.

SHoP use evolving computer-aided design technologies to produce innovative architectural forms but to also streamline the design and construction process and create new efficiencies and cost savings. The firm does not employ technology to extend any ideological agenda or formal boundaries but is rather used to create a lean, flexible and pragmatic practice that is committed to build work and is productive rather than technophilic. Despite the firm’s command of technology, they maintain an explicit connection to tactile reality and the changing demands of the process (Hawthorne, 2001). Communication is essential in the construction phase of a project and getting input from contractors
and subcontractors is a vital necessity. By creating a feedback loop in their design process, SHoP incorporates strategies for economic and logistical realities.

The Porter House (figure 4-4), a 10-story residential renovation and addition in Manhattan’s Meatpacking district allowed the firm SHoP an opportunity to explore a becoming simultaneously the client, developer-owner and marketers. SHoP engaged in a more holistic design than previously conceived (Castillo, 2006). As the project evolved, zinc was selected as a material for exterior cladding. While researching for the cost of the material, SHoP decided to customize the panels themselves and approach the source manufacturers in Europe. The customization system encoded the panels for fabrication, hence producing an efficient scheme for the cladding of the façade.

![Figure 4-4: Porter House residential complex facade.](image)

### 4.3.2 Interview

The interview was conducted on February 14 at 6 pm in SHoP’s New York office with two architects of the office- David Fano and Tim Martone. They were also responsible for installation and
maintenance of new software and technology within the firm. The interview took place in one of the two conference rooms that was also used for purposes of video conferencing.

Being involved first hand in the technological aspects of the firm, the interviewees were a great resource of information related to digitally mediated collaboration (table 4-5). They also asked questions in return and were very interested in knowing more about the participatory design studio conducted at Penn State. A relatively young firm, SHoP has been growing at a fast rate and is actively involved in installing state-of-the-art technology and software in the firm. Throughout the interview, they rattled many names of software ranging from animation to construction and scheduling being used and experimented in the firm. Dave Fano said, “We try to be software agnostic. Whatever is the best tool; we use it and try as general philosophy to use them as early in the design process as possible.”

Figure 4-5: Studio and teleconference room.
Table 4-5: Interview replies by SHoP.

<table>
<thead>
<tr>
<th>Who</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of people</td>
<td>From 1 to 10 depending on project</td>
</tr>
<tr>
<td>Type of people</td>
<td>Countless consultants- it gets really small as far as levels of specialty are concerned</td>
</tr>
<tr>
<td>When</td>
<td></td>
</tr>
<tr>
<td>Degree of collaboration in each stage</td>
<td>Initially- VC helped as &quot;we were beginning to know everybody&quot;</td>
</tr>
<tr>
<td></td>
<td>Schematic Design- VC could be used, before that it is too early. Waste of engineer's time</td>
</tr>
<tr>
<td></td>
<td>as design is changing constantly.</td>
</tr>
<tr>
<td>Which stage is most important</td>
<td>&quot;Completely depends on the project&quot;</td>
</tr>
<tr>
<td>When in stage is most important</td>
<td>&quot;We try to do it as early as possible, unless its govt. project- helps cut costs down&quot;</td>
</tr>
<tr>
<td></td>
<td>&quot;try to get all stake holders early. For eg, in a particular project, façade was</td>
</tr>
<tr>
<td></td>
<td>going to be pre-cast- so went to pre-cast fabricator plant, learnt how to pre-cast,</td>
</tr>
<tr>
<td></td>
<td>learnt material constraints- significantly less expensive&quot;</td>
</tr>
<tr>
<td>How</td>
<td></td>
</tr>
<tr>
<td>Tools used for collaboration</td>
<td>3Ds max, Rhino and plug-ins, Generative Components, Maya</td>
</tr>
<tr>
<td></td>
<td>Digital Projects, Revit, Inventor, Autocad</td>
</tr>
<tr>
<td></td>
<td>Buzzsaw, constructware but mostly traditional ftp</td>
</tr>
<tr>
<td></td>
<td>Videoconferencing system- Polycom-HD -used it a lot at first but now has tipped off-Pre-</td>
</tr>
<tr>
<td></td>
<td>schematic.</td>
</tr>
<tr>
<td></td>
<td>Revit- structures, MEP, Studio tools, sketch book pro, NavisWorks</td>
</tr>
<tr>
<td></td>
<td>alot of manufacturing and animation software, MS project, primavera</td>
</tr>
<tr>
<td>Effect on design process</td>
<td>Effects it for better</td>
</tr>
<tr>
<td></td>
<td>Communication effects design process</td>
</tr>
<tr>
<td></td>
<td>A lot of traveling to manage projects out of city</td>
</tr>
<tr>
<td>Tools preferred</td>
<td>Setting up small I-room; &quot;A room allocated to VC that is always on&quot;</td>
</tr>
<tr>
<td></td>
<td>Share point site- (file share domain) for the whole office to enhance collaboration</td>
</tr>
<tr>
<td></td>
<td>internally</td>
</tr>
<tr>
<td></td>
<td>Rhino and Revit are preferred</td>
</tr>
<tr>
<td></td>
<td>Video conferencing system to save trips to San Francisco- Bigger screens, better broadband</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>More people with rapid prototyping machines- send STL file to print digital models</td>
</tr>
<tr>
<td></td>
<td>Interactive boards -document cameras and multiple cameras</td>
</tr>
<tr>
<td></td>
<td>Desktop VC- just as IM -personal collaborative environment</td>
</tr>
<tr>
<td></td>
<td>Tablet PCs for construction management process.</td>
</tr>
<tr>
<td>Why</td>
<td></td>
</tr>
<tr>
<td>Importance of collaboration</td>
<td>Crucial as it is inherent in the building process. A building is a product for collaboration and can help control cost more.</td>
</tr>
<tr>
<td>Important aspects of collaboration</td>
<td>Getting to know everybody in early stage of design process.</td>
</tr>
<tr>
<td></td>
<td>Integrated Project Delivery Guide- AIA movement towards collaboration.</td>
</tr>
<tr>
<td></td>
<td>Communication (effects design) and Knowledge Transfer (efficiency not value enhancing).</td>
</tr>
<tr>
<td>Collaboration in current context</td>
<td>Virtual version of building in BIM to contractors. Rhino models were pretty receptive by contractors.</td>
</tr>
<tr>
<td></td>
<td>Fabricators are savvier in tools- use CATIA and inventor.</td>
</tr>
<tr>
<td>Need for synchronous Distributed</td>
<td>&quot;Technology is a facilitator of these kind of things...&quot;</td>
</tr>
<tr>
<td>collaboration</td>
<td>project in Gurgaon, India, US - west coast, Denver, Las Vegas, San Francisco, China, Tokyo.</td>
</tr>
</tbody>
</table>
The firm also had a Polycom HD videoconference system that they had used extensively on a project during the pre-schematic phase to familiarize themselves with the people working on the project (figure 4-5). However, it had tipped off since then and they thought that they might be able to use it again later during the Design Development phase. Both Dave Fano and Tim Martone felt that the most important aspect of collaboration was communication and knowledge transfer.

They have a growing number of projects that are outside New York, some even across the world in Asia. Therefore, they were interested in knowing if they could setup an ideal digital environment for collaboration, as a tool that would always be connected to another office. They also referred to similar tools they were aware of such as the i-room used by firms like Arup. For them the biggest limitation of the present was the limited broadband connection available to them. They envisioned having desktop versions of a digital collaboration environment but felt that the current bandwidth would not be enough for their needs.

4.4 CASE STUDY 3

4.4.1 Greg Lynn Form

Greg Lynn FORM was established in 1990 in Hoboken, NJ but relocated to Venice, CA in 1998 to take advantage of the knowledge and technology resources in both the manufacturing and entertainment industries of Southern California. He is the author of Folds, Bodies and Blobs: Collected Essays (1998) and Animate Form (1999). Greg Lynn is the principal of his firm and employs up to 10 professionals.

Greg Lynn’s designs are known to bring computers in the design process radically and from the start using programs developed for auto designers and film animators. He is one of the forerunners
in exploring the possibilities of digital fabrication, and converting complex forms to reality in terms of constructability and economics. His office incorporates state of the art hardware and software as a set of tools to investigate architectural performance within the framework of theories based on performance parameters that are being theorized in architecture. One of his designs, the Korean Presbyterian Church (figure 4-6) located in Queens was the result of a collaborative effort by three teams working in three cities: Garofalo architects in Chicago, Michael McInturf architects in Cincinnati and Greg Lynn Form.
4.4.2 Interview

The interview with Greg Lynn was conducted on February 26 at 4:30 pm in his office in Venice, California. For the interview, he had also invited Peter Frankfurt, Vice President of a design and marketing firm called Imaginary Forces (IF). They had recently completed a collaborative project called Imaginary Cities as an exhibit for the Museum of Modern Art. Having moved his practice to California some years back, Greg Lynn was immersed in the tools and ways of working of the film and aerospace industry. The interview was conducted in his office, which was filled to the brim with digital prototypes and models of his work, including the blobwall. Greg Lynn also had a range of digital fabrication tools including CNC cutter, laser cutter and 3D printers around the office. Figure 4-7 shows Lynn’s studio cluttered with models and a physical prototype of the blob wall.

One of the things that Greg Lynn strongly felt was the way architect’s skills were being used in much more interesting ways in the automobile, film and aerospace industry with regards to collaboration and there was a lot to learn from there. Having worked on many collaborative projects from the early phases of design and involving both artists and fabricators, including at times whole industries such as steel, he still felt that apart from digital communication, it was ever so essential to
personally meet with collaborators. He pointed out another paradox of the so-called digital ‘paper-less’
studios, while referring to his office, which actually produced more paper and tactile objects such as
models and prototypes as a result of this digital technology. Table 4-6 lists the interview with Greg
Lynn .

Table 4-6: Interview replies by FORM.

<table>
<thead>
<tr>
<th>Collaborators</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of people</strong></td>
<td>World Trade Center design project had over 50 people involved for 3 weeks.</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Industries of collaboration include Steel, Glass, Mass produced goods, system of constructions</td>
</tr>
<tr>
<td><strong>When</strong></td>
<td></td>
</tr>
<tr>
<td><strong>The most important stage for collaboration</strong></td>
<td>At conceptual stage- for example in Restaurant design where the client wants the idea of a &quot;brown derby hat&quot; to come across, collaboration with media firm IF (Imaginary Forces) is done as early as possible to come up with ideas and solutions and brain storm.</td>
</tr>
<tr>
<td><strong>How</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Tools used for Collaboration</strong></td>
<td>Tools used are identical to those used in that are huge established industries- film, automobile, game, entertainment and aerospace industries. Email- even when we sit in the same room &quot;sitting here sending emails to Adam&quot; (architect in office) Face-to-face- every 7 to 10 days for KBC. Phone calls every day CNC mill, laser cutter, 3D printer Chatting and sending files back and forth- No Video conferencing Google earth was used to see a site, never visited, in Dubai</td>
</tr>
<tr>
<td><strong>Effect on design process</strong></td>
<td>Small design firms can use tools to design big projects &quot; paper less office in fact become a more paper-filled office- volume of tactile objects has increased through the roof&quot; much more work is done -&quot;emails through blackberry&quot;</td>
</tr>
<tr>
<td><strong>Tools preferred</strong></td>
<td>A lot of companies are developing &quot;collaborative digital platforms&quot; -Oracle, HP New City- virtual city involves any one who wishes to join</td>
</tr>
<tr>
<td><strong>Why</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Important aspects of collaboration</strong></td>
<td>Experience of place and behavior. &quot;Its not about technology, its about behavior&quot;</td>
</tr>
<tr>
<td><strong>Collaboration in current context</strong></td>
<td>Learn from other fields- automobile, film, aerospace Architects lack entrepreneurial thinking. Gehry has software company &quot;Disparity between boutique practices and service providing firms will increase&quot; &quot;the way we practice does not acknowledge that we are dealing with hi-tech industries&quot; &quot;Future has happened, we are just catching up to it- gap between our way of living and what technology allows us to do”</td>
</tr>
<tr>
<td><strong>Need for synchronous Distributed collaboration</strong></td>
<td>&quot;Its already happening- HP (Hewlett Packard) has mirror system of teleconferencing&quot;</td>
</tr>
</tbody>
</table>
Both Peter Frankfurt and Greg Lynn often digressed from the topic and discussed some interesting aspects and effects of digital collaboration. For instance they felt that blackberrys have changed the way we work and has enabled constant mobile working. They also felt that digital collaboration was not restricted to only geographically dispersed settings, as they often emailed documents to their colleagues in the same room without ever having to get up from their desks. Both sensed that digital technology had a lot of potential that still hasn’t been tapped and referred to an experiment between HP and Oracle that was developing a collaborative digital platform. Apart from that, brief discussion on the changing trends of architectural practice was also discussed.

4.5 CASE STUDY 4

4.5.1 Garofalo Architects

Garofalo Architects was established in 1989 and grew to be one of the country’s leaders in bringing digital pedagogy into the practice of architecture. The work of Garofalo architects is grounded in the philosophy that both the practice and products of architectural design should actively participate in new developments that are redefining the culture and environment. He believes in collective inquiry that includes data analysis, exploration of precedents and conceptual and physical models. They feel that the process eventually culminates in a valuable record of collaborative thinking. Garofalo’s largest built work to date is the expansion of an old University of Chicago Press building for the new home of the Hyde Park Art Center (Rosa, 2006). According to Garofalo (2003), their design process illuminates valid opportunities to often engage collaborators that cross professional disciplines and geographical boundaries.
### 4.5.2 Interview

The interview for Garofalo architects could not be scheduled due to time conflicts. However, Douglas Garofalo, Principal of the firm agreed to reply to the interview questions via email (table 4-7).

He replied to the questionnaire sent to him on May 3, 2008.

<table>
<thead>
<tr>
<th>Collaborators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of people</strong></td>
</tr>
<tr>
<td><strong>Type of people</strong></td>
</tr>
<tr>
<td><strong>Need for synchronous Distributed collaboration</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Degree of collaboration in each stage</strong></td>
</tr>
<tr>
<td><strong>Which stage is most imp</strong></td>
</tr>
<tr>
<td><strong>When in stage is most important</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What tools</strong></td>
</tr>
<tr>
<td><strong>Effect on design process</strong></td>
</tr>
<tr>
<td><strong>Tools preferred</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Why</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Importance of collaboration</strong></td>
</tr>
<tr>
<td><strong>Important aspects of collaboration</strong></td>
</tr>
<tr>
<td><strong>Collaboration in current context</strong></td>
</tr>
</tbody>
</table>
4.6 FINDINGS

Based on the case studies, a few observations can be made on the nature of digitally mediated collaboration in the design process in firms. The analysis of interviews of the firms revealed certain obvious benefits of digital collaboration such as efficiency in time and cost. Certain opportunities for innovation and cutting edge design were also recognized as a fruit of this digital collaboration.

However, many issues emerged relating to digitally mediated collaboration in design, most of them transcending the scope of digital intervention. Concerns relating to favorable collaboration included basic aspects of teamwork such as trust, sharing common objectives and other team dynamics. Though all firms interviewed were deeply immersed in digital mode of practice in some form, they all had varying degrees of trepidation in relying completely on collaboration through a digital medium.

4.6.1 Benefits of Digitally Mediated Collaboration

4.6.1.1 Time and efficiency

Most of the firms proclaimed that digital collaboration benefited them the most with respect to time and efficiency. In Kieran Timberlake (KTA) for instance, previously a typical 4 hour meeting would take away a whole day due to the travel time taken to and from offices of consultants, sites etc. So while they felt Videoconferencing and other digital tools used for remote design communication saved their day, it was still clunky and cumbersome to use.

Another benefit that became apparent was faster feedback and changes being made constantly by digital communication. Greg Lynn said that by using his blackberry for email, he is now working almost round the clock. This fact exemplifies that ubiquitous computing has also created new opportunities for remote design practice to occur.
4.6.2 Issues of Digitally Mediated Collaboration

4.6.2.1 Mode of Communication: Face-to-Face vs. Digital

Despite having chosen firms that were immersed in the digital realm for their practice, none of them put digitally mediated collaboration over face-to-face communication during the design process. According to Jason Smith in KTA, the most important aspect for any collaboration to occur is trust. This is something that he feels is hard to build up without some level of social interaction. Moreover, Lynn feels that while f-t-f is vital within a design team, it is even more critical with a client. Smith validated the importance of f-t-f communication over distributed communication by stating that “Relationships aren’t built via telephone”. Fano in SHoP surmised that there was definitely a loss of physical charisma in digital mediation such as videoconferencing as one is unable to feed off the expressions of people virtually. Body language and gestures are lost in even the most sophisticated digital communications.

4.6.2.2 Common Objectives

Another important aspect of successful collaboration, apart from trust is sharing common goals and objectives with collaborators. In the realm of practice, each consultant, architect, fabricator and construction personnel have a specific role to play in what is termed by Kvan (2000) as exclusive collaboration. In order to improve their digitally mediated design process, SHoP visited one of the fabricators for a particular project to understand their production process and gain knowledge about the way they work. This helped them later on to design, keeping in mind the fabricators mode of practice, thereby enhancing their digital collaboration. Table 4-8 lists the findings based on the interviews.
Table 4-8: Findings based on firm interviews.

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Technical Issues</th>
<th>Social Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency in time (faster turn around due to speed) and cost</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| "4 hour meeting… Saves day of workers… but clunky and cumbersome."     | "Revit model lets you see where the conflict is… doesn’t ensure consultant is looking at it from their end" | "Face-to-face is vital both within a design team but more so with the client*"
| **Cost is cut down due to collaboration in earlier stages**             | "As little friction as possible in the design process. Don’t want technology getting in the way" | "Videoconferencing- one person talks, the other person listens… similar to telephone conversation- everything is pointed to something*"
| **Use of blackberry for email-working round the clock**                 | "Smart cameras. Work in the natural environment and technology just goes along with you." | "Its tricky, its like one point where everyone is looking at the camera and you don’t have the feeling that everyone is looking at you. Its bizarre."
| **Technical Issues**                                                    |                                                                                  |                                                                                |
| **Loss of information due to distributed collaboration**                |                                                                                  |                                                                                |
| "Revit model lets you see where the conflict is… doesn’t ensure consultant is looking at it from their end" | "As little friction as possible in the design process. Don’t want technology getting in the way" | "Face-to-face is vital both within a design team but more so with the client*"
| **Heterogeneity of software and compatibility issues**                 | "As little friction as possible in the design process. Don’t want technology getting in the way" | "Made everyone’s expectations higher…”
| "AutoDesk sharing is pretty clunky…."; "Consultants have issues with accessing ftp sites" | "Faster changes but not necessarily accurate… iterations and changes are expedient*" | Loss of physical charisma - feeding off the expressions in the room.
| **Broad band/ Email and storage space**                                | "Better broadband desirable for Video conferencing*"                           |                                                                                |
| "Exchanged files via email… consultants have 2 MB restrictions…"       |                                                                                  |                                                                                |
| **Social Issues**                                                       |                                                                                  |                                                                                |
| **Face-to-Face**                                                        |                                                                                  |                                                                                |
| "Face-to-face is vital both within a design team but more so with the client*" | "Made everyone’s expectations higher…” | "Went to pre-cast fabricator to learn about material and design within that*"
| **Trust**                                                               |                                                                                  | Need to design mobile workstations to enable clustering of teams. |
| "Relationships aren’t built via telephone…”                            |                                                                                  |                                                                                |
| **Common/goal objective**                                              |                                                                                  |                                                                                |
| "Use same structural engineer, local to us*"                           | "Went to pre-cast fabricator to learn about material and design within that*"     |                                                                                |
| **Ideal collaboration space**                                           |                                                                                  |                                                                                |
| **Physical Setup**                                                      |                                                                                  |                                                                                |
| "Looking at the same board drawing at the same time*" Multiple cameras in the room. Bigger screens for videoconferencing so you feel like the person is there | "Room setup like Arup’s office- always setup" | "Logistics- 3 conference rooms with VC system in one. Compromise on room use effects the collaboration and technology used*"
| **Design Representation**                                              |                                                                                  |                                                                                |
| "Generate live documents… sketches or computer displaying images*"       | "Room setup like Arup’s office- always setup" | "Logistics- 3 conference rooms with VC system in one. Compromise on room use effects the collaboration and technology used*"
| **Something is always missing- you don’t have that tangible…[sketches/models]** | "Room allocated to videoconferencing that is always on*" |                                                                                |
| **Models and physical prototypes are super important…all the time**    |                                                                                  |                                                                                |
4.6.2.3 Proximity

To achieve this type of collaboration, all firms believed that it was critical to have some form of proximity to the collaborators. Despite the facilities of digital collaboration tools that allow faster and remote communication, KTA prefers to use structural engineers that are available locally. In fact Lynn claimed that the biggest reason for his firm to move in Los Angeles was the proximity to the film animation and aerospace industry. This enabled him to be constantly in touch with the digital tools and software used by the industries and stay close to the pop culture of the region.

Even within the firm, KTA follows a culture of mobile workstations that enables them to create clusters of teams, bring people of a project to work together. SHoP also felt that they would like to incorporate a more flexible workspace for more interaction. But digital collaboration still plays a vital role within the same office as in Lynn’s case where he just prefers to email project files back and forth to colleagues in the same room for discussion and work.

A similar issue requiring need for communication is the dilution or loss of information when transferred through a digital medium. To illustrate this, Smith in KTA described a scenario where a Revit model helps inform you where the conflict is. However, this fact does not ensure that the consultant on the other side is aware and is looking at the same thing from his side. Therefore it is important to have good communication that transcends beyond digital mediation.

4.6.2.4 Change in Mode of Practice

A very important aspect that surfaced from the interviews was the change in mode of practice in architecture due to increased digital collaboration. Smith in KTA expressed his concern on using digital tools during design by saying “it has made everyone’s expectations higher.” Though all firms conceded that digital communication and tools did enable faster iterations and changes, they did not
make the time for design conceptualization shorter. Due to the perception of a faster rate of work, architects are often expected to come up with much more deliverables (renderings, BIM documents and detailed cost and energy analysis) than before. Using digital tools has made iterations and revisions expedient; however this has not ensured that these are accurate.

Overall it was felt that in practice, digital tools have been beneficial during the design development, data exchange and construction document stage. However, there has been very little evidence of how digital tools have helped shape the early design process and collaboration. Despite the interviews, it has been very challenging to figure out how the firms actually collaborate during this most crucial phase of design. Table 4-9 shows how the various firms collaborate with different people during various phases of the design process. Each firm does obviously have a lot of face-to-face interactions with all the collaborators through the entire design process, especially so in the early stages. Also architects such as Lynn and Garofalo collaborated with people related to art and media. Only SHoP claimed to interact with some consultants and fabricators and have explored videoconferencing as the medium of communication.

The most interesting and dynamic stage for digitally mediated collaboration occurs during the schematic and design development phase. This is when most interaction takes place between various people involved in the design and diverse mediums are explored. Garofalo claimed that for their project of Hyde Park, they collaborated with fabricators, technical, digital and software engineers along with specialty consultants such as lighting and environmental engineers. Except for Lynn, all firms declared that they shared 3D models of some type and used ftp login sites for design data exchange. This was also typically the phase where fabricators were involved in the design process. However, in the construction document phase, it can be observed that again there is more reliance on conventional modes of collaboration mostly via face-to-face meetings and telephone, some cases email and in some rare cases IM and ftp sites.
Table 4-9: Medium of collaboration in various phases of design.

<table>
<thead>
<tr>
<th>Phase</th>
<th>KIERAN TIMBERLAKE ASSOCIATES</th>
<th>SHOP</th>
<th>GREG LYNN FORM</th>
<th>GAROFALO ARCHITECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Phase Program Requirement</td>
<td>Design Team Client</td>
<td>Face-to-Face Email</td>
<td>Design Team Client Design Team Consultants Fabricators</td>
<td>Face-to-Face Video conferencing</td>
</tr>
<tr>
<td>Schematic Phase</td>
<td>Consultants Structural Engineer</td>
<td>Face-to-Face Email Sharing 3D models (Rhino)</td>
<td>Fabricators-metal</td>
<td>Face-to-Face Sharing digital models</td>
</tr>
<tr>
<td>Design Development</td>
<td>Consultants Fabricators</td>
<td>Face-to-Face Email Phone FTP sites</td>
<td>Consultants Contractors</td>
<td>FTP logins</td>
</tr>
<tr>
<td>Construction Document</td>
<td>Contractors</td>
<td>Face-to-Face Email Phone FTP sites</td>
<td>Contractors</td>
<td>Face-to-Face Email</td>
</tr>
</tbody>
</table>
4.6.3 Ideal Scenario of Collaboration

One of the objectives of conducting the interview was to discover how firms perceived digitally mediated collaboration and what according to them would be the ideal scenario for the same. In order to delve more into the matter, the firms were asked about what they thought the present limitations were and how one could overcome them. Consequently the firms were asked to imagine what possibilities and scenarios for digital design communication could present themselves in such an ideal collaborative setting.

4.6.3.1 Broadband Limitations

The most evident limitation at present was identified as broadband restriction and variation between collaborators. KTA said that they exchange files with consultants via email but they have a 2MB restriction that does not allow them to collaborate effectively all the time. SHoP felt that they could not afford faster connections yet as they used Verizon and would love to piggyback on some strong networks such as those available in universities. “Better broadband is desirable for videoconferencing,” was their reply to how frequently they would like to teleconference on a project. Similar issues faced by firms are server storage space, data exchange and interoperability. KTA sometimes have experienced consultants have issues accessing their ftp sites and though they have also tried Autodesk for sharing program purposes, they still find it to be clunky. However, Lynn seems unperturbed by this scenario and feels that problems associated with compatibility of software and common platforms will be solved eventually as many efforts are being spent on closing gap between contractor and consultants by using BIM.
4.6.3.2 Loss of Sketching Ability

Another major concern expressed by all the firms was the loss of ambiguity due to the implementation of digital tools, especially in the earlier design stage for expressing and generating ideas. Unable to pin down exactly what is required to avoid feeling this void, SHoP expressed that “something is always missing… you don’t have that tangible…” while collaborating digitally. Therefore it is important to take reconnaissance of the importance of the ability to sketch and identify what is required from digital tools to effectively express design ideas. KTA suggests that there is a need to somehow generate live documents, sketches or computers displaying images simultaneously. Greg Lynn reiterates this fact by saying that “models and physical prototypes are super important… all the time.”

4.6.3.3 Ideal Physical space for collaboration

All the firms considered the prospect of utilizing teleconferencing for successful digitally mediated collaboration. However, the setting in which this videoconferencing takes place raised some interesting issues that could be challenging to address. For instance, In KTA they compared videoconferencing to something like a telephone conversation, where one person talks and the other person listen. Moreover, “everything [everyone] is pointed to something [camera]. SHoP described the same problem at length describing video conferencing as: “It’s tricky, it’s like the one point where everyone is looking at the camera and you don’t have the feeling that everyone is looking at you. It’s bizarre.”

However, to offer suggestions, one of the things that SHoP felt was to probably have multiple cameras in the room. KTA felt that it would be great if everyone involved could be “Looking at the same board at the same time.” This would enable better referencing and idea exchange. Another suggestion
was to have bigger videoconferencing screens to heighten the feeling of presence [it is interesting to note that this was observed during the field study as well, however with tradeoffs of being both advantageous and unfavorable.]

Logistically some firms felt that a space or room should be permanently allocated for videoconferencing that is always on and ready to go as compromise on room use could effect the collaboration and technology used. While SHoP even made reference to the firm of Arup, who did actually have such a room setup that was always hooked for digital collaboration, Lynn and Frankfurt also attested to similar experiments being undertaken by HP. A simpler solution that all firms conceded to was the possibility of enabling teleconferencing at the scale of a desktop. This is easily attainable with the present technology as well.

In conclusion it can be said that there is definitely potential in implementing some form of digitally mediated collaboration in the design process of firms, as there is a lot technology can offer. The task would be to try and tap this potential by exploring various means by which digital tools can be utilized to enhance collaboration and thereby improve the design process.

The next chapter will further discuss research and trends in architectural practice along with conclusion of findings from both the field study and case study.
Chapter 5

CONCLUSIONS

Some obvious benefits of the opportunity to design in a distributed setting have been increased efficiency, both in terms of time and costs. Virtual collaboration is able to conserve and decrease the use of paper documents leading to possibilities of sustainability. However, it has been found that the lack of tactile design artifacts and the ease of printing both 2D and 3D models have led to an increase in the amount of prototypes churned out throughout the design phase. Also with the perception that digital technology conserves the time invested in design projects, the expectations in both the academic and professional realm have risen significantly.

One of the problems that became apparent during the study was the need to understand the broader context of the phenomenon of virtual design studio. Another endeavor could be to make the digital environment for design more flexible and scalable depending on the needs of the design process. Based on the findings, it was observed that most decision-making and collaboration took place during chat, email and conversations on individual desktops. This was a significant finding as it directs us towards increasing the individual ability to collaborate and interact using individual, distributed computers. Another important revelation was that digital collaboration did not necessarily take place over large geographical distances. Co-located designers also seemed to use digital mediation to collaborate during design due to the ease of transferring information and files. This proved that distance wasn’t the only factor for collaborating digitally. Therefore, it is important to understand the social as well as technical requirements for design collaboration to be able to better address the issues for future technology development.
5.1 FINDINGS

5.1.1 Issues of Digitally Mediated Collaboration

Various issues related to digitally mediated distributed design were identified through the study. These issues comprised of concerns that occurred both in the PDS research project and within the firms interviewed as case studies. Table 5.1 compares the findings from both the field study and case study below.

Table 5-1: Issues of digitally mediated design collaboration.

<table>
<thead>
<tr>
<th>Issues</th>
<th>Academia</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design related Issues</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Representation and Idea Exchange</td>
<td>Ability to sketch and convey design intentions. Sharing design ideas.</td>
<td>Need for more efficient tools to achieve better idea exchange.</td>
</tr>
<tr>
<td>Decision making</td>
<td>Ability to make distributed design decisions is time and cost efficient.</td>
<td></td>
</tr>
<tr>
<td><strong>Collaboration Issues</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trust</td>
<td>Arriving at a mutually agreeable concept.</td>
<td>Face-to-face interaction with clients and consultants is vital.</td>
</tr>
<tr>
<td>Teamwork</td>
<td>Understanding of interdisciplinary approach to problem solving</td>
<td>Leadership and clear definition of roles of each collaborator.</td>
</tr>
<tr>
<td><strong>Technical Issues</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data exchange</td>
<td>Tool’s transparency and ease of use.</td>
<td>Interoperability and common software platforms between consultants.</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Encouragement to experiment with emerging technology.</td>
<td>Restrictions due to limited access to high bandwidth and infrastructure.</td>
</tr>
</tbody>
</table>

Even though common issues were found in both the settings, their interpretation varied greatly due to inherent differences in the process of design. While design related issues such as decision making and conveying ideas to teammates was most important in design studios, firms were most concerned with the level of trust they had with their collaborators on the project. For instance, digital collaboration could never replace face-to-face interaction as it was most critical for collaboration in
both settings, more so in practice. However, it was realized that though digital mediation can never replace face-to-face collaboration, it provides newer opportunities and methods to practice design.

### 5.1.2 Limitations

Though this study helped in identifying broad issues related to digitally mediated design, the findings of this exploratory study cannot be generalized. In the first part, this study observed just one semester of an experimental design studio that was a proof-of-concept. This studio developed heuristically and the settings evolved based on trial and error. On the other hand, results from the open-ended unstructured interviews of the four firms cannot be generalized either, as each firm’s reply was detailed and specific to their context. Table 5-2 compares the varied setting and nature of collaboration in both the field study academia and the firms interviewed as case studies.

<table>
<thead>
<tr>
<th>Table 5-2: Comparison between academic and practical setting.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Setting</strong></td>
</tr>
<tr>
<td>---</td>
</tr>
</tbody>
</table>
| **Tools used** | 3-screen lab  
High speed internet  
Higher bandwidth and infrastructure capabilities | Teleconferencing systems  
email and face-to-face meetings,  
Limited server capacity |
| **Mode of Design Practice** | More emphasis laid on conceptual design phase. | Emphasis on entire design process, especially design development and construction documents |
| **Nature of Collaboration** | Similar roles - student team mates, professors | Diverse expertise, consultants and specialists-defined role in project |
| **Synchronous** | Design reviews and crit sessions with peers and professors. | Meetings with clients and consultants. |
| **Asynchornous** | Data exchange, design ideas and concept development. | Data exchange with consultants and specialists. |
| **Issues** | Teamwork, decision-making, mode of representation | Trust, client satisfaction  
Cost and efficiency |
Bridging the gap related to digitally mediated collaboration between academia and practice is challenging and difficult to apply due to different set of goals and design objectives. The comparison between issues prevalent in the educational setting and the realm of practice cannot yield ideal results due to the paradigmatic differences between the two. These differences between the two settings include unique methods of designing, the level of experience of designers, collaborators involved in the project and the goals to be achieved by students in a design studio on one hand and architects who need to get their designs built.

The other limitation of the study is due its inherent diachronic nature. Since the study attempts to understand issues related to the digital media, the findings might not be relevant few years from now. Speculations and hopes to predict how the technology could be developed to better help the design process might not be pertinent in the future due to unexpected changes and developments in the fields of technology and design. However the study can be useful and can be considered as a basis for further studies that delve deeper into the issues of collaborative design using digital tools.

5.1.3 Guidelines for future PDS

Based on the field study and case study, diverse issues emerged related to digitally mediated collaboration occurred. These issues and experiences provided lessons and led to some broad guidelines that could be considered in future distributed design studios of this nature. These guidelines are divided into three broad areas of physical setup, technological infrastructure and design studio curriculum.
5.1.3.1 Staging and Physical Setup

During the PDS, the IEL was used with three large screen configurations along with a conference room setup in Carleton. More experimentation could be done with the physical setup of the room and the seating of students. Also, to counter the eye-shifting effect, multiple cameras could be installed in the room. This would lead to a better understanding of what is being talked about or being referenced while the students progress with their design problems.

Since most of the collaboration took place outside the formal lab setting, the next step could be towards making the configuration of the connection between two studios more scalable. This would enable the students to work with their personal laptops or desktops and not be restricted with limited modes for distributed interaction. Also, more tools can be incorporated to encourage student’s ability to sketch such as tablet PC’s, smart boards and other devices that could be connected remotely to allow students to sketch simultaneously.

5.1.3.2 Collaborative Infrastructure Setup

A scalable configuration where students can work on their individual workstations could foster much better collaboration. Apart from the hardware, there is also a need to be able to work through varied bandwidths. While the PDS relied on high bandwidth connection, experiments and design sessions could be held with participants having a range of bandwidth. This would again enhance and increase the opportunities for effective remote collaboration to occur. Another important aspect that needs focus is the workflow and interoperability of software programs used during the design process. Creating seamless transitions of file formats from one program to another will help augment the creative design process of the students.
Another aspect that can be explored is the utilization of the Deep computing visualization and other resources available to create an immersive distributed environment. The three screens and high bandwidth connection can be potentially used to walkthrough virtual models that were created in remote locations in real time.

### 5.1.3.3 Teamwork in the design process

Since the PDS focus on collaboration, an overarching goal for the future could be fostering teamwork among students during the design studio. Based on the findings form the realm of practice as well as the insights of students in their journals, it was apparent that students weren’t comfortable working in teams. However, the design curriculum and pedagogy could include projects that expose students to various related disciplines and encourage them to work in teams. This also ties in with the established common ground theory (Monk, 2003), and would help students understand the significance of increasing specialization and distributed expertise.

### 5.2 FUTURE DIRECTIONS

The participatory design studio was conducted as an investigational project in the first part of this study. Based on the findings from this exploratory study, controlled experiments on design studios can be conducted. These distributed design studios could be set up between the Immersive Environment Lab (IEL) and the Immersive Construction (ICON) lab within Penn State. The research could focus on specific issues related to digitally mediated collaborative design. Comparable to real-life settings, these studios could include students from interdisciplinary backgrounds to collaborate on common design projects.
This study could also be used as a basis for research in related fields of design. Results from the study of theories and nature of collaboration in the design process could be applied in similar settings prevalent in the broader realm of AEC industry. Issues such as data exchange and interoperability can be further explored within the wide-ranging contexts of early design process to building information modeling.

Large amounts of data in the form of journal entries, video recordings of collaborative sessions in IEL and detailed transcripts of interviews have been collected throughout the duration of study. Extended data and content analysis could be undertaken to reveal more insights and results to the study.

5.2.1 Changing Trends in Architectural Praxis

Some of the cutting edge design firms are exploring new frontiers in the field of digitally mediated collaborative design. The following section demonstrates some instances of firms that are pushing the envelope as far as digital technology utilization in the design process go. According to Rosa (2003), a template for the new office is foretold in the short lived collaboration of Lynn, Garofalo, and McInturf, with each partner living in a different city and no central location for the “office.” The nomadic office (or studio) is ideal for the younger digital set, who teach at universities and institutes throughout the world. Conceptually, the office is the hard drive of the digital computer that houses all projects and can be accessed from any location. The only permanent address is email. Examples of nomadic practices include the progressive studios of Ocean D and SERVO both comprised of globally dispersed partners whose locations are subject to change in any given academic year.

Leach (2004) in *Digital tectonics*, claims that SERVO as a collaborative office has established a highly unusual form of practice. The office is based in several different cities and works as a co-
operative network. Moreover, they also collaborate with other design studios and operate at the interface between different design techniques and practice. Michael Hensel, founder of OCEAN D— an independent inter-disciplinary research network that conducts research by design and is in the intersection of architecture, landscape, urban, industrial and product design, engineering biology to musical composition. This practice works as a design co-operative based in different cities and straddles different disciplines (Leach, 2004). Based on Umberto Eco’s notion of the ‘open work,’ they feel that architecture should encourage a broad range of occupations rather than prescribing precise patterns of practice. They don’t make a distinction between digital and analogue and in fact use the notion of computing to generate fully inclusive design scenarios.

Another architect, Mark Goulthorpe from deCOI, “intended to allow for possibility of collaborative practice”, which has subsequently become essential to digitally networked creative enterprise. For his renowned project of the Aegis Hyposurface, the design team included collaborators as diverse as the art consultants, mathematics engineering, programming, system engineering, façade consultant, rubber research, adhesive research, pneumatic systems/ fabrication, facet manager and technical designers (Curtis, 2008).

Yet another architecture firm of UN Studio understands the changing roles of architects. “New production methods developed by the building industry, the current transnational nature of architecture, new design techniques and the changed, more functionally complex nature of the architectural project itself has led them to develop new working strategies”. They encourage “meticulous engineering & collaborations with graphic designers, photographers, stylists & new media designers” (http://www.unstudio.com). They feel that the architectural assignment has changed from an introverted process into a multi- party complex and differentiated collaborative process. They describe their firm as having a “highly flexible methodological approach- incorporating parametric
design & collaboration with leading specialists in other disciplines” They claim that “the dynamic nature of practice enables the exploration of new territories & adaptation to future challenges.”

To summarize therefore, the purpose of digitally mediated collaboration in architecture could be that it is becoming ubiquitous, as well as influencing and transforming the way architecture is practiced and theorized today. It epitomizes the sharing and exchange of knowledge and information to deal with the complex and multi-layered problems of our age.
BIBLIOGRAPHY


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Handbook of work group psychology. (pp. 25–52) New York: Wiley.


Appendix A

PDS Student Group Projects

Group no. 1: Orange Cord of Death- 5 teammates: 2 from PSU, 3 from Carleton.
Group no. 2: C.H.M- 7 teammates: 3 from PSU, 4 from Carleton.
Group no. 3: OPT- 6 teammates: 3 from PSU, 3 from Carleton.
Group no. 4: JPMS- 8 teammates: 4 from PSU, 4 from Carleton.
Group no. 5: **Team “Fly”** - 4 teammates: 2 from PSU, 2 from Carleton.
Group no. 6: Xpollination using Open Canvas – 4 teammates: 2 from PSU, 2 from Carleton.
Appendix B

Journal format

Journal for Collaborative Session

Team pseudonym:
Team Members:

Date turned in:
For completing the following information, please use a new form for each collaborative session.

Session no.
Date:
Team Members in session:
Time Started:

Time Ended:

Medium used for collaboration (Check all that apply):

___ IEL
___ Email
___ Chat
___ Other, specify
________________________________________________________________
________________________________________________________________
________________________________________________________________

In 2-4 sentences list the main outcomes of collaboration.
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
**Snapshot of design at start:** Please copy/paste an image/drawing of your design prior to the collaborative session, which gives a clear idea of the status of the project.

![Snapshot of design at start](image)

**Snapshot of design at the end:** Please copy/paste an image/drawing of your design after the collaborative session, which gives a clear idea of the changes to the project resulting from the collaboration.

![Snapshot of design at the end](image)
Appendix C

Survey Questionnaire

Computer Use and Skills

1. Age : _______ years
2. Gender: _____ Male _____ Female
3. Please estimate the average hours per week you spent using Form.Z this term.  
   This term, on average I spent _______ hrs per week using Form.Z
4. Please estimate the average hours per week you spent using Photoshop this term.  
   This term, on average I spent _______ hrs per week using Photoshop
5. Please list any other software you have used a great deal for design related work this semester.  
   Software – 1:
   Software – 2:
   Software – 3:
6. Please estimate the average hours per week you spent this term using Software – 1 from your list above.  
   This term, on average I spent _______ hrs per week using Software - 1
7. Please estimate the average hours per week you spent this term using Software – 2 from your list above.  
   This term, on average I spent _______ hrs per week using Software – 2
8. Please estimate the average hours per week you spent this term using Software – 3 from your list above.  
   This term, on average I spent _______ hrs per week using Software - 3
9. Please estimate the average hours per week during this term that you spent using any computer for course related activities. Please include all your courses in your estimate and consider all course related activities for which a computer was used (for example word processing, computer aided design, multimedia design and presentation, course related e-mail etc).  
   This term, on average I spent _______ hrs per week using a computer on all course related activities.
10. Please estimate the average hours per week during this term that you spent using any computer for any personal or leisure related activities (for example personal e-mail, chat, games, watching movies, online shopping etc).  
    This term, on average I spent _______ hrs per week using a computer for personal or leisure related activities.
11. Please estimate your experience with 3d-modelling with computer aided design softwares (Form.Z, AutoCAD, SketchUp, 3dStudio Max, etc) in general.  
    I have _______ months experience in 3d modelling with computer aided design software.
12. Please estimate your experience with 2d-graphics softwares (Photoshop, Illustrator, InDesign, QuarkExpress, etc) in general.

I have _______ months experience in using 2 dimensional graphic design software.

Please rate your confidence level in using the following software

*Image Editing / Drawing Packages*

**Adobe Photoshop**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident

**Adobe Illustrator**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident

**Adobe InDesign**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident

**Macromedia Fireworks**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident

*CAD / Modeling / Drafting Packages*

**Form.Z**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident

**VectorWorks**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident

**AutoCAD**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident

**Autodesk 3D Studio Viz**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident

**3D Studio Max**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident

**Maya**
Not at all confident 1 2 3 4 5 6 7 8 9 10 Very Confident
<table>
<thead>
<tr>
<th>Software</th>
<th>Not at all confident</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Very Confident</th>
</tr>
</thead>
<tbody>
<tr>
<td>SketchUp</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td></td>
<td>Very Confident</td>
</tr>
<tr>
<td>Video Editing</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td></td>
<td>Very Confident</td>
</tr>
<tr>
<td>iMovie</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td></td>
<td>Very Confident</td>
</tr>
<tr>
<td>Adobe Premiere</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td></td>
<td>Very Confident</td>
</tr>
<tr>
<td>Final Cut Pro/Express</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td></td>
<td>Very Confident</td>
</tr>
</tbody>
</table>

Please list any other software you have used and your confidence level

1. Not at all confident | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Very Confident
2. Not at all confident | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Very Confident
3. Not at all confident | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Very Confident
4. Not at all confident | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Very Confident
5. Not at all confident | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Very Confident
6. Not at all confident | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Very Confident

Thank you for completing this survey!
Recruitment email for firms

Sub: Penn State grad student seeking info regarding research

[Address of firm]
[Date]

Mr. [last name of architect addressed to],

I am a graduate student in Pennsylvania State University pursuing my masters in Architecture with specialization in Digital Design.

My Research Interests include the phenomena of architectural collaboration with a focus on 'digitally mediated collaboration in the design process' that has emerged due to the advent of information and visualization technologies in recent years. Architectural practice is undergoing transformation in this highly networked digital realm by creating design possibilities that could take place over distributed geographical areas synchronously.

During spring 2007, I was involved in a research project of a collaborative design studio conducted between Penn State and Carleton University, Canada. This participatory design studio allowed students to collaborate in real-time by sharing computational resources, geometric datasets, and multimedia content including high-definition video.

For my masters thesis, I want to study how design firms, such as yours engage in digitally mediated synchronous/real-time collaborative partnerships with other designers, firms, specialists, consultants or even clients during the early stage of the design process using digital tools and technology.

Based on my literature review and discussion with faculty and experts, I am really interested and keen to have your firm [Name of firm] as a case study and hope that you could give me an opportunity to visit your firm and interview you.

I believe that your opinions and ideas could help in defining the nature of design collaboration in the present context as well as inform the possibilities and future directions/implications and relevance or importance of collaborative workspaces in architecture.

I’m planning to conduct interviews and collect data from end of January through April. I’ll be very grateful if you could let me know your interest and what would be an ideal time for you to give this interview.

Looking forward to your reply,

Sincerely,
Sonali Kumar
List of Firms (in alphabetic order):

**Asymptote** is a firm that leads developments in architectural and interactive digital design and has produced a body of work that has placed their practice at the forefront. They have designed virtual buildings that exist solely on the Internet.

Email: info@asymptote.net
561 Broadway Apt 5A
New York, NY, 10012-3918
P 212.343.7333

**Garofalo architects** has been widely recognized for its innovative and creative approaches to the art of building. They have actively pursued architectural design to include forms of collaboration that cross both geographical boundaries and professional discipline, extending conventional design practices by taking full advantage of the capacity of electronic media.

Email: doug@a-node.net, dougg@uic.edu
3752 North Ashland Avenue
Chicago, IL 60613
Tel: 773-975-2069

**Greg Lynn FORM** is a forerunner in exploring the possibilities in digital fabrication. The firm is experienced in working in collaborative partnerships on international projects ranging from boutique interiors to public housing. Time Magazine has profiled Greg Lynn in their projection of 21st century innovators in the field of architecture and design.

Email: node@glform.com
1817 Lincoln Boulevard
Venice, CA 90291, USA
310-821-2629

**Kieran Timberlake Associates** is an architecture firm noted for its research, and innovative design and planning services.

Email: timberlake@kierantimberlake.com
KieranTimberlake Associates LLP
420 North 20th Street
Philadelphia PA 19130.3828
V 215 922 6600 F 215 922 4680

**Michael Mcinturf Architects** is a research-based building practice that collaborates digitally with a number of other architects.

Email: Michael.mcinturf@uc.edu
1116 Race St.
Cincinnati, OH 45202-7219
P 513 639-2351

**SHoP** represent a new kind of firm that is riding the crest of architecture’s digital wave. They have both a command over technology and an explicit connection to the tactile reality.

Email: studio@shoparc.com
11 Park Place Penthouse
NY 110007
P 212 889-9005
INTERVIEW QUESTIONS GUIDELINE

Background Information:

Name of Firm:

Address/ Contact:

email:

Year of Establishment:

Organizational structure (Size of Firm):

1. How would you describe your firm (design philosophy)?
2. How many people work in your firm:
   a. Principals:
   b. Senior Associates
   c. Designers
   d. Others
3. What are the types of projects your firm is typically involved in?

Collaboration:

WHO (People- collaborators):

4. How many people/ teams are typically involved in one project?
5. Who are the different specialists (designers, engineers, fabricators, etc) that you collaborate with during a design project?

WHEN

6. According to you, What stage of the design process necessitates collaboration and why?
7. When do you typically collaborate in the design process?

HOW Technology

8. What digital tools and technology do you use to design in your firm?
9. What digital tools and technology do you prefer to use for design collaboration?
10. Do you feel the present trend of communication technology affects the design quality and how?

WHY

11. How important do you think collaboration is in the field of architecture especially in the current context/ scenario of practice?
12. What would you feel are the reasons to collaborate during the conceptual design phase?
13. What according to you is most important aspect of collaboration: information exchange, conveying changes, concepts and idea development.
14. What according to you are the possibilities of distributed design given the present potential of tools and technology?
**FIRM PROFILE**

**Address**

**Year of establishment**

**Firm Description**

**PEOPLE IN THE FIRM:**

**PRINCIPALS**

**SENIOR**

**ASSOCIATES**

**DESIGNERS**

**TECHNICAL STAFF**

**OTHERS**

**DIGITAL TOOLS:**

**DESIGN SOFTWARE:**

**EXCHANGED FILE FORMAT:**

<table>
<thead>
<tr>
<th>Software</th>
<th>Ms word</th>
<th>Adobe pdf</th>
<th>Ms Excel</th>
<th>Jpegs</th>
<th>2D Cad</th>
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</thead>
<tbody>
<tr>
<td>MS Power Point</td>
<td>MS Project</td>
<td>Tiff</td>
<td>DXF</td>
<td>3D</td>
<td></td>
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<tr>
<td>Adobe Illustrator</td>
<td>Adobe Photoshop</td>
<td>Digital video/ Audio</td>
<td>DWF</td>
<td>MS Visio</td>
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<tr>
<td>Primavera</td>
<td>Flash</td>
<td>Other</td>
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**HARDWARE CONFIGURATION:**

<table>
<thead>
<tr>
<th>Workstations</th>
<th>MAC</th>
<th>PC</th>
<th>LINUX</th>
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<tbody>
<tr>
<td>Network</td>
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<tr>
<td>File Transfer</td>
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<tr>
<td>Protocols</td>
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<tr>
<td>Video Cards</td>
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