Ontic Occlusion and Exposure in Sociotechnical Systems

by

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Have the elder races halted?
Do they droop and end their lesson,
wearied, over there beyond the seas?
We take up the task eternal,
and the burden, and the lesson,
Pioneers! O pioneers!
— Walt Whitman, *Leaves of Grass*

"One only understands the things that one tames," said the fox. "Men have no more time to understand anything. They buy things all ready made at the shops. But there is no shop anywhere where one can buy friendship, and so men have no friends any more. If you want a friend, tame me..."
"What must I do, to tame you?" asked the little prince.
"You must be very patient," replied the fox. "First you will sit down at a little distance from me, like that, in the grass. I shall look at you out of the corner of my eye, and you will say nothing. Words are the source of misunderstandings. But you will sit a little closer to me, every day..."
"Goodbye," said the fox. "And now here is my secret, a very simple secret: It is only with the heart that one can see rightly; what is essential is invisible to the eye."
— Antoine de Saint-Exupéry, *The Little Prince*

Anyone who tells you doing original research is easy obviously hasn't done it.
— Judith S. Olson

To the memory of Dr. Susan Leigh Star

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Abstract

Living inside built environments - infrastructure - it is easy to take for granted the things that we do not need to engage, but are at work behind the scenes nonetheless. Well-designed systems become invisible, but to engage them, how do we know which perspectives, objects, and relationships are useful? I examine the University of Michigan Digital Library (UMDL), a mid-1990s interdisciplinary project attempting to build an agent-based digital library architecture. Through analyzing project data, I develop the concept of *ontic occlusion and exposure* - mechanisms of choice regarding objects and relationships that enter discourses and representations.

By analyzing project artifacts, interview transcripts, and meeting records, this study identifies key sets of discursive elements bridging concepts between disciplinary communities on the surface, but were the fundamental sites of contestation between groups' understanding of project goals. I examine narratives of project personnel to understand the positioning of terms and ideas relating to project design, execution, and assessment, and discuss the role of the ontic in interdisciplinary work.

Using data from the UMDL project, I discuss the tension between occlusion (the hidden) and exposure (the revealed) in understanding the *digital library* as an object through meetings of the project operating committee - the primary engagement site between researchers from different departments, primarily computer engineering and library science. Examining interpretive differences, use of fundamental terms, and observations about the contested responses toward resolution, we can better understand the outcomes of the project, the disciplinary positioning of institutional change, and perspectives of evaluating the project in the subsequent years.

This dissertation contributes to an understanding of discourse development in interdisciplinary projects where shared language is important to design, execution, and evaluation. It combines perspectives in philosophy, digital libraries, and interdisciplinarity studies. The complementary mechanisms of ontic occlusion and exposure are useful devices to decode and describe change in sociotechnical systems, and highlight the need to examine more closely both what is rendered in accounts of infrastructure, and residual categories often left unaddressed.

Chapter 1

Introduction

Between 1992 and 1998, the University of Michigan undertook two transformative projects, both related to formative information infrastructures. The first project was a federally funded research program to design a new type of digital library that would meet the needs of a rapidly emerging digital environment. The second project was the institutional transformation of the School of Information and Library Studies (SILS) into a new School of Information (SI). Both projects took place in the same environment, shared a significant number of researchers, administrators, and other personnel. This dissertation examines the digital library project as a case study to explore mechanisms of transformation in sociotechnical systems. Through the story of the failure to build a digital library but successfully launch a new school, it explains how discursive practices represent deeper issues of coordination, commitment, and world views. It introduces a complementary set of explanatory mechanisms, *ontic occlusion and exposure* as a framework for understanding consequences and outcomes of interdisciplinary work.

Large sociotechnical projects have a tendency to become invisible when they are working well. The fact that we do not need to pay attention to them or think about them in order to go about our work and daily lives is one of the most useful features about them. At the same time, these systems and projects can break or otherwise need attention, and because they have been out of our view for so long, our understanding is limited or fragmented with respect to how they were designed, built, maintained, and came to be the way that we now see them. Large sociotechnical systems and infrastructures are heterogenous, representing the negotiations of many players – individuals and institutions alike – and are the result of many decisions and assertions of what is important and what is not, what gets represented and what does not. Sometimes, the facts and perspectives that may be critical are cast aside and forgotten, or are blocked from view. The problem of reconciling these decisions takes place at both temporal ends of the sociotechnical system life cycle. During design, how do project participants with different goals, backgrounds, and disciplinary languages align the efforts of work to produce successful systems? At the other end, the evaluation or assessment end (either because assessment is a standard milestone for a system, or assessment because the system has somehow stopped working properly and must be re-evaluated), how do we account for the outcomes and effects of systems that grow, connect, sprawl, and become part of coordinated networks and infrastructures?

The University of Michigan Digital Library project (UMDL) that took place in the 1990s involved the work and coordination of people from all corners of the University of Michigan campus and community[1]. Different departments and disciplines, roles, and backgrounds came together to build two contemporaneous systems. In building a digital library, it is easy to take for granted that basic terms are universally understood - library, data, access, users, collections, and so on. Since the work of the UMDL operating committee was primarily discursive, fundamental terms served an important role in coordinating the distributed research activities in a complex set of projects with multiple teams contributing. Because the UMDL operating committee membership also had significant overlap with the founding faculty members of the new School of Information, we can see connections and influences between the work done in both projects. At their core, both projects were concerned with building a future for the burgeoning areas of research and application enabled by digital and networked technologies. In times of such rapid change, project work is as much bricolage

[1]Throughout this dissertation, I use quotations from interviews conducted with members of the UMDL and other DLI-related projects. To protect identity, each informant has been designated an alphanumeric code that appears in parentheses at the end of the quoted material.

and taking advantage of emergent opportunities, rather than following a specific plan. At the same time, the capacity to adapt is heavily reliant on communication and coordination across boundaries (74).

I came to study the digital library project approximately 17 years after its inception. The UMDL project began with a call for proposals from the National Science Foundation for a "Digital Libraries Initiative - Phase One" (DLI-1) in 1993, and covered a funding period for the academic years 1994 to 1997. The DLI-1 project ended, and then progressed to a DLI-2 phase, in which the University of Michigan did not take part. For this work, I consider the transformation of the School of Information as a significant secondary story that can be conveniently demarcated by two dates: 1992, when Dan Atkins, then dean of the College of Engineering, was placed at the helm of SILS and began making significant changes to the institution; and 1996, when the UM Board of Regents officially re-chartered the school under its new banner, "School of Information." Both dates are significant, but for different reasons. The former date represents the beginnings of substantive change in philosophy, culture, and work located at the school. The second date, while in the technical sense only represents the signing of a line item a Regents' meeting, is symbolic of a critical set of discursive and ideological debates relating to the shifting identity of the school, and of a transforming information science field. Unlike the UMDL project, there is no identifiable completion date for the SI project, as the School of Information is an apparently successful and persistent educational and research enterprise.

1.1 Ontic Occlusion and Exposure

Ontic occlusion and exposure are mechanisms by which representational differences exert control over discourse. That is to say, one representation of an idea, situation, or event can take precedence and occlude, or block, another representation. Thus, the elements of the occluded representation do not enter into the discourse and are left without legitimate roles in shaping the narrative. Ontic exposure is the complementary mechanism that brings discursive elements back into the representation and makes them legitimate. Before moving further, I would like to deconstruct the phrase and explain the constituent parts. (A more historical explanation of the ontological/ontic concept is discussed in Chapter 2.) Ontic occlusion and exposure are positioned to decode the transformation of sociotechnical systems by examining what and how objects and relationships are leveraged to guide and render discourse. The main assertion here can be stated as the following:

1. **Assumption:** Where there is change or transformation in sociotechnical systems, there is accompanying discourse.
2. **Assumption:** Where there is discourse, choices are made to include and exclude existing objects and relationships.
3. **Definition:** When objects and relationships are excluded from discourse, ontic occlusion occurs. When objects are relationships are included from discourse, ontic exposure occurs.
4. **Implication:** Where there is discourse, ontic occlusion and exposure occur.
5. **Implication:** Where there is change or transformation in sociotechnical systems, ontic occlusion and exposure occur.

The claim coming out of these statements is that by understanding better what we choose to include and exclude in our accounts – how we leverage our own ontic subscriptions as well as attend to those of others – we can better understand or decode the transformations of our sociotechnical systems. By invoking the mechanistic framework of ontic occlusion and exposure, we can be more exacting about the discursive elements that describe the state of, for our primary case, institutions and infrastructures *here* and their state *there*. What were they *then*, and what are they *now*?

The term *ontic*, as may be intuited, is closely related to the term *ontological*. While the ontological is the conceptual domain of relevant objects and their potential relationships, the ontic is a specific subset of an ontology that exists, is manifest, or can be the specific object of inquiry. In this sense, the ontological represents a broad conceptual space of all possible objects[2] and all of the possible configurations in which they could be expressed.

[2]"All objects" as a general statement. When thinking of disciplines, the ontological represents the relevant objects and relationships with which the discipline concerns itself or validates are within its epistemic purview.

The ontological is the stuff of possibility, potential, innovation, imagination – all that could come into the world by combining the building blocks one has at one's disposal. The ontic lies at the opposite end of development. It is the realized, the specific, the particular instantiation that has come into the world from the ontological description. For example, we could speak of building a new house, but there are many kinds of houses that could be built – shapes, styles, materials, etc. From there, we could narrow down particular details - a two-story Colonial style house with red brick and a hipped roof. We eventually make decisions about which contractors, what wood, bricks, concrete, and other materials to put into the house. With each step, we move further away from the ontological and closer to the ontic. Eventually, we have a house – one that can be occupied and lived in. At this point, we have arrived at the ontic - a particular instantiation of a house: *these* bricks (some of which may have discolorations), *those* roof tiles (which in a few years will need to be replaced since the contractor cannibalized roof parts from a teardown job across town), *these* pipes and wires within the walls, and *this* slab of concrete poured into the driveway that now bears your 5-year-old daughter's handprint. The ontological is what might be. The ontic is what you actually have. Moving away from the purely physical and toward the representational, we can also speak of disciplines or fields having ontologies and ontics. The ontology of a field is an account of the relevant objects and relationships out of which the discipline (colloquially) "builds the world'." Physicists discursively construct the world out of mass, energy, forces, and particles. Sociologists construct the world using people, groups, social interactions, agency, contingency, and other dynamics. Microeconomists describe the world in terms of actors (rational or otherwise), decisions, games, incentives, resources, prices, etc. Each field recognizes and names a set of primitives or elements and the relationships to each other that can be expressed to construct epistemologically valid and disciplinarily legitimate claims about the world. The ontic, in this case, would be a particular rendered explanation for a phenomenon of interest – the trajectories and particle types detected in a particular experiment in FermiLab's particle accelerator in its circular configuration. A sociologist's explanation of a workgroup's communication practices on the GEON cyberinfrastructure project taking place in meetings on a specific set of dates. And so on – the ontic is the specific, the particular, the grounded discursive elements that are invoked to render an explanation or assertion.

Constructing the narrative or discourse out of elements involves choice. Inclusion automatically creates complementary exclusion, and the boundaries of one ontic set of elements necessarily mean that other elements and objects are not used to construct the discourse. It seems natural to us that physicists do not explain the world using people as a primary element, or that the economist does not present a world built of molecules and chemical reactions. Still, multiple views and ontic invocations may be applied to describe the same objects or phenomena, though in wholly different ways. Materials scientist Mark Eberhart explains these multiple views elegantly.

> For almost everyone, the word "structure" evokes a strong visual. For most it is the image of something that has been built – a bridge, a building, or even an entire skyline. For a few, however, the work is, not unlike beauty, in the eye of the beholder. When asked to describe the "structure" of the Golden Gate Bridge, a civil engineer will often respond by describing it as a suspension bridge. On the other hand, an architect is as likely to emphasize its art-deco design and graceful silhouette. A traffic engineer might first call attention to the reversible lanes and one-way toll. For a metallurgist, not too far down the list of structural attributes comes a description of the main suspension cable made from thousands of laced wires and the arrangement of the individual metallic grains within each of these.
>
> The dictionary defines structure as a building, bridge, framework, or other object that has been put together from many different parts. It is the latter half of the definition – put together from many different parts – that accounts for the egocentric interpretation of the word. For an engineer or a designer, structure becomes a personal thing: something made of many different parts that *I* can put together. What distinguishes a particular engineering or design discipline from another is only the palette of things to be put together. A civil engineer fashions designs from a palette of I-beams, reinforcing rods, and concrete. A metallurgist crafts a metallic mosaic from a palette of crystalline grains of varying shapes and composition. A chemist creates molecules with the elements of the periodic table. So to each, the concept of structure becomes intimately entangled with the arrangement of those things they are trained to put together – I-beams and concrete, metallic grains of different shapes and composition, or

> atoms of different types.
>
> Yet simply putting things together from the appropriate palette does not qualify one as a designer, or the process of putting them together as a design. Design requires that yet-to-be-made structure be characterized by predictable properties. It is not sufficient to assemble a structure, measure its properties, and then conclude that you have designed something. You must know how the structure will behave before it has been constructed. The civil engineers designing the Golden Gate Bridge knew that it would carry the weight of all the cars and trucks driving across its length. The traffic engineers knew how many vehicles could move across this bridge safely. The metallurgical engineers knew from which alloys to build the main suspension cable so that it would not sag excessively over time. In each case, this knowledge derived from well-established relationships between structure and property. These relationships are the foundations for all forms of design. (49)

As Eberhart points out, the perspectives advanced through ontic selection are, through enactment, the process of design. Thus, our systems, networks, and infrastructures are the products of our ontic commitments and discursive practices, in addition to the physical and resource-based substrates that compose them. The structures do not exist separately from the discursive practices that create and recreate them, or of the disciplinary narratives that highlight aspects at the expense of others and draw our attentions privileging one interpretation and casting another into the shadows.

This is where the concepts of *occlusion* and *exposure* come into play. Each taken on their own terms, they describe states of relative ontic bases. Occlusion describes the state where a dominant ontic perspective hides or blocks the view of an alternative perspective. The alter is occluded. Exposure is the opposite state where a previously occluded perspective is reintroduced to the discourse and rendered apparent, visible, or legitimate. Moving beyond these static descriptions, *occlude* and *expose* in verb form are perhaps more appropriate, as they describe the oscillation between the two states. The movement between hidden and revealed aspects of discourse gives *animus* or propulsion to interactions and practices. We can describe development in system-building (and as I will show through both examples and the UMDL case, development throughout the design, implementation, and evaluation phases of project life cycles) in the dynamic context of ontic occlusion and exposure. By framing the cycle of development through these mechanisms, we can come to a different, possibly more robust sense of progression by making explicit the perspectives and viewpoints that are central, peripheral, and dismissed within a project. As the next section highlights, the ontically occluded can sometimes contain the most relevant information or objects to solving a particular problem or understanding the nature of systemic change.

Interpretivist approaches to scholarship, ethnographies certainly falling into this category, need to strike a balance between representing and weaving together stories from many informants, points of view, phenomena, objects that are situated and positioned in many different worlds. Positivist approaches are not necessarily different, and the high-paradigm claims of "truth" and "objectivity" encode and render mostly silent the epistemic agreements of those within the field. If one chooses even a slightly different application of a method, the outcomes may change. As popular advertising culture blithely warns, "Your results may vary." This observation about the nature of perspective is a trope that has occupied many people, in many fields, over a long history. In his allegory of the cave, Plato describes the difficulties of discerning the object behind casting shadows on the cave wall. How can we know the nature of objects from the fleeting glances at shapes only represented by projections (121)? Entire branches of geometry and geometric calculus have been dedicated to understanding subspace projections of complex objects, and the techniques required to recover the character of the projecting object [3]. Sir Fredrick Bartlett's work with reconstructive memory showed how narratives, over time, were reconstituted products of cultural and individual schemata (11). One of the most famous examples describing the dynamic of multiple perspectives is the *Rashōmon Effect*, most contemporarily named for Kurosawa's 1950 titular film (2). The Rashōmon story is concerned with the trial of a murdered samurai, with five different accounts of the events presented containing a number of incommensurable details. Each of the informants tells the story details from his own vantage point, which speaks to the contested nature of perspectival truth. The story itself has a long history, as the Rashōmon

[3]For a relatively extensive bibliography on techniques, Wolfram has assembled an excellent list at http://mathworld.wolfram.com/ProjectiveGeometry.html.

film was based on a volume of short stories written in the 1920s by celebrated Japanese author Ryūnosuke Akutagawa. For those who wish to find the original story, the second short story in the collection, *In a Bamboo Grove*, is the thematic story of the Rashōmon tale. The film and effect take their name from an unrelated short story that begins the collection. Descriptive of an even longer history, Akutagawa based his Rashōmon collection on a series of 12^{th} century morality tales, suggesting that the underlying issues of ontic occlusion and exposure have occupied attention across time and culture. Here, I mention a few to provide some indication of the corners of the world that have addressed aspects of the problem. Clearly, this list is not exhaustive: every field I have encountered has its own articulation of the problem and history of inquiry with reconciling multiple, and often conflicting views. Next, I present two recent historical examples suggesting ontic occlusion and exposure in more detail to show how considering the hidden and exposing later can be an entry into serious and necessary analysis.

1.2 Perspicuous Examples

Science & Technology Studies (STS) and Information Science journals are filled with accounts of socio-technical systems that have failed in myriad ways. Some of the most well-known focus on unpacking spectacular catastrophes that initially provided overly simplistic or reductionist explanations. The catastrophic is useful as an entry point for a larger conversation focusing on the design and evaluation of large sociotechnical system - the general topic of this dissertation. The spectacular renders visible the aspects of infrastructure which are normally invisible (one of the hallmarks of successfully working infrastructure (25)). The events of catastrophe and failure, as I hope the reader will come to understand, are not what I claim as the most important events, nor are they typical of most large systems. They just happen to catch our eye, our attention, and serve as exemplars to highlight aspects of design and modes of interpretation or evaluation. In this sense, they are representational tools or caricatures described by Michael Lynch as *perspicuous examples* whose exemplary attributes serve to sharpen and clarify the point being made(101; 102). The extreme cases are often these perspicuous examples, and failure is one type of extreme case that often yields tremendous insight. For example, we know much of what we know about the life cycles and physics of stars by observing supernovas - the noticeable and measurable catastrophic event directly preceding a star ejecting its mass. Without the catastrophic event, we wouldn't derive the knowledge about what came before, what composes the system, or even that we should be looking. These events cause us to look, to cast our gaze and interpretation, to places and shadows where things are certainly happening - potentially important and critical things - positioned to surprise us under the right conditions.

During the evening rush hour of August 1, 2007, the I-35 bridge in Minneapolis, Minnesota collapsed into the Mississippi River below, killing 13 people and injuring 145 more (42). Occurring on the heels of levees breaking in New Orleans during Hurricane Katrina in 2005, the nation watched the catastrophic failure of another piece of civic infrastructure with shock, anger, and compassion. I, too, watched with interest both as a Wisconsin native who had driven across the bridge several times, as well as someone who studies the lives and stories of large socio-technical systems. Like many, I anticipated an account of how and why the bridge had failed, and if anything could have been done to avoid such loss.

Five months later, on January 11, 2008, the National Transportation Safety Board (NTSB), working with a team of experts and analysts under the Federal Highway Administration (FHWA), released an interim report detailing the cause of the bridge collapse (78). The investigation found that two metal gusset plates of inadequate thickness and construction for the weight placed upon them had failed[4]. The report – dense with diagrams, tables, and equations – was clearly written for a reader versed in physics and structural/materials engineering, but not for a lay audience. The conclusive claim of the interim report was that

[4]The final report, published by NTSB, attributed undue stress on the bridge to the added weight of two inches of concrete poured earlier in 2007 for repairs along the length of the bridge, as well as 270 tons of construction equipment that had recently been placed upon the bridge for new project work(112).

unusual physical demands, coupled with "inadequate design" were the causal factors in the bridge's collapse.

Four days after the interim report's release, the Honorable J. Richard Capka, administrator of the FHWA, released a four-page safety recommendation to accompany the interim report, serving as an executive summary (26). The tone of the safety recommendation, however, differed substantially from the report itself by not only echoing the placement of blame on the physical structure, but also introducing the claim that no individual, organization, or inspection process could have foreseen this type of failure in the bridge[5]. Subsequent letters to the editor in the Minneapolis-St. Paul newspapers represented an angry public who demanded some measure of organizational accountability. The response circled back around to the report, pointing to the thorough analysis, complete and plausible explanation, and commitment to build a better bridge that would not fall.

The events surrounding the I-35 bridge collapse, in particular the stilted dialogue between the public and the government, lead to questions that move beyond the expected,"What went wrong?" The interim and final NTSB reports provided, by all official accounts, a satisfactorily robust and complete explanation saying, "Here is what went wrong." The focus of the reports on material and structural causes is only part of the story, and this narrowly constructed account is arguably what the public sensed and found difficult to accept. The story delivered by the NTSB and FWHA was not only provided to obscure or occlude particular interpretations or explanations of what went wrong, but in a *de facto* sense was created to make it impossible to see critical causal factors[6].

Another well-known contemporary example is sociologist Diane Vaughan's expert account (supplemented by those of statistician Edward Tufte and late Nobel prize-winning

[5]To placate the public, incensed by the lack of administrative accountability, the final report authors do not retract the claim that blame cannot be placed, but do make the remediation of inspection processes a focal point in the policy promises made by the NTSB and FHWA (112).

[6]This is not to say that these choices were made deliberately or with guile, though there is some cause to think that strategy in the selection of *who* did the analysis and created the account was done with some forethought. Had Capka stuck to introducing only the material explanation, the question of "who?" would have been more difficult to ask legitimately. By pre-emptively deflecting the social elements of causality in his memo, he brought attention to exactly what the account was trying to avoid – 'tipping his hand', so to speak.

physicist, Richard Feynman) of the NASA Space Shuttle Challenger explosion[7] in 1986 (155)(148)(53). Inital reports provided by NASA management reduced the explosion to the failure of "the O-ring", a small rubber ring that had been unable to withstand the cold temperatures on launch day. Vaughan and others presented a compelling argument that the O-ring story was one of convenience and expediency, and the Challenger explosion was the result of a complex web of tensions among the social and technical structures of verification, diagnostics, reporting, and politics within NASA. The I-35 bridge story, similarly, could not have been only about two small plates. The deeper story more likely involves questions of the same sort posed by Vaughan and her colleagues. How did we come to build bridges like this? How did we build roads and cities that required bridges like this? Given the claim of design inadequacies, what did the designers in the mid-1960s understand about the conditions in which the bridge would function, and how did those change over the 40 interim years? A more compelling story of the bridge would require us to assemble elements from the history of transport, bridge and road construction. studies of urban sprawl, the dispersion of economies and logistical arrangements, etc. The story comprises enough elements that it is difficult, if not impossible, to tease apart clear roles and causalities that led to the bridge's failure.

Approaching the year 2000, expectations about the world's computer systems failing to function drove widespread paranoia, concern, and investments by companies to update and test systems to ensure a smooth transition to the new millennium. The Y2K event is an excellent example of anticipating catastrophic failure at a different level of scale. From an interview with a prominent researcher involved in the early formation of the network protocols leading to the Internet:

> "But why in the 1960s, when we realized that this was going to be a problem, didn't we address it? It's a very simple answer. Memory was staggeringly expensive in those days. Remember, those were the days when a disk drive, a big disk drive – these big platters you used to see – a stack of 20 platters, 14

[7]Other well-developed examples have been written in the cases of the Three-Mile Island and Chernobyl nuclear reactor incidents, the Tenerife airplane collision, and the Tay Rail Bridge Disaster, among others.

inches in diameter held 20MB of data. When I entered the business in the late 1960s, IBM's biggest disk drive was something called the 2314. The Center had rows and rows of them, each with 20MB on them. So when we were developing this code in the 60s and 70s, we knew this stuff wasn't going to work in the transition, but the tradeoff was that we couldn't – doubling the amount of storage to hold the year was simply unaffordable. There was a very conscious decision on everybody's part back then of the tradeoff. There's probably a little twist to it because people back then couldn't believe that the systems they were writing would still be in use. The assumption was that maybe the things we were writing would be used for five or ten years and then be replaced. I think the reality is that systems didn't get replaced: they got extended. And even when you went in and extended your system, you couldn't just make the change in your system, because all these things were exchanging data with other systems. It wasn't until there was a crisis, when you had to, en masse, fix all of these concurrently that there was enough of an impetus to make the change. Now, as memory got cheap in the 90s, you could say, "Well, maintenance was being done on all these systems over time. Why didn't you fix it then?" The answer was that you couldn't fix it in isolation. Basically, just because I modify – you go into this one program and change the data structure of the date because storage is cheap – all the other programs that read it would have to be fixed as well. Probably around 1998 was when we, the world, got serious about remediating it. We really were running up against the Doomsday Clock, and that gave you enough incentive and impetus to say that we now had to go and fix this problem concurrently. That's what we did." (XDU)

But the turning of the millennium came and went with little incident, and the world did not see the predicted catastrophic failure. Was this a dodged bullet, or as the more cynical might suggest, was the entire buildup to Y2K more alarmist than realistic?

"It would have been disastrous. There's no question. To me, one of the frustrations – and this is frustrating to anyone who was involved in this – is because nothing bad happened, the assumption was that – there were certainly a lot of scare tactics about what was likely to happen. Ignoring the remediation that was being put in at all levels, but unfortunately that became conflated with "it must not have been a big deal to begin with because nothing happened." Unfortunately, in a lot of people minds, because nothing happened, even the early attempts to raise the level of awareness were viewed as unnecessary. Nothing could be farther from the truth.
...
Now, your question was what if we weren't aware of it. To me, it's unquestionable that the world would have come to an end. Certainly most electronic commerce would have come to an end. It would have been more than disruptive.

> Pretty much, given the degree to which the economy now depends on electronic commerce in the broadest sense. ” (XDU)

The Y2K problem, in this expert’s estimation, was poised to become a catastrophic failure with unforeseen effect. While the “end of the world” statement is possibly overstated, it speaks to an understanding that the reach and scope of information failures are vast, powerful, and potentially devastating.

The list of perspicuous examples is lengthy, especially in the area of catastrophic failure and disaster. Beyond Eberhart’s descriptions of materials failure, Vaughan’s Challenger analysis, Y2K, and the I-35W bridge, litanies of missed details, not-quite-right explanations, oversimplifications – tales of looking directly at a system that was about to fail and not seeing – come to us over and over in tales of nuclear power, railroads, aircraft, genetic science, lead water pipes, oil drilling, electrical grids, and others (145; 120; 32; 34; 33; 147; 87). Though the lessons of spectacular failure are numerous, most systems do not fail on such a grand scale, if at all. The everyday working, the invisibility of infrastructure, the slow and often unrecognizable change of sociotechnical systems from one form to another – to be useful we must turn from the spectacles of failure, having learned that ontic occlusions and exposures are there to be found and leveraged, and turn to more everyday matters of course, and of work. As a less perspicuous, but apposite case, this project looks at the construction of a digital library.

1.3 Research Context

I came to the idea of *ontic occlusion and exposure* as explanatory interpretive mechanisms for systemic change gradually. Through coursework and project opportunities, I garnered an interest in large sociotechnical systems and infrastructures, in particular systems and infrastructures in which information plays a significant role, either as the resource being handled, or as the substrate by which systems are transformed.

Through studying the German TollCollect system, a hybrid GPS/GSM system for commercial toll collection laid on top of the German Autobahn, I encountered narratives from drivers about they changes they perceived in German industrial, social, and economic structures as a result of this change, even though the direct application of the collection system was limited to more efficient charging of commercial trucking. This observation cultivated my interest in the non-linear and n^{th} order effects of technological systems that are embedded larger sociotechnical arrangements. Around this same time (Winter 2006), Paul Edwards exposed me to historical and theoretical work on infrastructures through a class that reoriented my thinking about large sociotechnical systems. Engagement over the next few years with Paul Edwards, Geoffrey Bowker, and Steve Jackson resulted in developing a perspective that we can understand future systems and infrastructures, and approach their development and governance, through a better understanding of successful historical infrastructures (52).

Bruno Latour brought into focus the critical roles that non-human actants and technological implements play in constructing interpretive chains of actor networks by claiming that *technology is society made durable* (96). I realized that this statement is especially true of the assumptions that we encode into systemic structures, and in particular the way we allow them to link together, pass information and resources across boundaries, and make selective representations in the way they may be approached. In this sense of what is seen and unseen, and what is and is not allowable, *standards are social values made technical.* Standardized processes, policies, curricula, shared vocabularies – these are all technologies of negotiation that reflect choices based upon values of what is important and what is less so. This tension between the kept and the discarded or ignored, and the ways in which they become codified, brought me further along to understanding why the ontic is a useful way to understand sociotechnical change.

On another conceptual track that would eventually converge with the infrastructure studies, I also became interested in the formation of interdisciplinarity. Being a member of an interdisciplinary program and department that had formed only a few years before my arrival, I was acutely aware of the excitement and the frustration that comes from negotiating new conceptual territories. There was intense awareness at the time of the previous state of the school – the previously existing School of Library and Information Science (SILS) and its continuing transition. One of the founding faculty, George Furnas, expressed the change in terms of creation myths. He stated that there were at least two creation myths to the School of Information. Creation myth #1, as he called it, was the story of a dying library school that would not have survived on its own, and a group of visionary researchers coming together from other corners of the university with information as a common object of study. In this creation myth, the visionaries took pity on the library school (though not incidentally because they were looking for a physical home, space always being a premium resource within the academy) and offered to let them come along for the ride, giving them a chance at survival. The library faculty saw this chance for survival, and took the deal. Creation myth #2, as Furnas related it, was markedly different. In the second mythology, the library school was an early entrant in realizing the changes information technologies, and in particular the digital revolution, were having on the fundamental relationship between people and information. To pioneer this change, the library school invited scholars from all corners of the university to join in creating a new school with information at the center. The result was the first iSchool (Information School) and began a movement that has been taken up by over 30 universities across North America. In these two creation myths Furnas presented, he reflected that the truth probably existed somewhere between the two stories.

Admittedly, I found the idea of the iSchool creation myths entertaining, but also problematic. The two stories did not specifically mark ends of a spectrum (though I was later to find out that the relevant dimension in these two myths was polar with respect to the relative power of and respect for the library science field.) Further, as I heard accounts from other faculty, from students and staff who had been present for the change, and experiencing the daily practices the change had affected, I sensed there was a deeper story here of how the institution transformed, and the mechanisms that allowed the school to shift from one incarnation to another. When I encountered versions of the creation myths again through the dissertation interviews around the University of Michigan Digital Library story, I came back to the creation myths realizing that these were only two stories out of many. The narrative history of this institutional transformation was a prescient example of the Rashōmon Effect. Each person who related the story had a slightly different view, depending on role and position. Within the stories, though, was an interesting and consistent thread that bridged the institutional narratives and the the tensions expressed about the UMDL project by operating committee members, among others. In particular, an awareness of difficulties in working across disciplinary boundaries in the operating committee was exposed by acknowledging common fundamental terms – building blocks of each epistemic culture's discipline-based world – and eventually realizing their underlying misalignment. The existence of ontic occlusion and exposure in the iSchool transformation story is significant in that the tensions created in the digital libraries initiative experienced an institutional transference to the new school, which continues to expose these ontic primitives as sites of interdisciplinary negotiation in curriculum and pedagogy.

1.4 Summary

I have organized this dissertation in six chapters. Chapter 1 introduced the UMDL/DLI-1 projects briefly and brief notes about the SILS to SI transformation, as well as the concept of *ontic occlusion and exposure* with perspicuous examples. Chapter 2 reviews related literature on ontology and ontics, sociotechnical systems and infrastructure, digital libraries, and interdisciplinary work. In Chapter 3, I describe the dissertation project's primary methods of data collection and analysis, as well as limitations of this project. Chapter 4 discusses the UMDL project and the occurrences of ontic occlusion and exposure at two levels and presents data from 45 interviews conducted with members of the UMDL project, founding members of the School of Information, funding agency and industrial partners of the DLI-1 projects, as well as interviews with researchers on several of the other DLI-1 projects. Chapter 5 addresses issues of ontic occlusion and exposure in the design and evaluation of sociotechnical system-building projects and develops the ontic occlusion and exposure mechanisms to describe the development and outcomes of these projects. Finally, in Chapter 6, I provide a summary of my findings and suggest avenues and directions for future research in this area.

The goal of this dissertation is to develop a proposed set of mechanisms that serve as decoding device for explicating complex social phenomena that have consequences, conclusions, and outcomes arising from representational and discursive practices. The UMDL serves as a case to develop and explain the theoretical concepts of ontic occlusion and exposure, and show how through framing ideas in terms of ontic subscriptions and their interrelationships, we can better understand the dynamics of development, engagement, and assessment with the large sociotechnical systems that surround and support us.

Chapter 2

Related Literature

As with most interdisciplinary arguments, the tendrils of connection can find their way into many corners of academic literature (and not-so-academic literature as well.) The idea that we make choices in representations, and that we face difficulties in reconstructing the multiple perspectives, narratives, voices, and accounts in varying degrees of legitimation and centrality to a phenomenon is a trope that has been articulated in almost every field and age. The literature that has influenced me most in constructing and considering ontic occlusion and exposure, and that I have chosen to detail in this chapter, can be separated into four categories.

First, I explore a brief history of the ontological perspective and present views leading from the ontological to the ontic, beginning with Aristotle's categories, and concluding with Charis Thompson and AnnMarie Mol's work with ontological choreographies in ethnographies of medical science. Second, I describe some of the foundational literature on sociotechnical systems and infrastructures to give a perspective on the complex, heterogenous, and expansive nature of built systems. Third, I present literature on digital libraries as a construct. While there is a dearth of literature on the operations, production, and service aspects of digital libraries, this section will restrict itself to perspectives on the formation of digital libraries as they relate to the DLI-1 and related national projects. Fourth, since the UDML project was an experiment in multi-departmental and interdisciplinary work, I review recent literature on the construction of interdisciplinary work and production, framed in particular as they are relevant to the system-building perspectives of cyberinfrastructure and large sociotechnical systems, such as digital libraries.

2.1 The Ontological and the Ontic

What is so interesting about the ontic, and why does it play an important role in the way we construct discourse? To understand and appreciate the power of the ontic, we should first start with the *ontological* from which it derives. In this section, I present the ontological and the ontic from several perspectives. First, the early Aristotelian categorical work resulting in a universal ontological description. Next, a jump forward to Martin Heidegger, his phenomenological positioning of ontology, and the transition to the ontic. I then present a brief description of the ontic reconceptualization by English philosopher of science, Ray Bhaskar, and finally, I touch upon the work of some contemporary scholars within science and technology studies that actively leverage the ontic and ontological as analytic frames.

2.1.1 Early Ontology and Categories

In Categories, Aristotle introduces the foundations of classification by claiming that there are objects in the world to be named, and that these objects have ten attributes that describe their nature and their relationship to other things in the world (6). The first six categories relate to the attributive nature (substance, quality, quantity, relation, place, and time), then two relating to the relative attributes as a result of residing in the context of other objects (position and state) and the last two relate to the object exerting or experiencing influence from outside itself (action and affection). Together, the Categories form the foundation for ontological work, defined as "the science or study of being; that department of metaphysics which relates to the being or essence of things, or to being in the abstract (136)." Aristotle's ontological construct was undifferentiated, and all things fell under the categorical purview of the system. Thus, Aristotle's categories also implied that all of existence fell into one grand and universal ontological system. While revolutionary as a philosophical construct, the universal ontology is not useful for the myriad ways in which the evolution of scholarship and science would specialize and sub-specialize in the ensuing centuries. As schools of thought and disciplines emerged, a more reflective definition of ontologies might be "a rigorous and exhaustive organization of some knowledge domain that is usually hierarchical and contains all the relevant entities and their relations (149)", which the George Miller and the Princeton WordNet project team attribute to the computer science field, but I argue is a definition of suitable generality that it may be applied to describe disciplinary and domain-based relationships to shared knowledge within a field. This development is in concert with Weber's ontological observation about the information systems field, but is again applicable as a general statement of progress in knowledge work.

> Consider three ways in which a discipline might manifest diversity: (a) diversity in the phenomena (problems) addressed; (b) diversity in the theories used to account for these phenomena; and (c) diversity in the research methods used to understand and predict the phenomena. (157)

I suggest that within the ontological framework that Weber submits in his work, there is at least another possibility of: (d) diversity in the constituent objects and relationships used to represent the phenomena. This is primarily an observation about discourse, and that fields are brought into existence and made real and actionable – as organizational scholar Karl Weick would supply, *enacted* (158) – through speech and discourse that employs particular vocabularies, objects and ontological commitments. As should be clear, but is best pointed out and made explicit, the particularity of a field's ontological commitments implies that the objects and relationships represented are but a small subset of the larger scientific discourse, and a minute corner of Aristotle's ontology. Disciplinary discourse introduces the conceptually manageable, and renders all else external by not introducing it at all. The consideration of what is and is not introduced through the discursive statement, Carnap and Bar-Hillel show that a statement's content is more than simply the information represented by the constituent primitives presented, but also becomes a proxy for the associated systems it logically implies (10; 28). “A discourse has more content if it has covered the reality being talked about in a more thorough way than say another discourse attempting to cover the same reality. If a substantial segment of the reality under consideration as not been covered, the content of a discourse is seriously deficient. (88).” By these measures, much of the early conversations in formative interdisciplinary work are seriously deficient of content. The early work of identifying common vocabularies begins with gross acts of finding common terms, though as we will see through the UMDL operating committee work, common terms do not imply common meaning or understanding. First. common terms are used and continue to be adequate joint referents despite underlying misalignment until we understand that the elements of discourse in this case are not only used to communicate information and ideas across boundaries, but are also enactments to prompt action and construction in the “real” world(163; 50). We construct reality discursively, but we also take other actions as a result of constructed realities. In the case of interdisciplinary projects like UMDL, the problematics of equivocal terminologies become apparent when people begin to take incompatible or incommensurate actions and begin to acknowledge the tensions and gaps between parts of the system that much be joined together. The discourses of disciplines, both within the boundaries of practitioners, as well as those used to communicate knowledge and findings to the outside world (or, as may be the case, arcane languages designed to enforce the boundaries even more strongly), necessarily are composed of an ontological subset of Aristotle’s universal set of categories.

2.1.2 Heidegger and the constraints of Being

A significant influence on the philosophical field of ontology in the 20^{th} century arises through the work of phenomenologist Martin Heidegger. WIthout reconstructing the considerably difficult holism of Heidegger’s work, there are key concepts that are apposite in constructing the ontic occlusion and exposure concepts. In <u>Being and Time</u>, Heidegger presents a metaphysics of objects with language to describe their roles as actors and as tools (71). Heidegger's occupation with the nature of Being, and the ability to know and reflect upon that existence, gave rise to several constructs of particular relevance to the ontic occlusion and exposure concept. First, Heidegger explains the difference between the ontological and the ontic, and the conceptual bridge over which we cross to understand the difference. This is perhaps best detailed by Hubert Dreyfus in pointing the requisite facticity of the ontic (46, p. 20). The act of design, bringing into being, must then move from the ontologically imagined to the ontic or factitial. The act of evaluation, then, is also focused on that factitial, concrete, and existing product of design. To consider being from a phenomenological perspective, one must consider the world as it is, and not as it is wished to be. Design is making the world, concealing the aspects of being we do not wish to attend. Evaluation is revealing those things that we agree to attend, and still further conceal those that we reject or cast as residual (152).

In his later work, Heidegger returns to his earlier occupation to describe the relationship between things and their essences, put forth as the relationship between *physik* and metaphysics (73, p. 337). In Mindfulness, he makes the strong claim that the primary barrier to knowing *truth*, as it exists in relationship to states of Being, rests on the tension between things that are unconcealed because of their mere presence, and those that are unconcealed to us because we make a deliberate turn to look at them. He states, "What is important here is the undisplaced, undistorted emerging in itself of what presences,that is, the emerging of what maitntains itself fully in its ownmost, that is, in the presencing of its 'what' (the turning unto)." I make a break with Heidegger here by substituting the word *unconcealment* with *exposure*, as the latter does not presuppose that any ontic had previously been the focus (i.e., to unconceal something, it must have been concealed, which speaks to intentionality. On the other hand, something may be exposed when it had not been previously unexposed.) These acts of concealment and revelation are largely played out through discourse, and in particular, truth claims. In describing Heidegger's analytical frame, Carman explains,

> Discourse is a fundamental feature of being-in-the-world, reducible neither

> to the disposedness that orients us in our given situation nor to the understanding in which we project ourselves into future possibilities. Discourse is a primitive way in which entities show up and are intelligible for us; it is a basic structure of being-in-the-world (27).

The combination of discourse and the dynamics of concealment and revelation in understanding Being also led Heidegger to an acute concern with technological advancement and our relationship to the world. I believe this to be Heidegger's enduring genius in recognizing that his concept of throwness (that we are not all equal in our being-in-the-world, and our circumstances into which we are thrown – our *throwness* – is determinant of our native reflexivity) and the enframing of our being by technological constructs, what we contemporarily call *infrastructure* or *cyberinfrastructure*, are core to our ability to engage the discourses that lead to our truths.

> Enframing does not simply endanger man in his relationship to himself and to everything that is. As a destining, it banishes man into that kind of revealing, which is an ordering. Where this ordering holds sway, it drives out every other possibility of revealing. Above all, Enframing conceals that revealing which, in the sense of *poiēsis*, lets what presences come forth into appearance (72).

In Heidegger's estimation, and as a central theme of "The Question Concerning Technology", we are warned that the deep dynamics of concealment not only stand in the way of understanding the truer nature of being-in-the-world, but also may foreclose possibilities of discovering alternative revelations.

Two of Heidegger's contemporaries make relevant philosophical contributions to understanding the role of the ontic in the interpretation of sociotechnical systems. Such large systems are often built to stand longer than the human lifespan. Thus, the narrative of their existence and stewardship is shared across generations, giving a sense of historicity to their being. Because these systems, infrastructures, go unnoticed and invisible for most of their operating lives, the historical accounts can be fragmented. Walter Benjamin comments on the dubious nature of material historical narrative.

> Historicism contents itself with establishing a causal connection between various moments in history. But no fact that is a cause is for that very reason historical. It became historical posthumously, as it were, though events that may be separated from it by thousands of years. A historian who takes this as his point of departure stops telling the sequence of events like the heads of a rosary. Instead he grasps the constellation which his own era has formed with a definite earlier one (15).

and further

> The historical materialist cannot do without the concept of a present which is not a transition, in which time originates and has come to a standstill. For this concept defines precisely *the* present in which he writes history for his person. Historicism depicts the "eternal" picture of the past' the historical materialist, an experience with it, which stands alone. Hie leaves it to others to give themselves to the whore called "Once upon a time" in the bordello of historicism. He remains master of his powers: man enough, to explode the continuum of history. (14)

Benjamin establishes that the flow of material history is narrated from the vantage point of the present, which necessarily "fills in" the segments between recorded events and resulting artifacts to create a flowing, linear narrative. This reconstructive act to resolve our fragmented sense of historicity is at the core of the mechanism by which historical accounts give rise to ontic occlusions. Because our histories are incomplete, we make choices in their linear reconstruction, often discarding actual occurring events because there are no enduring or detectable records or traces, or because they pose threats to the desired linearity.

As a student of both Benjamin and Heidegger, political philosopher Hannah Ardent gives voice to an elegant restatement of why remembrance is critical, and how cycles of remembering and forgetting have qualities of enabling and constraining human progress.

> With the loss of tradition we have lost the thread which safely guided us through the vast realms of the past, but this thread was also the chain fettering each successive generation to a predetermined aspect of the past. It could be that only now will the past open up to us with unexpected freshness and tell us things that no one has yet had ears to hear. But it cannot be denied that with a securely anchored tradition – and the loss of this security occurred several hundred years ago – the whole dimension of the past has also been endangered.

> We are in danger of forgetting, and such an oblivion – quite apart from the contents themselves that could be lost – would men that, humanly speaking, we would deprive ourselves of one dimensions, the dimension of depth in human existence. For memory and depth are the same, or rather, depth cannot be reached by man except through remembrance (5).

And as further explicated by Maurizio Passerin d'Entreves to interpret Arendt's synthesis of Heidegger's deconstructive turn to render ontologies visible and Benjamin's problematics of historical fragmentation in deriving those categories:

> To re-establish a linkage with the past is not an antiquarian exercise; on the contrary, without the critical reappropriation of the past our temporal horizon becomes disrupted, our experience precarious, and our identity more fragile. In Arendt's view, then, it is necessary to redeem from the past those moments worth preserving, to save those fragments from past treasures that are significant for us. Only by means of this critical reappropriation can we discover the past anew, endow it with relevance and meaning for the present, and make it a source of inspiration for the future (40).

The movement from Heidegger's ontological development into a broader discussion of specific ontologies, Quine asserts that hermeneutic facticity must conform to existential logics. In a discussion on Quine's description of the semantic absurdity in considering a "round square cupola", Jacquette engages a discussion developing "ontological commitments" whereby we commit to an ontology that permits a round cupola or a square one, but not a round square cupola (85). This is to say that our ontological commitments must resonate with an operating logic or calculus prescribed by our phenomenological positions. Extending from Jacquette's rejoinder to Quine, the idea can be extended to ontic commitments. These ontic commitments are not only the agreements about what can logically and legitimately be named and described in the world, but an acknowledgement of what particular manifestations exist in a case, and agreement that they do indeed exist (and what their qualities might be, returning to Aristotle's original ten categories.)

2.1.3 Post-Heideggerian Ontology

The concern with ontology and ontics has found continued relevance beyond the phenomenological concerns of Heidegger and his immediate descendants. Philosopher, computer, and information scientist Brian Cantwell Smith. Smith relates the ontological to sociotechnical systems by constructing a view of computer science and society such that the world represent the *throwness* into which technology finds itself and must adapt, but concurrently our evolved large sociotechnical systems, infrastructures, and cyberinfrastructures represent another type of throwness that frame the phenomenology of people (137). Since the language of ontology has significant claim both in the humanities as well as in computer science, but has come to mean quite different things to those respective communities (and, no doubt, many others who find a stake in the ontological), Smith's discussion bridging the classical and computational senses of metaphysics, relations between being in the world and being in computation, and the journey from naturalistic object to constructed computer object – these stories lay a strong argument that the ontological remains a core concern for designing, understanding, and interpreting or evaluating the complex arrangements of technologies and resources that produce the operating world [1].

English philosopher of science, Roy Bhaskar, makes particular note of the ontic, as opposed to the ontological, in a way that is most closely articulated with the sense that I wish to convey in the ontic occlusion and exposure concept. Within the operating discourses of interdisciplinary work, the ontic as attached to the disciplinary denotes the concrete (17). As Bhaskar defines:

> I differentiate the 'ontic' ('ontical' etc.) from the 'ontological.' I employ the former to refer to (1) whatever pertains to being generally, rather than some

[1] Information systems and business researcher Lucas Introna makes heavy use of Heidegger, Latour, and other familiar sources to mine in discussions of information technology and systems design. On a similar but separate track, he focuses more heavily on the deontological rather than the ontological, and questions the morality and ethics embedded in the co-constituted relationships between society and technology (83; 84). While these are, of course, interesting and important questions, I do not explore Introna's work in this review as I am more intently focused on ontic questions of what elements and perspectives are in discursive play, rather than the ethics and morality of their inclusion and exclusion.

> distinctively philosophical (or scientific) theory of it (ontology), so that in this sense, that of the *ontic*$_1$, we can speak of the ontic pre-suppositions of a work of art, a joke, or a strike as much as a theory of knowledge; and within this rubric, to (2) the intransitive objects of some specific, historically determinate, scientific investigation (or set of such investigations), the *ontic*$_2$. The ontic$_2$ is always specified, and only identified, by its relation, as the intransitive object(s) of some or other (denumerable set of) particular transitive process(es) of enquiry. It is cognitive process-, and level-specific; whereas the ontological$_2$ (like the ontic$_1$) is not. Thus, a world without human beings would have an ontology$_2$ (although obviously there would be no one in such a world to articulate it) but not an ontogeny$_2$; the ontological$_2$, but not the ontic$_2$, compasses the intransitive objects of non-actualised (and perhaps humanly impossible) scientific enquiries; and the ontological$_2$ includes, while the ontic$_2$ excludes, the processes of scientific enquiry of which the ontic$_2$ in question is the ontic$_2$[2]. 'Epistemology' pairs with 'ontology', and the 'epistemic' with the 'ontic'. . Consequently an epistemic$_2$ process or product falls within the ontological$_2$ (and ontic$_1$), but not within *its* ontic$_2$, though it may of course become the ontic$_2$ of a higher-order, or reflexive, enquiry.

Bhaskar's sense of the ontic is specific and rarified to a more intense philosophical discussion than is necessary to understand the ontic occlusion and exposure mechanism; however, the distinction he makes that the ontic$_2$ is the product of intentional inquiry is significant insofar as it distinguishes the commitments required for disciplinary work from the commitments required for more general social interaction and function, as in ontic$_1$.

Focusing more intently on the social nature of disciplinary work, there are particular problems of coordinating work that passes between groups, disciplinary cultures, different ontological commitments, and in the work itself, ontic constructions. Two researchers who address this problem brilliantly do so in the context of medical practice. Charis (Cussins) Thompson looks to infertility clinics to understand treating medical patients (both parents and embryos) and their transitions from humans with agency to objectified subjects for insertion into medical technology. Through this ethnographic analysis, Cussins introduces the concept of *ontological choreography*, a process by which ontological subscriptions

[2] *Continuation of Bhaskar quote*: "My concepts of the 'ontological' and the 'ontic' are not equivalent (or theoretically indebted) to Heidegger's. But Heidegger's 'ontological', the realm of everday pre-understood being, is encompassed within my umbrella 'ontic$_1$'; and Heidegger's 'ontic', having nothing to do with entities, overlaps with my 'ontic$_2$', the specific intransitive objects of particular scientific, more or less empirically-based, enquiries."

and commitments of different communities are realigned to allow information, agency, intention, and action to move across the boundary while maintaining the authenticity of actors on both sides (37; 146). Much like the analog in dancing, ontological choreography involves intentional work to achieve a plan of action that multiple actors can perform with successful coordination. Following this stream of work, but concentrating more specifically on the ontological choreography involved in producing scientific work, medical anthropologist AnnMarie Mol presents a detailed view of the social and ontological construction of arteriosclerosis as an object as information is passed between the clinic and pathology departments of a Dutch hospital (109). Since clinicians experience the disease indirectly through the signs and symptoms of living patients, and in representations rendered through medical technology, the terms, concepts, physiological primitives and relationships used to describe atherosclerosis make ontological commitments to dynamic states. Pathologists, on the other hand, experience the disease more directly through direct observation of necrotic tissue, measurement of cells and arterial radii, and other static ontological constructs. If we can accept that arteriosclerosis is mainly transformed into sets of information representations that move between the clinical and pathological worlds, it becomes clear that substantial ontological choreography must be done to reconcile the dichotomies of necrotic and live tissues, direct and indirect observations, and most importantly, tending to the care of a live patient versus taking time to understand disease at the pace of laboratory science. What Mol and Thompson do not express explicitly, but is certainly present in their writings and observations, is that not only the ontological as a pre-enacted choreography plays a role, but that once the choreographed plan is set in motion (i.e., the performance), the ontic becomes the central figure of operating objects and relationships – not what arteriosclerosis could be, but what *this* patient presents, and how it is translated into *that* set of samples for the lab, which are appropriate for *these* analytic tools of the pathology trade. The transition from the ontologically choreographed to the ontically enacted is emblematic of typical transitions from present-at-hand to ready-to-hand allowing fluidity of everyday interactions and the production of useful knowledge.

The present-at-hand and ready-to-hand states Heidegger describes are fundamental to our ability to consider Being. In the case of ontic occlusion and exposure, they are the crux of fluidly moving between the hidden and revealed elements composing sociotechnical systems. To further extend this concept and its relevance to organizational structure and work, Weick proposes another category of *un-ready-to-hand*.

> If an ongoing project is interrupted, then experience changes into an *unready-to-hand* mode. Problematic aspects of the situation that produced the interruption stand out in the manner of figure-ground organization, but people still do not become aware of context-free objects. For example, if one is delayed leaving the house to catch a scheduled train, then time and the train station become salient as do shorter routes, one-way streets, anticipated parking problems, timetables, back up departure times, etc. (160)

Extending this idea further, ontic occlusion and exposure present a complement to Weick's observation. Namely, the construction of narratives that occlude the relevant contributions of others, those that create unseen or residual categories occupied by important perspectives, relationships, and other discursive elements are *unpresent-at-hand*. For example, if a digital library is designed and constructed primarily by engineers, then computer architectures, rational agents, and content should and must follow an elegant and efficient path from the problematized statemtent to the eventual form of the solution. Because the world of engineering does not contain a library patron's indecision, relative lack of knowledge about a subject, apprehension, curiosity, or pure whimsy (note: these are human aspects that reference librarians encounter and manage as daily course), some of the relevant aspects of digital libraries *in use* remain unpresent-at-hand in explicit discussions and constructions of a digital library.

Coming out of a discussion of the ontological and ontic in relation to considering (cyber)infrastructure and sociotechnical systems, there are four framing concepts that are particularly relevant. First, that categories and classifications create both enablements and constraints in the ways narratives about the world are constructed and communicated. Second, that the ontic as a mode of acknowledging the realized or manifest is a reasonable frame to discuss change in sociotechnical systems and projects. Third, throwness, or the contexts in which configurations of humans and machines find each other, is an equally important set of elements to consider when designing and evaluating sociotechnical systems. Fourth, it is useful to understand the transitions between *present-at-hand* and *ready-to-hand* states of objects in order to understand ontic coordination and choreography in producing both work and artifacts.

2.2 Sociotechnical Systems

2.2.1 Assembling What Lies Beneath

The complicated, ever-present systems that undergird the operational existence of society have come to be studied as "infrastructure", a compound of the Latin *infra-*, meaning "below" and *structus* or *struere*, meaning "to build or assemble[3]." There are several accounts for the introduction of the term, some claiming its use in 19^{th} century France and others marking 1927, when the American military culture began to use the term to describe the interconnection of roadways, electrical resources, waterways, etc. Despite the origins, the term generally refers to the heterogeneous interconnection of systems that support the fluidity of services and interactions that are the attention of everyday matters. It is because of this supporting nature that the *infra-* tag is important. Infrastructure lies below the attention of those who use it. It is typically transparent, only becoming visible when it does not function properly. There are several canonical pieces describing the development of infrastructure, which I will briefly outline. One of the most concise and well-formed is found in the section entitled *Dynamics* in a recent report to the National Science Foundation on Understanding Infrastructure: Dynamics, Tensions, Design (52). I will mention the main points, but leave the fleshed-out description to the report, rather than recreating it in entirety here.

[3]From the 2006 Random House Unabridged Dictionary

The history of infrastructure draws from many examples ranging from the expansive and impressive sewer systems in Paris (98), to the HAFRABA Association's plans for a German Autobahn that was realized by Hitler (150)(151), to the rise of railways (62), electrical power (64)(79), and telephone/telegraph systems (63) in the United States (30). More recently, the compelling infrastructure story has been told around the development and adoption of the Internet (1). The earlier descriptions of infrastructure growth, especially those told by Friedlander, comment that historical U.S. infrastructures have grown with substantial private and government subsidization, and often with governmental regulation. Even modern infrastructure stories, particularly those from the literature on megaprojects[4] (3)(59), include the political tensions of funding and coordinating large-scale public goods development. Curiously, the story of the Internet, while still rife with politics, government investment in the early stages of ARPANET and NSFNET, and attempts at regulation (as seen with the recent controversy over net neutrality), does not have the same spectre of ongoing centralized governance hovering over its advance.

Despite these differences, historians, philosophers, and sociologists of science and technology have come to describe commonalities of what we identify as infrastructure. Susan Leigh Star and Karen Ruhleder have outlined a list of attributes found in infrastructures (142). Specifically:

Embeddedness: Infrastructure is sunk into, inside of, other structures, social arrangements, and technologies.

Transparency: Infrastructure is transparent to use in the sense that it does not have to be reinvented each time or assembled for each task, but invisibly supports those tasks.

Reach or scope: This may be either spatial or temporal – infrastructure has reach beyond a single event or one-site practice.

[4]Megaprojects, according to Bent Flyvbjerg, a leading scholar in the area, are infrastructure projects that typically cost more than US$1 billion, and are usually public goods such as bridges, tunnels, transnational thoroughfares, toll collection systems, etc. Flyvbjerg shows evidence that most megaprojects are of substantial risk and have a high incidence of failure, especially in terms of budget control and timelines.

Learned as a part of membership: The taken-for-grantedness of artifacts and organizational arrangements is a sine qua non of membership in a community of practice. Strangers and outsiders encounter infrastructure as a target object to be learned about. New participants acquire a naturalized familiarity with its objects as they become members.

Links with conventions of practice: Infrastructure both shapes and is shaped by the conventions of a community of practice; for example, the ways that cycles of day-night work are affected and affect electrical power rates and needs. Generations of typists have leaned the QWERTY keyboard; its limitations are inherited by the computer keyboard and thence by the design of today's computer furniture.

Embodiment of standards: Modified by scope and often by conflicting conventions, infrastructure takes on transparency by plugging into other infrastructures and tools in a standardized fashion.

Built on an installed base: Infrastructure does not grow de novo; it wrestles with the inertia of the installed base and inherits strengths and limitations from that base. Optical fibers run along old railroad lines, new systems are designed for backward compatibility, and failing to account for these constraints may be fatal or distorting to new development processes.

Becomes visible upon breakdown: The normally invisible quality of working infrastructure becomes visible when it breaks; the server is down, the bridge washes out, there is a power blackout. Even when there are backup mechanisms or procedures, their existence further highlights the new visible infrastructure.

Is fixed in modular increments, not all at once or globally: Because infrastructure is big, layered, and complex, and because it means different things locally, it is never changed form above. Changes take time and negotiation, and adjustment with other aspects of the systems involved.

It is with these defining attributes of infrastructure that we move forward. Of course, there is no guarantee (or implication, for that matter) that this list is exhaustive. As we study and understand infrastructure further, more patterns and interpretations may emerge.

2.2.2 Systems and Hughes' LTS View

Thomas Parke Hughes, historian and sociologist of science, is arguably one of the most prominent figures in generating widely-accepted theories concerning infrastructure and its rise. Hughes cast the growth of infrastructure not as a grand scheme that is conceptualized from the outset; rather, he described the local and entrepreneurial construction of *systems* that, over time, are assembled into larger systems, networks, and networks of networks (or *internetworks*, to employ a phrase used by Paul Edwards[5]). In Hughes' view, systems are differentiated from innovation or inventions by the fact that they are constructed to deliver a *service* rather than a *function*. A primary example is the attribution of the lighting system created by Thomas Edison (80). While others had already invented the light bulb, Edison was the first to consider not only the immediate effects of the bulb, but the larger set of innovations that were required to deliver not just light, but the service of lighting (transformers, cables, power supplies, etc.) Systems are conceived and constructed, then, by a *system builder* who is entrepreneurial in nature. Thus, Hughes provided both an actor and a mode of agency to the construction of infrastructure or, as Hughes' theory has come to be known, LTS or Large Technical Systems.

The pattern of infrastructure development described by Hughes follows a proscribed path as follows (79).

[5] An excellent point was made by Marianne Ryan of the University of Michigan School of Information on March 28, 2006, regarding the systems/networks/internetworks view of infrastructure. Specifically, she cautioned that these terms are structural, whereas infrastructure itself is functional. While the structural terms are quite helpful in demarcating the historical periods in the growth of infrastructure, these transition points should become blurred, seamless, transparent, and largely irrelevant once an infrastructure reaches the point when it is working properly. By extension, we may also ask whether these terms are only useful in historical analysis of infrastructure, or if they may assist in the ongoing dialogue of infrastructural inversion.

1. *Invention* – At the basic level, the fundamental elements that are to be later assembled must be built. Typically, this is at the level of the individual technology (i.e., the light bulb).
2. *Development* – Still at the level of the individual technology, the efficiency and design are refined.
3. *Innovation* – This is the point at which the system builder/entrepreneur conceives a wider application and the systemic requirements that must be assembled to construct a locally-working instantiation.
4. *Technology transfer* – After one successful copy is created, the system must be able to survive in other environments. Since the context varies, adoption after transfer leads to changes in the system that allow contextual adaptation (and, arguably, systemic robustness).
5. *Growth* – When a large enough number of separate installations exist, standardization takes place. The system can be recreated with less overhead and cost of making mistakes.
6. *Competition* – Separate systems of standards emerge and vie for dominance in supplying the system.
7. *Consolidation* – The differentiated market tends toward either monopoly or oligopoly structure and standardization achieves a certain measure of closure. From here, systems (or in further cycles, networks) can be linked to scale up toward working infrastructure.

Edwards points out that the diffusion and adoption rates of these large technical systems follow a typical S-shaped curve (52, excerpted from Grübler and Nakâcenoviâk 1991). Other LTS scholars, though, suspect that this may be an overly deterministic view, and that later phases of infrastructure building may be punctuated periods of equilibrium and disequilibrium (144)(153).

Not to be missed in Hughes' estimation of large technical systems, nor to be betrayed by the privilege given by the term's focus on the technical, there are undoubtably social aspects to infrastructure. As pointed out by Erik van der Vleuten, in reference to Hughes' 1987 article,

> Another original LTS argument that is still important is that technical infrastructure elements are increasingly intertwined with non-technical ones (79). In the establishment phase(s) technical designs are adapted and coupled to an actor playing field, organization structures, marketing strategies, legal frameworks etc; in the expansion phase such sociotechnical intertwinement is further strengthened to the degree that technical and non-technical elements interlock and make the whole thing difficult to change (154).

Based on this interpretation, it may be more prudent to think of Hughes' view on infrastructure as Large Sociotechnical Systems, not just built for actors to use, but to incorporate them into the structure itself.

2.2.3 Reverse Salients

When major breakthroughs are made, it is not uncommon to look back and see that several innovators made the same discovery at roughly the same time, though it is clear that there was no communication among them. This has given rise to the concept of "an idea whose time has come." Still, there is no mechanism in the aphorism to explain why this happens. For instance, the method to measure the parallax of a star was discovered in 1838 by three independent scholars, Bessel, Struve, and Henderson, each working independently and without knowledge of the others' work (100). Science and technology studies are filled with similar phenomena.

Hughes addressed this problem with the first plausible and non-mystical explanation (79)(80). The idea of the *reverse salient* was drawn from a military examples, where the advancing line of soldiers is held back at one point. Another apt metaphor for reverse salience is that of moving a rubber band across a piece of wood with a nail sticking out. The band remains straight until the nail is encountered, but when the band snags on the nail and the edges of the band keep advancing, tension builds at the point of the snag until something gives (in physical terms, this would usually be the rubber band snapping, but for our purposes, let us assume that the band is indestructible and can pull the nail out of the board.) Suddenly, the band snaps back into place. Hughes' explanation was that apt and savvy innovators can sense this growing tension in systems, and know where to look for new ideas. Then, he believed, it stood to reason that several people, all sensing an opportunity and working on similar problems, would produce solutions in a relatively short time frame.

The reverse salient is the explanation for the realization of technologies (both human and non-human, social as well as mechanical) that appear to allow systems to grow, connect, and advance. Through Hughes' explanation, we can provisionally understand how and why infrastructure slowly assembles as the need for coordination scales upward.

2.2.4 Infrastructure as a Term Without Closure

The academic study of infrastructure tends to use historical examples. Infrastructures are identified after they have become ubiquitous. While they may not have achieved closure of the systems involved, they must achieve a certain level of stability to gain transparency. Still, they shift, grow, and take on new meanings as other systems are built and changed around them, and ultimately connect to them in new ways. Bowker and Star provide one of the field's most concise and well-used descriptions of analyzing infrastructure and making the transparent visible. It bears discussion, though, that there are limitations to any lens for examining infrastructure. For a target that is constantly shifting and of such sprawling complexity, any tool bears periodic examination. Following is a reaction to the first chapter of Sorting Things Out: Classification and Its Consequences. (25). While the discussion raises more questions than it could possibly hope to answer, the hopeful point to be made is that open questions remain and any framework for looking at infrastructure can be a contested tool.

This opening chapter of Bowker and Star's book on infrastructure introduces the concept of infrastructural inversion as a technique for understanding and analyzing the complexity of infrastructure. The title of the chapter, "Tricks of the Trade," implies that there are lessons learned in constructing useful stories of infrastructure; however, there seem to be more than tricks at work. Rather, there are several theories and models that come together.

The first point made is that good information infrastructure is invisible, forgotten, or transparent to the user. It is unclear whether this is simply a characteristic of good design, or that it is beyond the routine cognitive abilities of people to hold such complex structures in mind, or whether it is useful to do so in mode with Heideggerian tool-being dichotomy (69)(71).)The first paragraph indicates that unless we have reason to consider the nature of the infrastructure itself, issues of scale related to defining the boundaries of an infrastructure make it inefficient to consider the totality of the system. At the bottom of the page, the authors mention “we can achieve a deeper understanding of how it is that individuals and communities meet infrastructure.” Is this to say that individuals are separate from infrastructure, or that communities are not examples of social infrastructure[6] (or that social infrastructures are different from other information or technological infrastructures?) The next page makes a statement which does not bear out by the end of the chapter. Specifically, the authors claim that infrastructural inversion is not simply descriptive, but exposes the causal factors in the operation of systems. Looking at the list of attributes that define infrastructure, none address causality directly. For convenience, a recapitulation with a few interjected notes, infrastructural attributes are:

- *Embeddedness:* How do we measure embeddedness? At what threshold is an element or system“ embedded enough,” and what purchase do we gain by saying it is so?
- *Transparency:* Infrastructure is never transparent to everyone at all times. Actors can concurrently embody multiple roles, and the electrician who uses a television at home and also repairs power lines cannot be assumed to be aware of electrical infrastructure in one situation and not in the other. It is possible that transparency can only be claimed contextually or temporally.
- *Reach or Scope:* This is defined by Bowker and Star as spatial or temporal. Are there any other ways to define scope that would be helpful?
  - Economic
  - Speed (in terms of bitrate transfers within technological networks or diffusion rates of diseases)
  - Physical properties of materials (such as hydrophobic and hydrophilic properties within protein infrastructures)
- *Learned as a part of membership:* This crosses over with Etienne Wenger’s descriptions of communities of practice and legitimate peripheral participation (161), as mentioned in the original; research on virtual environments shows that this process of learning is not completely understood, and that implicit social structures can be transmitted quickly through decentralized means (95).
- *Links with conventions of practice:* Could this be in line with Karl Weick’s theory of enactment (159)? Various other theories of organizational routines?
- *Embodiment of standards:* Even standards are a tricky and shifting platform upon

[6]This is, of course, making the assumption that the idea of infrastructure can be extended to human or social systems, or systems that rely on both in chains. This interpretation would be consistent with the Latourian description of human-technology chains in systems (96).

which to stand, as shown by Forster and King discussing standards in the air cargo industry. The caution is well-deserved in stating that standards must be generated below the level of the work, or else contend with significant organizational and work culture barriers (60).

- *Built on an installed base:* This indicates that history is important. Is the nature of infrastructure path dependent (39), or phat dependent (118)?
- *Becomes visible upon breakdown:* or, clearly, upon infrastructural inversion, or in the case of cyberinfrastructure, when it is the constant object of discussion.
- *Is fixed in modular increments, not all at once or globally:* But how do we discern the proper units of scale or aggregation for analysis? These choices, in themselves, are constraining in interpreting and telling infrastructure stories. This also seems to indicate that it is not useful to understand infrastructure as a "snapshot" and that infrastructure is about process - following information or resources through the network to see where they go. This is descriptive of propagating and/or causal effects. Is this where the causal argument is being made? If so, it is not explicit.

The example of infrastructural concerns that used the infrequency of unusually long concerts is engaging. Why are full performances of Wagner's Ring Cycle difficult to produce, save the simple fact that it is difficult for performers? The same argument applies to unusually short concerts. No one would pay for parking, nor would a performance house likely rent out space for a 15-minute piece. Can it be said that in order for infrastructure to work well and efficiently, there is a "sweet spot" or, in economic parlance, "bliss point" for resources? Incidents that are outside of this sweet spot are the ones which tend to make us sit up and take notice. Spectacle is always – spectacular. It is a matter of concern (in the Latourian sense (97)) when we see a staging of the Ring Cycle, or an art installation that is larger than life. Are we in awe of the art, or in awe of the infrastructure that has become highlighted? The size of doorways in museums and galleries are an infrastructural limitation of art installations, and "These constraints are mutable only at great cost, and artists must always consider these before violating them." Now that digital art is gaining ground, these traditional infrastructural constraints seem to fade in relevance, making way for an entirely new set of infrastructure and attendant enablements and constraints.

A subproperty of ubiquity is interdependence. While this makes sense in a practical way, it does not follow from the preceding sentences, "This categorical saturation furthermore forms a complex web. Although it is possible to pull out a single classification scheme or standard for reference purposes, in reality none of them stand alone." The implication from the statement, as given, is that all things that are interdependent are ubiquitous. This is simply not true. It would seem that the opposite is really what the authors are trying to say. That is, that all things that are ubiquitous are interdependent. Even this is not necessarily true. Either way, it seems only reasonable to say that ubiquity and interdependence are correlated - and that they seem to be strongly correlated in the case of infrastructure, possibly enough to suggest causality, but the simple argument put forth is not enough to establish this link. Further on page 38, the "in between" spaces are discussed – the places between established standards and the undefined or undefinable parts of infrastructural modularity. What really happens here? Are these the domain of ad hoc behaviors? How does this operate? Infrastructure works, so these ad hoc methods must work as well. This phenomenon seems like a prime target of research. Fertile ground for developing theories. The last sentences on the page, "It is a struggle to step back from this complexity and think about the issues of ubiquity rather than try to trace the myriad connections in any one case. The ubiquity of classifications and standards is curiously difficult to see, as we are quite schooled in ignoring both, for a variety of interesting reasons." This sounds more akin to philosophy than science. To reground in science, the explanation offered is aligned with Russell's views in "The Cost Structure of Sensemaking," suggesting that these unexplored spaces and difficulties in mastering the complexity carry too high a cost in assimilating the conceptual residue in our current understanding of infrastructure (128).

The discussion of materiality and texture makes some good points, but may be limited in requiring classifications and standards to have a physical component. Specifically, in On the Origin of Objects, Brian Cantwell Smith puts forth the idea that ontologies (which are undeniably systems of classification and standardization) are not anchored to the physical constancy of objects, and are in persistent states of flux, constructed from multiple stances of interpretation, each correct in its own right (137). Materiality and texture are attributes of physical systems of which we consistently make use in constructing classifications and standards, but they are by no means necessary and/or sufficient conditions for a working ontology. “When we think of classifications and standards as both material and symbolic, we adapt a set of tools not usually applied to them.” Are there cases where this is not useful? This section invokes an ANT approach to explaining infrastructure, which is anti-theoretical. Is this helpful?

The section on indeterminacy of the past strongly implies “remediation” and “postdictive interpretation.” Again, anti-theoretical in the sense that if postdiction is the interpretive lens, a theory of infrastructure would not satisfy the often-adopted requirement that theory be predictive (126). The passage goes on to comment on multiple voices and silences. This is reminiscent of Kuhn’s observation that in order for theory to progress, we must disavow and forget previous theoretical explanations (93). In parallel, in order to embrace a new, more robust classification system, we must also forget the previous classification, denouncing it as archaic. This is not so easily done when the infrastructure is ubiquitous and the cost of shifting high. For example, the Dewey Decimal System is still entrenched in today’s library classification structures, where psychology remains a subclassification of philosophy and unrelated to the natural sciences; curious in an age when the academic practice of psychology research is firmly rooted in the tradition of mainstream (and traditional) practices of scientific method.

The next section exposes my clear tendency toward using the most recent classification systems to interpret phenomena. The example of classification of English, Irish, Scots, French, etc. in an age that had no concept of “national genius” seems refutable. If there is available data to prove that factions developed along these nationalistic lines, the argument that the peoples involved were unaware of the delineations loses salience, regardless of whether the language to describe the factions existed at the time. Very often in clustering or sorting, we know the attributes in order to discern objects before we have decided the names of the bins in which we place them. The phenomena persist. In a similar vein, the rise of “revolution’ through Marx’s writings does not nullify the fact that revolution existed before Marx's observations. Revolution is a purely postdictive interpretation. How does one realize that one is in the middle of revolution, or when it will end? Arguably, the world is in a constant state of revolution, so creating classifications to aggregate historical events in an interpretable way is a useful tool, whether anachronistic or not. This is not to say that it is not important or useful to understand what classifications were in existence at the time, and the infrastructural constraints that may have influenced the historical event; however, modern science should feel obligated to bring its accumulated knowledge to bear in reinterpreting historical events to discern patterns accurately.

In the following section on infrastructure and politics, the question arises: Should classification schemes, and the way we define infrastructure, first be designed and then implemented or applied, or should they be emergent? This is like a snake biting its tail. The structures of the physical world, of cognitive structures and ideas (even of semiotic relationships) have inalterable and irreversible properties resulting from their path-dependent histories. Thus, there are emergent aspects that can be called infrastructure. Within these constraints, we form strategies, policies, laws, and politics to make the most efficient use of the existing infrastructures that we can. Which came first? Do they co-evolve? This seems likely. The section concludes remarking that it is difficult to manage the politics and policy creation process because while people are concerned with infrastructure, they are rarely looking at the same parts of it while using parallel language. Once again, we see problems regarding levels of scale and aggregation. Bowker and Star refer to this as granularity, but the fact remains - we need to be more attendant to matters of scale and the scales that matter, rather than simply labeling and shelving the issue.

After a description of the interaction between psychological/psychiatric practice, insurance requirements, and the DSM (One may ask here, what "shadow systems" are in place, and what can be found there (134)? Are these strong boundary objects (141)?), the chapter ends with the statement that schizophrenia may only be defined in one way. Specifically,

> This blindness occurs by changing the world such that the system's de-

> scription of reality becomes true. Thus, for example, consider the case where all diseases are classified purely physiologically. Systems of medical observation and treatment are set up such that physical manifestations are the only manifestations recorded. Physical treatments are the only treatments available. Under these conditions, then, logically schizophrenia may only result purely and simply from a chemical imbalance in the brain. It will be impossible to think or act otherwise. We have called this the principle of convergence.

There are two descriptions needed, and we are provided with one. The first, as rightly pointed out, is *convergence* – the path or process. The missing element is *closure*, which defines the point at which convergence is reached and does not change significantly, the result of the ergodic process inherent to path dependence. What, then, are the tips and tricks in interpreting infrastructure that Bowker and Star promise at the outset? The ending statements about infrastructure being a matter of deals in backrooms filled with smoke relegates it almost entirely to the difficult realms of ethnographic sociological inquiry. This is methodologically limiting. The study of infrastructure, it would seem, is a melange of theories, methods, and tools, drawing from sociology, complex systems, anthropology, psychology, library science, technology studies, computer science, history, and philosophy. The closing thought about this is that infrastructure, based in classification systems and schemes, and as presented by Bowker and Star, tends to be rooted firmly in the problem of language games that Wittgenstein presents in Philosophical Investigations. That is to say, classification systems are sets of rules – language rules saying, "A belongs in category X and not Y, and B belongs in category Y and not X." As Wittgenstein points out:

> This was our paradox: no course of action could be determined by a rule, because every course of action can be made out to accord with the rule. The answer was: if everything can be made out to accord with the rule, then it can also be made out to conflict with it. And so there would be neither accord nor conflict here. It can be seen that there is a misunderstanding here from the mere fact that in the course of our argument we give one interpretation after another; as if each one contented us at least for a moment, until we thought of yet another standing behind it. What this shows is that there is a way of grasping a rule which is not an interpretation, but which is exhibited in what we call "obeying the rule" and "going against it" in actual cases. Hence there is an inclination to say: every action according to the rule is an interpretation. But we ought to

> restrict the term "interpretation" to the substitution of one expression of the rule for another (162)

2.2.5 Infrastructure and Cyberinfrastructure

In January 2003, a blue-ribbon panel appointed by the National Science Foundation released a groundbreaking report on the future of scientific research in the networked age (8). Dubbed "The Atkins Report" (after Daniel Atkins, former dean of engineering and founding dean of the School of Information at the University of Michigan, and the chair of the NSF panel producing the report), the report laid out an initial consolidating vision for a trend that was already underway within the science and engineering research communities. Recognizing that the fundamental nature of how science is conducted vis-à-vis the advancing adoption of information technologies[7], and that this endeavor requires the linking together of many heterogeneous systems, cultures, actors, and resources along a wide spectrum of scales, it became immediately apparent that the task at hand was managing a form of infrastructure. Since the Internet is the primary mode of information transmission in this environment, and a differentiating term was needed to identify the agenda to those with funding power[8], the term *cyberinfrastructure* was chosen. The Atkins Report formally introduced the term into the NSF base of literature. Within the report, cyberinfrastructure is defined as follows.

> The base technologies underlying cyberinfrastructure are the integrated electro-optical components of computation, storage, and communication that continue to advance in raw capacity at exponential rates. Above the cyberinfrastructure layer are software programs, services, instruments, data, information, knowledge, and social practices applicable to specific projects, disciplines, and

[7]There is a large literature on the enablement of distance-based work that is relevant to this line of thought, specifically that of Computer Supported Cooperative Work (CSCW). While an examination of this literature is outside the scope of this paper, one of the dominant lessons learned in the field is that distance and the absence of co-location significantly affects production (116). Further, within the CSCW field, the focus on collaboratories suggests that distributed teams of collaborating scientists and engineers are becoming more common in the scientific research, possibly more in number than independently-working researchers (54)(55).

[8]This story was anecdotally expressed by Suzi Iacono, acting division director for Information and Intelligent Systems, NSF Directorate for Computer and Information Science and Engineering (CISE) at the "History and Theory of Infrastructure: Lessons for New Scientific Cyberinfrastructures" workshop at the University of Michigan in September 2006.

> communities of practice. **Between these two layers is the *cyberinfrastructure layer* of enabling hardware, algorithms, software, communications, institutions, and personnel.** This layer should provide an effective and efficient platform for the empowerment of specific communities of researchers to innovate and eventually revolutionize what they do, how they do it, and who participates[9].

Within this definition, we clearly see strong elements both on the technical and social sides, remaining faithful to the descriptions of general infrastructure that have come before. This indicates that the blue-ribbon panel also believes that cyberinfrastructure, like previous infrastructure, must address both technological as well as organizational and individual development issues.

The interim years since the original release of the Atkins report have seen a proliferation of reports pertaining to cyberinfrastructure needs and states within various disciplines[10]. Curiously, but not unexpectedly (as will be discussed in a later section on interdisciplinarity), the Cyberinfrastructure and X reports are primarily focused on the needs for funding and cyberinfrastructure development support that do not transgress the boundaries of X. In contrast, the Atkins report also clearly states

> There exists universal sentiment in the community that significant discovery has been enabled by the PACI[11] centers, and that many, even more significant discoveries will be possible in the future. A good portion of these are anticipated to occur at the intersection of disciplines as well as in the context of societal implications, and made possible by Grid and related capabilities. Multidisciplinary teams will continue to proliferate, and efforts must be made to support them(8, Appendix B).

In addition, a pervasive theme throughout the Atkins report is the strong need to develop a multidisciplinary workforce to engage, advance, maintain, and manage cyberinfrastructure and cyberinfrastructure-based work. The content of the Cyberinfrastructure and X reports

[9] Emphasis not included in the original.

[10] The NSF Office of Cyberinfrastructure web site has catalogued 29 major reports on cyberinfrastructure, referred to as the "Cyberinfrastructure and X' reports" (where X is a domain science). The current list can be found at http://www.nsf.gov/od/oci/reports.jsp

[11] Partnership for Advanced Computational Infrastructure

indicates that domain sciences have not yet internalized this agenda into their own. This fact represents an obstacle in shifting the culture of networked science and engineering to engage and consider cooperative relationships in domain sciences outside their own.

In June 2006, the Office of Cyberinfrastructure (OCI) at the National Science Foundation issued a draft release of the updated vision, a follow-on to the 2003 report (9). The report was much shorter, oriented toward action, and laid out specific goals in a five-year plan (2006-2010). A shift in tone can be detected in this report toward the prioritization of the technological – petascale computing facilities, middleware and software development, Grid facilities, data, data analysis, visualization, and so on. Making a new appearance in the 7.1 report is the language of*services* created for and adapted to the needs of cyberinfrastructure (which will be discussed in the next section). The final section does address the need for training to create professionals who can advance this type of innovation, but the social and organizational transformations needed to adapt to cyberinfrastructure seem largely to be de-emphasized. The reasons for this are not obvious to the casual reader, nor are indicated in the text itself. This trend feels reminiscent of earlier infrastructure projects, when the goal of system-builders was primarily to link together objects, systems, physical and tangible resources. Edwards argues that cyberinfrastructure is still in the early system-building stages, and has not yet reached the expansive and ubiquitous designation of "infrastructure." Unlike previous infrastructures, though, cyberinfrastructure is being approached as something to be built out of sheer will and coordination, rather than the slow, organic, long time cycles of past projects that we retrospectively label as infrastructure.

What, then, if any purchase do we gain by appending the term *cyber-* to infrastructure? The descriptions laid out by the Atkins report and the current 7.1 Vision Document articulate at various points all of the attributes of infrastructure described by Star and Ruhleder as goals (142). There does not seem to be a strong case built yet for considering cyberinfrastructure as fundamentally different than other historical infrastructures, save for the increased sense of intangibility or elusive to define qualities of the medium being transmitted (data and metadata, as opposed to trains, goods, cars, electricity, etc.) Perhaps novelty and lack of retrospection tempts us to think, "Oh, but this is different, and needs to be approached in a new way." It may be that the purpose of the new term is political in nature (as suggested by Iacono), or only serves to market and encourage enrollment into the agenda. It may also be the case that we are re-inventing the wheel, so to speak, by adding the words *virtual* and *cyber* by believing it to be something new. The closest articulation to the difference, less than compelling, is the statement in the introduction to the Atkins report,

> The term *infrastructure* has been used since the 1920s to refer collectively to the roads, power grids, telephone systems, bridges, rail lines, and similar public works that are required for an industrial economy to function. Although good infrastructure is often taken for granted and noticed only when it stops functioning, it is among the most complex and expensive thing that society creates. The newer term *cyberinfrastructure* refers to infrastructure based upon distributed computer, information and communication technology. If *infrastructure* is required for an *industrial* economy, then we could say that *cyberinfrastructure* is required for a *knowledge* economy[12].

Although standard arguments exist that the rise of the network society and economy have fundamental differences from ages preceding it (29), it is not a foregone conclusion that these alter the fundamental nature of infrastructure, cyber- or otherwise.

2.3 Digital Libraries

To continue from the general concept of infrastructure and large sociotechnical systems, we can choose a particular instance emerging since the 1980s and achieving significance through research and investment by academics, government, and industry – digital libraries. Though the topic of digital libraries was not new at the time the DLI-1 call for proposals came from the NSF, NASA, and DARPA in 1993, it was the first major investment by federal agencies into the development of information and knowledge infrastructure that would be built for large-scale deployment, represent the consensus of both technology and library

[12] Emphasis contained in the original.

scholars and major voices from the disciplines, and set the stage for evolving standards in digital information work (61; 68).

2.3.1 Defining the Digital Library

What is a digital library? In order to have an initiative, it is useful to have a vision for what is being built; however, the open nature of this question may have been both the strongest and weakest points in the DLI-1. Before interrogating the object constructed through the DLI-1 project and the scholarship of the times, it helps to ground ourselves by returning to accepted definitions of our terms, both in isolation and combination. From the Oxford English Dictionary, the pertinent entries for this discussion (136):

digital (4) Of, pertaining to, or using digits; spec. applied to a computer which operates on data in the form of digits or similar discrete elements (opp. analogue computer).

library (1b) A building, room, or set of rooms, containing a collection of books for the use of the public or of some particular portion of it, or of the members of some society or the like; a public institution or establishment, charged with the care of a collection of books, and the duty of rendering the books accessible to those who require to use them.[13]

Digital, as a definition in this case, refers specifically to the digitization and storage of artifacts, as well as the stewardship of "born digital" forms and representations. The construct of *a library*, culturally, is rooted in the idea of a building with physical holdings - books, manuscripts, perhaps maps and other references. As information technologies came into more popular use and content was either converted to digital form, or born in a digital

[13]The OED does provide another definition for *library*, necessitated after first appearance of the term in 1950 in *Proc. R. Soc. A.*, and giving a definition of "An organized collection of routines, esp. of testbed routines suitable for a particular model of computer." While it is best to leave this discussion until the later discussion of ontic exposures and mismatched vocabularies, it is notable for the moment that the world of computer science and engineering does have legitimate claim to the term reaching several decades before the DLI-1 projects and the development of the digital library field.

format, the forms and functions of the library institution moved beyond the former clauses of the library definition focusing on the instantiation, and shifted to the latter half of the definition, rendering new forms of digitized information accessible to the relevant publics. The movement from *library* to *digital library* created a lag between the traditional definition with considerable cultural inertia, and the emergent forms being transformed and updated by accelerating technologies as they became available for use.

In the spirit of defining the digital library as a large sociotechnical system, academic librarian and professor Candy Schwarts offers the following definition of *digital library*. "Digital libraries are complex systems that stretch institutional resources and capabilities, but also offer unparalleled opportunities for new and improved user experiences. (133)" She offers this definition subscribing to the often highlighted service- and user- orientation of practicing libraries and librarians (as opposed to the technical and object orientations of engineers, a primary tension of ontic subscription or commitment in the UMDL project) in contrast to other definitions ranging from the formal to the quite loose, but notably to only definitions that focus on the collections, holdings, or technologies that comprise alternative digital library definitions.

In a thorough treatment of the term "digital library", Christine Borgman reviews the state of the art as it was emerging from the work of the DLI-1 (22). The 1999 article seeks to bring focus to a discussion that had been taking place through the emergence of separate conferences, publications, and communities claiming the term. Soon after the publication of Borgman's piece, a number of efforts – digital libraries conferences separately hosted by the Association for Computing Machinery, Texas A&M University, IEEE, and others – were brought together in 2001 under the conference banner of the "Joint Conference on Digital Libraries". While the project – along with other activities occurring at the intersection of libraries, information retrieval, and computer science – did solidify the term as a signifier (though of precisely what was still up for debate), the broader discussions of "what is a library" and "what is digital" are not the same conversations that produce an answer to "what is a digital library?" The categories of defining the digital library that Borgman highlights (content, collections, and communities; research objects; institutions or services; databases) can be seen formatively in the reflections of the DLI-1 participants at various levels.

The open nature of the digital library as a term, and as a construct, may have been a source of contention and wayfinding for the research communities that engaged it, but that is not to say that the idea space into which these communities were thrown was unintentional. Some of the initial and discursively significant discussions and decisions – creating strong path dependencies – were as mundane and powerful as the choice of a number. As expressed by a DLI-1 researcher,

> The Computer Science Technical Reports project, the very first meeting, started off with Vint Cerf saying, "Now what we want to do is to think about the architecture of the digital library" Notice, singular. We spent the rest of the entire meeting saying, "Don't you mean *libraries*?" Vint said no – he meant library. We spent several hours discussing whether we met library, by which we fundamentally meant an integrated architecture. So, this question of do we mean digital library or digital libraries was not just semantics. It was a philosophical question about architecture. Now, I believe that this is historically correct, but allegedly, putting out the solicitation, although DARPA and NASA were partners – when it came time to put out the solicitation, I believe at the very last moment, Steve Griffin called it the Digital Libraries (plural) Initiative, and by his act – his bureaucratic act of labeling the solicitation "Digital libraries" – he actually created and made the term the standard term. I believe Steve, in putting up a solicitation and calling it "libraries", was how the term came to be. Steve's philosophy is interesting. Steve believes that the NSF it's at its best when it puts out a solicitation with quite a lot of opportunity for proposers to come at it from different directions. NSF is not good when it puts out a very structured solicitation. So, "Digital libraries" encourages different architectures, different models, different approaches, and so forth; whereas, "digital library" you end up with something like DataNet at present, which I think is a very – well, it's a very worrying program at NSF because it is so highly structured in advance that it doesn't allow flexibility. Digital libraries, plural, was the NSF stating that they were interested in a variety of different approaches to this problem. Because of the importance of this project, that name seems to have stuck. (WVV)

The implicit and encoded rejection of the monolithic construct *library* in the OED (1b) sense, was then important as it opened the innovation space for a radical reconceptualization of digital libraries. The ability for each proposer to approach information architectures without catering to the incumbency of the traditional library configuration of provisioning set the projects in directions that simply re-creating the (1b) library in a digital, electronic, or virtual format would not. By pursuing digital *libraries* instead of *the library* moved emerging research in the shifting information field to a science capable of embracing accelerated change and new forms of digital content, rather than a science of simulacra. This was a potentially important distinction, since early transformations of the library were focused on digitization efforts and creating systems of effectively indexing, searching, and retrieving traditional resources (i.e., books, manuscripts, and other print materials) in electronic form. As these systems were developed and accessed, the amount of information that was "born digital" was small, and quite likely was not present enough to declare primacy as relevant collections or objects around which to modify the library paradigms. It would stand to reason, then, that with organizations like Elsevier and JSTOR working to digitize the back store of existing journals – the significant corpus used and demanded by the academic community the first digital libraries were designed to serve – the seed content of digital libraries was electronic simulacra of physical holdings. It would have been easy enough for the emergent digital library architecture to follow suit and re-inscribe the operations of a traditional bricks-and-mortar library. The expectation that the DLI-1 projects would present novel forms of operational library architectures that were extensible to new forms of information resources set the stage for a number of longer-term project successes, but also framed some of the difficulties encountered by the researchers constructing the UMDL itself.

2.3.2 Evolving a Practice of Digital Library Evaluation

Much of the digital library literature used as common reference today was generated contemporaneous to, or directly through the activities of the Digital Libraries Initiative. Slightly preceding and during the project, a number of groups (many involving Michigan scholars on the UMDL project) addressed the transformation of libraries in the digital dimensions by casting the change in the language of business, shifting from ideas such as "patrons" and "institutions" to "customers" and "enterprise" (123; 16). Digital technologies were not only shifting the forms and provisioning of information, but also the traditional concept of service that the library world embodied so strongly. Library services underwent a transformation into an economic and price-based system of services (as in *goods and services*) To prepare for this shift, academic and government libraries and library schools motivated to discuss the changes needed to remediate the existing bases of physical resources, develop infrastructure for handing the coming deluge of data, and shift training programs to produce a new generation of librarians and information professionals with the skills and flexibility to navigate the ambiguity of the coming age (86; 115; 122; 47; 105).

Digital library scholarship also reflects the primary disciplinary divide articulated by project participants in that the cultural encounter of computer science and engineering with the library science world. The literature produced through the projects, and in several post-mortem articles and books, has distinct community orientation. As seen in Appendix B, the corpus of journal articles generated by the UMDL project alone has a heavy slant toward the engineering side. On the other hand, the library communities involved generated a separate literature out of the projects. This divide may be in part because the available publishing avenues expect and accept only submissions that are clearly within disciplines' boundaries. At the time of the project, highly interdisciplinary articles would not have been accepted. The published articles and book chapters do not show a high degree of cross-departmental co-authorship. Library scholars still published with other library scholars; engineers and computer scientists with other computer scientists. The outcomes certainly advanced scholarly knowledge about digital libraries, however the library side tended to publish reflections on service, outcomes of usability testing, and changing social contexts of the library as it transformed into a digital resource (70; 4; 19; 76).

Since the DLI-1 project, a number of articles reflect the maturing view that digital libraries have since advanced to become part of the larger infrastructure, and more particularly, cyberinfrastructure of knowledge production systems both inside the academy and out. The team from the UIUC project pointed out this expanding nature right away, indicating that new methodologies were absent and needed to evaluate digital libraries, and more broadly, emergent digital knowledge infrastructures (20). This absence of evaluation preparedness was also echoed by library researchers at Rutgers, a participant institution in the DLI-2, but not DLI-1 (130). In the ensuing years, several other digital library projects have been conducted to varying degrees of reported success, with multiple perspectives lending voice to evaluative criteria and disciplinary interest ranging through knowledge management and business, computer science, and traditional information science (31; 131; 107).

Digital libraries underwent development both as an object and also as a field in a relatively short period of time. As pointed out above, many no longer distinguish between "digital library" and "library" in an applied or professional sense. The question is no longer what is a library, and what is a digital library; rather, all libraries are digital to varying degrees. The more relevant question is what aspects, services, components, and holdings are dealt with through digital technologies. To this end, there is likely a large corpus of literature that addresses aspects of digital librarianship or digital libraries, but has not been explicitly indexed or identified as such. This fact may indicated that digital libraries have, in short order, sunk to the invisible level of infrastructure, and require explicit resurrection as an object of study (23).

2.4 Interdisciplinarity

It is a popular idea that diversity is an important, if not fundamental, element to the structure and advancement of various systems. Beginning with the well-established evolutionary metaphor popularized by Darwin in his 1886 treatise, the preferred and robust method for improving the chances of survival is by exploring the design space thorough trials of variation or diversity (38). In the subsequent 150 years, the evolutionary metaphor and value of diversity has been applied to phenomena ranging quite far from the original biological context, becoming ubiquitous with many descriptions of dynamic change[14] Until recently, the application of the diversity metaphor to sociotechnical dynamics has been precisely that – a metaphor. While a useful tool in shedding light on the mechanisms of social structure and change, it does not have the traction of a stronger tool – proof. Economist, political scientist, and complex systems scholar Scott Page has taken a step in remedying this shortcoming. As an alternative, he provides an economic proof of the value diversity provides in advancing social systems, in particular those embedded within established infrastructures (e.g., education, governance, corporate firms) (119). He begins with a description of a set of counterintuitive results from a set of agent-based simulations run during his early career, where groups of heterogeneous agents with moderate ability to solve sets of problems consistently outperformed homogeneous groups of agents with high (and relevant) ability. This discovery led to an economically-based examination of how domain knowledge and tools for inquiry may be defined and categorized, and who the interaction of differing tool sets can lead to higher performance. Page describes the toolbox for diverse thought in terms of four elements:

- *Perspectives:* individual interpretation of objects, situations, and other stimuli. The frameworks chosen to arrange the elements of a problem.
- *Heuristics:* the rules or patterns applied to describe patterns within one's perspective, and the strategies for moving through a search space for an optimal solution.
- *Interpretations:* the formulation of perspectives, heuristics, and elements into words, providing a conceptual mapping of the problem at hand.
- *Predictive models:* Assembling the information about the situation to create models that lead to better expectations of behaviors or outcomes.

[14]As is likely evident, I disagree with this widespread subscription to the evolutionary metaphor. First, this is owing to the fact that Darwin's described mechanisms of evolution are only one of many. Other models and algorithms exist under the general category of evolution that bear stronger resemblance to contemporary dynamics. For example, Lamarckian evolution, where phenotypic changes in one generation are immediately incorporated into the genotypic structure of offspring, has much closer relevance to the evolution of code bases and libraries in open source programming projects. The point here is that the evolutionary metaphor has been applied carelessly in many cases, leading to diluted power in communicating the value of diversity.

The observation that a framework or perspective is necessary to solve problems is certainly not new. Kuhn clearly puts forth the claim that scientific inquiry is primarily advanced by the subscription to and application of a particular framework (93). In addition, economist Herbert Simon echoes this sentiment with his claim, “Solving a problem simply means representing it so as to make the solution transparent. (135)” Page applies these claims with the logic that if a perspective is key to solving a problem, then an array of perspectives increase the probability of finding the right perspective that will render a complex or multi-dimensional problem (or subset of that problem) transparent. Heuristics, according to Page, provide us with sets of actions that may be taken in response to an experienced or observed situation (for example, “It is starting to rain, so we should find shelter.” or “It is starting to rain, but we will get just as wet whether we walk or run, so we might as well walk.”) Again, the multiplicity of heuristics provides an increased set of options for action when searching a solution space. Interpretations, as a mapping of concepts into language, provide a method of communicating these options among actors. In the case of homogeneous high-ability actors, the shared language may promote efficiency in making sure all group members understand the elements in play, but may concurrently limit the ways in which the solutions may be described, leading to the problems of groupthink (as played out, for example, in the events that led to the explosion of the NASA Challenger shuttle (155)). Predictive models, in Page’s view, are most effective as simple and crude constructs that (in my interpretation) form an internal Bayesian model that accounts for prior experiences and over time refines the expectation of outcomes. Since each person’s experience set is different, the increased set of prior experiences provides more robust examples upon which to form a posterior distribution of expected outcomes. Page spends most of the remainder of the book exploring concrete examples of each of these elements, accompanied by economic axioms and thought experiments.

The point here is that Page provides a solid and probabilistically-based proof that diversity, in many situations and environments (though not all), leads to more optimal outcomes in problem solving than reliance on a well-developed, but inflexible framework. Page consistently chooses the word diversity to describe this state, and only engages the word interdisciplinary twice within the entire book; however, I believe the transfer of the concept to the interdisciplinary dialogue is clear. As we ask and seek to answer more complex questions, an increased representation of perspectives, heuristics, interpretations, and predictive models only serve to increase the probability of finding a suitable solution.

One interesting example given by Page, and bears strong synthesis with the activities seen in interdisciplinary academic environments, relates to the relatively new phenomena of "X-Prize" competitions, where a complex and difficult problem is put forth by a sponsoring individual or institution[15], and an open competition for the solution ensues. Page provides evidence that the consistent winning teams of X-prizes are interdisciplinary in nature, providing workable solutions faster than assembled teams of experts from one field alone. Clearly, this is the basis of many contemporary problems in academic and scientific research as well. The activities at Bletchely Park, a British endeavor to break the German Enigma Code during World War II, brought together mathematicians, linguists, engineers, cryptographers, and even crossword puzzle experts. This is a recognition that the value of interdisciplinarity has been recognized by research communities for quite some time, and that we have long known that there are certain classes of problems that extend beyond the ability of a single discipline to provide solutions (75).

2.4.1 A Short History of Interdisciplinarity as an Object of Study

Interdisciplinarity, as a topic of modern inquiry, first became popular in the 1920s. Although arguments are made that interdisciplinarity has been a root element of knowledge discourse since Plato's advancement of philosophy as a unified science (which was overturned by his student, Aristotle, and the entrenched ideal of delineating between categories of object,

[15]Recent examples include: the first private manned spaceflight, NetFlix's call for improving the accuracy of their recommender system by 10% or more, and creating a method for genomic processing that costs less than $1000. More examples can be found at xprize.org, the website of the X-Prize Foundation.

knowledge, and representation, leading to the basis of our current paradigm of scientific inquiry (6)), the historical discussion of interdisciplinarity with respect to research in the academy becomes interesting and relevant to the topic at hand with the opposition to the "craft exclusiveness" of the disciplines generated by a group of scholars at the University of Chicago: Dewey, Veblen, Mead, Angell, Boas, and Merriam (89). Their attempt to cross-fertilize the social sciences lagged, but gained more widespread attention in the 1930s and 1940s. This school of scholars took upon themselves the task of unifying the social sciences through rational positivism.

Still, the enrollment in the idea of interdisciplinarity remained confined to a corner of the social sciences, and through the early 1970s, when the metaphors of "bridge building" and "restructuring" were introduced by the British Group for Research and Innovation in Higher Education. During this time, several examples of interdisciplinarity were generated as concrete instantiations to which those wishing to advance the agenda could point. In terms of a field, general systems theory rose as an exemplar of synthetic thought. As a concentrated example, Shannon's work at Bell Labs in information and communication theory was heralded as a skillful weaving of several fields to produce an interdisciplinary piece of knowledge.

Within the academy, the period from 1970 to 1985 saw the rise of several interdisciplinary centers in the form of area studies and various forms of cultural studies, including the legitimation and institutionalization of departments for women's, African-American, Asian, Latin, and later, Queer studies (91). Klein claims that during the 1970s and 1980s, continuing through to the present, interdisciplinary studies in the social sciences (and spilling over into design and engineering) were propelled by the fields of urban planning and STS (Science and Technology Studies) as a form of social and academic reaction to the growth of technological research in the cold war era, and detecting a need for a strong science program that approached problems from multiple perspectives (90). From the 1980s and onward, we can see within the academic (and related academic circles), the founding of an increasing number of interdisciplinary endeavors, including but not limited to complex systems departments and the Santa Fe Institute (156), information schools, bioengineering, neuroscience, and media studies (of the type found at the MIT Media Laboratory.) In 1996, Lisa Lattuca published a dissertation at the University of Michigan School of Education, producing an ethnographic review of the extent to which researchers in the sciences, social sciences, and humanities engaged in interdisciplinary research (99).The conclusion of the study was that interdisciplinarity is happening within the academy at high levels across the domains; however, many researchers, especially those who are mid-tenure, are loathe to admit to this type of scholarship, feeling that the reward structures in place, and the general disposition of disciplinary scholars is a quite real impediment to advancement for those who actively practice interdisciplinary work as their primary bread-and butter-science. She indicates that there is a strong need for the reconceptualization of science and discipline, stating that the evidence from her interviews with many faculty from different departments suggest that the strongly held boundaries of the disciplines are firmly in place despite the popular rhetoric.

Departing from Lattuca's cautionaries, other groups are finding thriving interdisciplinary scholarship in pockets of the academy, in industry, and funded by the government. The Interdisciplinary Studies Project, a part of Project Zero at the Harvard Graduate School of Education, has done significant work since the late 1990s in identifying and examining exemplary institutional projects that are defined by their interdisciplinary nature. Led by psychologist Howard Gardner, the project has used qualitative methods (mostly ethnographic) to identify qualities of high-performance groups. As predicted by Page, the diversity of scholarship represented in these groups is consistently cited as the factor that leads them to produce innovative science (119).

The first major piece published by the Project Zero group produced a definition of interdisciplinary understanding. By examining students' modes of learning in two cross-disciplinary courses merging historical and scientific lenses, applied to issues in (1) Nazi concepts of obedience and authority and (2) eugenics, Mansilla, Gardner, and Miller show that students' command of critical engagement is enhanced by considering multiple views contingent upon "(1) an emphasis on knowledge use, (2) a careful treatment of each discipline involved, and (3) appropriate interaction between disciplines. (104)" After establishing this working definition, the group turns from ordinary knowledge acquisition in a multiple-lens environment to the issue of knowledge production, specifically focusing on "exemplary interdisciplinary work (103).

For these analyses, three highly visible projects were chosen: the MIT Media Laboratory, the Santa Fe Institute, and CIMIT (Center for Integration of Medicine and Innovative Technology.) The findings of the studies acknowledged that even though superficial qualities differ among the organizations (such as local versus virtual collaborations, organizational goals, funding structures, size, etc), the practitioners of exemplary interdisciplinary science identify a core set of requirements including particular strategies to bridge disciplinary differences: fluid integration, translation, and explicit integration. Practitioners also identified (and these are similar to the categories in Page's toolbox) common skills that "allow researchers to navigate the interdisciplinary terrain: analogical thinking, common languages, and metadisciplinary views[16](43)(44)(45).

Finally, in a 2004 paper, the group performed a meta-analysis of the previous studies (which grew to include examination of groups at Xerox-PARC, the Santa Fe Laboratory for Arts and Sciences, and the University of Pennsylvania Center for Bioethics.) The final report identified three main themes to guide future understanding of interdisciplinary environments and projects (108):

1. Challenges of Work Across Perspectives

[16]Michael Finkenthal puts forth the claim that western culture has centered itself around a Galilean-Newtonian paradigm of disciplinary thinking which has gone largely undisputed by the scientific community. By tracing the ingrained nature of classificationist approaches from early Greek scholars to the present (in a surprisingly short volume), he concludes that the rise of interdisciplinarity is an intermediate form that creates tension leading to a new metadiscipline, forcing us to re-examine the relationships and ontologies that construct the scientific understanding of the world (56).

   (a) Differing units of analysis – in short, scales, methods and tools matter. The reconciliation among the tools used by collaborating disciplines is a process of negotiation, and relies upon the willingness of each group to positively consider the legitimacy of methods that are not its own.
   (b) Communicating across perspectives – negotiating the lexical and linguistic conventions of each community of practice. This subject is taken up in detail in the next section on pattern language.
   (c) "Measuring up" to differing, sometimes conflicting, standards – different disciplines have differing views of what constitutes rigor and acceptable standards for validity. As with other aspects, this is a constant negotiation and confrontation of assumptions embedded in each disciplinary culture.

2. Making Integration Happen: Cognitive Bridges

   (a) Reasoning through analogies – promotes the active mapping of one cognitive domain to another. When one discipline teaches another through analogy, each group can expose new perspectives, relationships, and properties to the other.
   (b) Creating compound concepts – the active construction of language that hybridizes the related content of different domains, and the adoption of these terms by all actors. This process anchors the legitimacy of the boundary-spanning (compound) concept.
   (c) Building complex and multi-causal explanations – while this approach seems uncomfortable in that it defies the accepted Occam's razor approach to science, the added efforts may be worthwhile in reconciling the explanatory perspectives brought by multiple disciplines may expose inconsistencies, gaps, or otherwise ignored or erroneously-taken-for-granted aspects of a single disciplinary view.
   (d) Advancing through checks and balances – engaging other disciplines that can challenge the disciplinary assumptions in play, keeping each group "intellectually honest."
   (e) Bridging the explanation-action gap – realizing that certain disciplinary perspectives privilege explanatory aspects of inquiry, while others are more appropriate for defining paths of action or solution. This strategy makes the relationship between the two explicit and demands a balanced approach.

3. Explicitly Acknowledging Different Degrees of Integration (definitions taken directly from Miller, 2004)

   (a) Mutual ignorance – Individuals demonstrate a lack of familiarity with, and even hostility toward, other disciplinary perspectives.
   (b) Stereotyping – Individuals show an awareness of other perspectives and even a curiosity about them. Still, there is a stereotypical quality to the representation of the other's discipline, and individuals may have significant misconceptions about the other's approach.
   (c) Perspective-taking – Individuals can play the role of, sympathize with, and anticipate the other's way of thinking. Individuals raise objections to their own

preferred ways of thinking by taking account of other approaches. Individuals demonstrate less naïve or stereotyped representations of other disciplines.

(d) Merging – Perspectives have been mutually revised to the point that they are a new hybrid way of thinking, and it is difficult to distinguish separate disciplinary perspectives in the new hybrid.

Each of these aspects of interdisciplinarity found by the Project Zero team has been, at different points, acknowledged as a point of concern for the cyberinfrastructure agenda. This can be seen in online blog transcripts discussing the social aspects of cyberinfrastructure[17].

2.4.2 Interdisciplinarity and working within Large Sociotechnical Systems and Cyberinfrastructures

The value of and demand for interdisciplinarity exerts itself as a critical component of the cyberinfrastructure movement as well. During a 2006 University of Michigan conference, "History and Theory of Infrastructure: Lessons for New Scientific Cyberinfrastructures," several comments were made regarding the need for interdisciplinary training, especially with regard to new PhDs who may, in time, take the reigns of leading and coordinating large-scale projects of the type that cyberinfrastructure engages. In particular, William Dutton of the Oxford Internet Institute spoke of the need for "extreme multi-disciplinary training (48)." Similar sentiments have been expressed within the SSME community, with HP Labs Bristol claiming the need to create a new form of polymath who is able to span the requisite disciplines needed for understanding of the new field (110), and Jim Spohrer of IBM, one of the creators of the SSME agenda, outlining the various academic fields that are necessary to assemble a basis for a new interdiscipline of service sciences (139).

The stated need for interdisciplinarity is echoed on a larger level as well. The current state of doctoral education, ostensibly the primary source of scientists, administrators, coordinators, and leaders in the cyberinfrastructure movement (as well as the upwardly trending nature of cross-boundary inquiry more generally), needs to undergo transformation with regard to fundamental perceptions of the role of interdisciplinarity as well as the reward

[17] To be found at http://icd.si.umich.edu/∼cknobel

structures in place for pursuing such work. As it stands, interdisciplinary studies are at odds with the entrenched disciplinary and subspecialized structure of the academy (66). Helga Nowotny describes this tension as rising from a transformation from *Mode-1* knowledge production, where traditional disciplinarity and progressive subspecialization (and, by inference, balkanization) is the mode of inquiry, to *Mode-2* knowledge production, to which Nowotny ascribes particular qualities, many of which are regular features of cyberinfrastructure-based projects (113). Nowotny enumerates these qualities as:

1. Contextual application of research: "...contemporary research is increasingly carried out in the context of application, that is, problems are formulated from the very beginning within a dialogue among a large number of different actors and their perspectives."
2. Heterogeneity: "...multiple actors bring an essential heterogeneity of skills and expertise to the problem solving process[18]."
3. Transdisciplinarity: This is Nowotny's term of art, specifically referring to the joint production of new and hybrid concepts resulting from the fusion of disciplinary knowledge, rather than knowledge that simply forms in the interstices of disciplines, the elements of which are still assignable to one discipline's contribution.
4. Accountability: institutionalized responsibility to the production of such knowledge. While accountability is primarily an informal process, it is strongly embedded in organizational routines, giving it a semi-formalized nature. It is by this process that those enrolled into the transdisciplinary community of practice become aware of how scientific knowledge is produced.
5. Quality control: Nowotny admits to quality control being the "Achilles' Heel" of transdisciplinarity, since, unlike disciplinary sciences that have achieved relative closure on the definitions of acceptable and legitimate science, transdisciplinary endeavors must re-negotiate these criteria with each new configuration of multidisciplines. Here, she makes the interesting statement that a transdisciplinary project must go beyond each discipline being value-added, to being value-integrated.

Seen in Nowotny's criteria for transdisciplinary (and ignoring the semantic arguments, extending the concepts to the broader class of interdisciplinary) research, the cyberinfrastructure agenda has, and continues to struggle with all of these issues. Thus, if these issues are elements of interdisciplinarity, and cyberinfrastructure engages them at a fundamental level, then we can reasonably conclude that the cyberinfrastructure environment is inherently

[18]In this same section, Nowotny also notes that "Universities are precisely the opposite type of such organizations. For the most part they are still highly hierarchical, fixed towards disciplinary structures. We find in Mode-2 almost the reverse of that."

interdisciplinary. The question then remains, as stated before by Dutton, Spohrer, and others – where will we find, and how will we train those who are properly equipped to manage the cross-disciplinary complexity that is to be found in the future of cyberinfrastructure?

In a recent report on the future of doctoral education, The Woodrow Wilson National Fellowship Foundation states:

> ...further, bland praise of the interdisciplinary sacrifices intellectual opportunities of key import. The interdisciplinary often arises because the world beyond academia needs something that crosses the academic boundaries or because a scholar in one discipline is led by her research to questions that land her beyond the line. This is a freshening moment; it is the very history of knowledge in the making. But some such moments may be unique (some may even be unfortunate!) while others are endemic. The deeply contentious nature of the interdisciplinary – it seeks, after all, a reorganization of knowledge – should lead to very exciting debate, allowing the traditional disciplines a new understanding of themselves in the process. And the variety of this genre, ranging from a single individual's perspective to the very different circumstance of a multidisciplinary group to which each individual brings a disciplinary perspective, barely gets acknowledged (164).

Across the academy, industry, and government, the consistent acknowledgment arises that inter- or trans-disciplinary knowledge, orientation, culture, and priority will be key requirements for the success of scientific research in general, and cyberinfrastructure and service science in particular. If taken, then, as a given requirement, how should we best proceed in these skills and recreate scientific and research cultures?

An approach to addressing the complexity of interdisciplinary negotiation in cyberinfrastructure and large sociotechnical systems work was put forth during the "History & Theory of Infrastructure" conference by JoAnne Yates. She stated that the process cyberinfrastructure system-builders should engage is based in the work of Peter Galison: establishing *trading zones*[19] and allowing language to develop from a *pidgin* to a *creole* (65). The result of this protracted interaction and negotiation would eventually result in collaborative groups gaining interactional expertise, enabling fluid interaction (35).

[19] Trading zones are conceptual spaces in which two communities of practice are able to negotiate rules of engagement.

In all of these examples, the evolution of interdiscipline is rooted in practice and in language (discourse). Why does this have particular relevance to the cyberinfrastructure movement, and to the issues of ontic occlusion and exposure in sociotechnical systems? In closing this line of thought, it seems prudent to ground the issues of language, interdiscipline, and infrastructure as the convergence of historical forces given new form in information- and cyber-infrastructures.

2.5 Summary

In this chapter, I have presented literature from four topical areas that have contributed to the development of the ontic occlusion and exposure concept. A discussion of the philosophy of categories and ontology from Aristotle to modern philosophers and science and technology frames some of the basic concepts of *physik* and *metaphysics*. Next, a broad review and discussion of literature pertaining to infrastructure studies and views of large sociotechnical systems gives a grounding for matters of scale. Third, a short exploration of the digital library as both a subject and object of design, development, and evaluation provides some insight into why the construction of a digital library through the cultural encounter of library scientists and computer engineers might result in tensions. Finally, as the UMDL and forming School of Information were grand experiments in cross- and inter-disciplinary work in the field, I review scholarship on interdisciplinarity as an object of study. With this groundwork in place, we move forward to an brief explanation of methods employed in this dissertation, and then to the UMDL as a site to explore ontic occlusion and exposure in play.

Chapter 3

Data Collection and Analysis Methods

3.1 Selecting the UMDL as a site to study Ontic Issues

I came to study the University of Michigan Digital Library and the Digital Libraries Intitative-Phase One at the combined suggestion of two dissertation committee members. I had been developing the mechanism of ontic occlusion and exposure for some time previous, but was looking for an appropriate case. First, James Duderstadt suggested that I turn to the considerable historical bank of rich projects funded by the National Science Foundation. He advised that there were many studies within the NSF that have been documented well, are clear examples of developing cyberinfrastructure, and would likely have many of the project personnel available for interview. A year later, at a Santa Clara University workshop on Values in Design, Leigh Star, in a hallway discussion about the ontic occlusion and exposure concepts, directed me to look at the DLI-1 set of projects claiming that I would find several good instances of these mechanisms at play on various levels of scale. I was fortunate that one of the DLI-1 projects had taken place at the University of Michigan, and was primarily located (both physically and intellectually) in my own department. I was given direct access to the existing project archives and documentation by Dan Atkins, the UMDL project principal investigator, and was also assisted by JoAnne Kerr, who had been the administrative project manager for the majority of the project.

3.2 Individuals, tribes, and institutions

An analysis of the UMDL project necessarily involves actors and aggregations at different levels of scale. Individuals can express their ontic commitments through their own choices and representations in spoken statements and attributable writings. Institutions and groups represent their ontic sets mostly through products – reports, publications, and sometimes embedded in the technological and social artifacts that they create, though this is less apparent and requires analysis such as that found in Science & Technology Studies.

Another categorical concern in this project, and one that is well-known to produce differences in perspective or construction in truth claims, flows from the various epistemic cultures taking part in the digital libraries project. Knorr-Cetina explains that although these perspectives do originate with individuals, there is a process by which the individual disappears and the representation becomes attributable to the field or discipline (92). Knorr-Cetina's described mechanism allows the ontic commitments to fluidly scale between individuals and the collective aggregations of tribes and institutions. As Tony Becher points out, the metaphor of "tribes" is apt to describe the interactions, communications, and relationships among academic disciplines (13), particularly with respect to the gaps that exist between them. Like physical separations between villages in Becher's metaphor, the intellectual distance can pose limitations to interdisciplinary projects and endeavors in system building. One faculty member involved both in the UMDL project as well as in the transformation of the School of Information remarked, "And, unfortunately, during the UMDL, we came from different tribes, and we didnt speak each others language. That was another difficulty with UMDL because it was truly as though we were different tribes. Each of those tribes had their own cultures. Each of them had their separate languages. (4Q3)" This self-generated tribal metaphor for the UMDL project is not surprising in that it conforms to the early stages of interdisciplinary relationship formation described by Miller (108). In the case of UMDL, as pointed out by this respondent, but echoed by many taking part in the project, the environment for both the UMDL and the new School of Information to emerge was primarily defined by two cultures, defined by epistemologies, departments, and even physical campuses. The encounter of cultures in this particular arrangement, though, is not novel, and scholars have observed the tensions arising, well captured by English physicist and novelist, C.P. Snow.

In The Two Cultures, Snow details the existence of two distinct cultures in the academy. His account, locally situated at Cambridge in the late 1950s, but convincingly argued that a cultural difference exists more broadly, draws a distinction between *scientists* and *literary intellectuals*[1] (138). As Snow describes:

> I believe the intellectual life of the whole of western society is increasingly being split into two polar groups. [. . .] Literary intellectuals at one pole at the other scientists, and as the most representative, the physical scientists. Between the two a gulf of mutual incomprehension sometimes (particularly among the young) hostility and dislike, but most of all a lack of understanding. They have a curious distorted image of each other.
>
> The non-scientists have a rooted impression that the scientists are shallowly optimistic, unaware of man's condition. On the other hand, the scientists believe that the literary intellectuals are totally lacking in foresight, peculiarly unconcerned with their brother men, in a deep sense anti-intellectual, anxious to restrict both art and thought to the existential moment. [. . .] On each side there is some of it which is not entirely baseless. It is all destructive. Much of it rests on interpretations which are dangerous. (pp 4-6)

Forty years later, the stories and narratives related by UMDL project members speak to the continued relevance of Snow's structural observations. The cultural encounter between the world of library science and the fields of computer science and engineering gave rise to significant frictions through their involvement both in the UMDL and the transformation of the School of Information. Their extended exposure and joint work, though difficult, produced an interstitial space in which new types of scholarship, and new types of scholar,

[1]In the intervening years since Snow's exhortation, the western academy has divided into three main sectors humanities (mapping to Snow's literary intellectuals), physical and natural sciences (mapping to the scientists), and social sciences (which seems to be a residual role in Snow's classification scheme. As an observer of the cultural phenomena, it is possible that the social science role is the one in which Snow casts himself; however, the existence of third culture, fourth, or beyond, lay on the table.

could emerge to synthesize aspects of the two cultures. This marked difference is used in the project as a delineation and categorization for assigning ontic perspectives.

3.3 Qualitative and Quantitative work

The analysis of qualitative data from archives and interview transcripts took place throughout the data collection process. I used a constant comparative approach to analysis, consistently returning to my assumptions and reflections about the UMDL project and about interdisciplinary communication (67). Through these interwoven activities of data collection, transcription, and analysis, I was better able to refine the mechanisms of ontic occlusion and exposure and understand the local, contextual, generative outcomes of these mechanisms.

I was also guided at a methodological level by two other influences - one formal and distant, the other more informal or conversational and close. Organizational scholar David Boje brings an approach to narrative analysis that engages deconstruction as epistemology – rather than method – to explore the messy middle spaces between traditional qualitative strategies (21). His "antenarrative" approach inspired me to look at particular tensions for examples of the occlusion and exposure phenomena. Two areas of Boje's antenarrative approach were particularly useful in this study. First, the *microstoria* approach finds itself in the middle ground between pure deconstruction and fully-developed thick description. Instead (and working against the "grand narrative" approach to narrative construction), microstoric analysis collects a reasonable representative sample of individual stories that are locally situated and likely proximate to the object of study, and applies the constant comparison to produce interpretation that remains sensitive to three goals:

- Trace microhistories across the time span of a grand narrative
- Reclaim forgotten knowledge
- Seek middle ground

Through the course of qualitative analysis, two areas of particular attention emerged, both core to the resulting observations and argument.

- Dimensions of success and failure: articulations of the criteria by which the UMDL and DLI projects may be evaluated, whether explicitly included in the project RFP.
- Narratives of cultural tension: articulations of dominance and subjugation, disagreement and resolution, departmental or epistemic divides, mismatches in vocabulary, ontological commitments and subscriptions, and claims on significant elements to the historical construction of the UMDL story.

While there were many other themes arising in the interviews, some as parallel stories and structures, others fascinating aspects of UM and SI history in their own right, the project limits the scope of analysis to interview responses and artifacts that speak to the ontic occlusion and exposure concepts, in the service of advancing discussions about design and evaluation of large sociotechnical systems.

The decision to engage a secondary quantitative approach through the use of social network analysis was, at first, uneasy. Writing a dissertation in an interdisciplinary department that engages both qualitative and quantitative traditions suggests that a scholarly product can and should demonstrate use and coordination, if not synthesis, of both (falsely dichotomous) worlds. In this research project in particular, I chose to represent presence, participation, and change in the composition of the UMDL operating committee by counting the eminently countable in the meeting notes – attendance – and generating a sense of centrality, influence, and suggestions of occlusion and exposure through a differently formalized epistemology.

3.4 Data collection

Documents and archival materials were housed in several different locations – some physical, but most electronic. JoAnne Kerr, the administrative coordinator for much of the project, was instrumental in locating and accessing information. There were three main locations for archival data used in this study. First, physical project archives that had been stored in boxes housed at the University of Michigan School of Information. Second, boxes of archived documents that had moved several locations on campus during the interim years as Dan Atkins, the UMDL principal investigator, had changed offices. Finally, the existing electronic documents had been archived on a retired server possessed by the School of Information Computing Office. The computing services staff put the server back online so I could create copies of the artifacts, and then re-retired the server. I confirmed with Kerr and Atkins that although the server was not actively online, that the data provided was publicly available. For the electronic project artifacts generated in the early- and mid-1990s, I was required to convert several unsupported formats of word processing programs into readable format. The interviews were conducted in person, over the telephone, and via Skype (both voice and video). I recorded the interviews on an iPhone 3G using the HT Professional Recorder application from Applied Voices LLC. Transcript recordings were transferred to the HyperResearch software package for transcription. Transcript coding and cross-coding with other artifacts were done by hand.

3.5 Data sources

3.5.1 Archival Materials

Documents or Materials	Information the Data Provide(s)
NSF Digital Libraries Initiative RFP	Initial framing of the UMDL/DLI project from funders
UMDL Project Proposal	Names of researchers, staff, and affiliates. Named components of project. Departments involved. Projected budgets
Operating Committee meeting notes	Meeting attendees, topics of focus, relevant objects
All-project meeting notes and slides	Representations of project shared with funding agencies and other DLI-1 institutional
UMDL Annual progress reports	Evolving representations of the UMDL project, updated lists of involved researchers and staff
Various workshop reports	External sources about the UMDL and DLI roles in an evolving discourse of digital libraries (Santa Fe, LOC, Research Libraries Group, etc.)
UMDL Website	Represented objects and "official" documents claimed by the UMDL project
NSF DLI-1 Website	Different view of the UMDL project in the context of the funding agency and the other five DLI-1 projects
Journal articles from UMDL	Represents the discursive elements of UMDL presented through legitimated channels of academic reproduction

Table 3.1 Archival materials

3.5.2 Interview Participants

While many of the names associated with the UMDL and DLI-1 projects are a matter of public record through published journal articles, names on the UMDL and NSF DLI-1 web sites, available federal and institutional reports, and other associated digital and print literature, I have taken care to anonymize the responses of my interviewees to the largest extent possible. Given the sensitivity of some statements, I have opted to only associate quotes, statements, and perspectives with vague terms like “library scholar” or “engineering perspective”. Of course, the actual participants of the project may be familiar with enough detail to surmise sources; however, I have made every attempt to make direct quotes non-attributable, and general statements made as the synthesis of more than one respondent. For the following list of interview participants, I list general categories into which the 45 conducted interviews can be sorted, along with their general contributions to the UMDL project.

Project Role	Summary of Involvement
UM Faculty - SILS	Conduct primary research on UMDL project. Primarily working in ontology development and evaluation components.
UM Faculty - EECS	Conduct primary research on UMDL project. Focused primarily on AI and agent development, managing programmers, designing architecture.
UM Faculty - Library	Conduct primary implementation of the UMDL production system within the university library.
UM Faculty - Other	Conduct primary research on UMDL project. Various foci depending on area. Most concentrated in education, economics, interface design, and policy.
UM Faculty Administrators	Includes project PI and co-PIs. Conduct research and manage research teams. Determine direction and vision of the UMDL project. Coordinate and represent UMDL at All-Hands meetings. Generate reports to funding agencies.
UM Administrative Staff	Support UMDL researchers and administrators in various capacities including clerical, finance, scheduling, resource management, reporting, and personnel management.
UM Programming Staff	Receive requirements from all teams working on the UMDL project to produce digital library components.
UM Graduate Students	Conduct primary research on UMDL project under the direction of UM faculty in relevant departments.
Other DLI-1 Researchers	Conduct primary research on projects located at the other five DLI-1 awardee institutions.
Agency Managers & Staff	Direct and manage the DLI-1 projects according to the interests of the funding agencies - NSF, DARPA, and NASA.
Industry Partners	Provide content and resources to the UM Digital Library.
Other Experts	Digital library scholars and experts in the field fulfilling advisory or evaluation roles for the DLI-1 and UMDL projects.

Table 3.2 Interview Participants

3.6 Data analysis

I extracted themes from my data by coding relevant passages in notes, interview transcripts, and archival documents related to the two themes in Section 3.3. I was able to conduct follow-up interviews with a number of participants, allowing me to check assumptions and confirm updated information as I came to understand the dynamics of the UMDL project more fully. During the transcription process, which took part during the course of interviewing, I approached the coding using a holistic approach, identifying the themes related to episodes of ontic occlusion and exposure (41; 129).

I used social network analysis to demonstrate empirically the relative representation of departments and tribes within the operating committee spanning the three years that they met about the UMDL project. (academic years 1994-1997). I compiled the data from the UMDL Operating Committee notes that were taken at each scheduled meeting. I constructed two matrices for the social network analysis. The first data set contained a binary designation for each operating committee meeting whether an individual was present (1) or not present (0). The second data set contained the name of each person in the first data set, and categorical designations of their departmental affiliation (affiliation) and disciplinary background (tribe). The second data set was later used in analyses to designate attributes of nodes within the network. I used the UCINet software package to perform the social network analysis, first calculating a 2-mode network of people and meetings. I calculated this graph for the full three-year period, as well as each of the three academic years independently. I then converted the data into a 1-mode network representing dyadic relationships among meeting attendees. If two people attended the same meeting, they would receive a tie. This analyis was calculated for:

- Full network 1994-1997
  - Full network {by affiliation, by tribe, by tribe with weighted links}
  - Full network minus people attending only one meeting {by affiliation, by tribe, by tribe with weighted links}

- Full network minus people attending 10% of meetings or less {by affiliation, by tribe, by tribe with weighted links}

- Academic year 1994-1995
  - Full network {by affiliation, by tribe, by tribe with weighted links}
  - Full network minus people attending only one meeting {by affiliation, by tribe, by tribe with weighted links}
  - Full network minus people attending 10% of meetings or less {by affiliation, by tribe, by tribe with weighted links}

- Academic year 1995-1996
  - Full network {by affiliation, by tribe, by tribe with weighted links}
  - Full network minus people attending only one meeting {by affiliation, by tribe, by tribe with weighted links}
  - Full network minus people attending 10% of meetings or less {by affiliation, by tribe, by tribe with weighted links}

- Academic year 1996-1997
  - Full network {by affiliation, by tribe, by tribe with weighted links}
  - Full network minus people attending only one meeting {by affiliation, by tribe, by tribe with weighted links}
  - Full network minus people attending 10% of meetings or less {by affiliation, by tribe, by tribe with weighted links}

For each network analysis, I also calculated measures of centrality (degree and betweenness). Under the assumption that presence and participation are correlated with representation and influence, centrality measures indicate the inclusion of a disciplinary representative and, by suggestion, a particular ontic insertion into the discourse. I also calculated dyadic constraint measures to determine the influence of one tribal or departmental member over another within the core working group. Similarly, I calculated dyadic redundancy measures to understand the extent to which the working group was strongly or tightly connected.

3.7 Limitations

3.7.1 Single case

The issue of the single case study arises between the frequentist approach that looks for generalizability through repeatability or replication and the depth of understanding and context that a case study approach and focus can provide(12; 106) . There are a number of indications that even within the DLI-1 project, the UMDL was an outlier in several dimensions - project size and scope, number of disciplines and departments enrolled, level of abstraction and ambition. Upon completion of this project, it seems obvious that a greater understanding of the digital library phenomenon, and the ability to make a truly robust statement about the era of formative cyberinfrastructure marked by the DLI-1 requires case study development of the remaining five institutional projects. Still, the aim of this dissertation research has not primarily been to provide a thorough historical record of the UMDL project; rather, an understanding at a depth that demonstrates existence of the ontic occlusion and exposure mechanisms. For this, the case study method is ideally suited. As Runyan makes the point, after responding to four common criticisms of the case method,

> First, it is certainly true that for the specific purpose of testing general causal relationships, the case study has substantial limitations. Even though case studies can be designed to increase their power in yielding causal inferences, case studies are, compared to experiments, relatively ineffective means for testing casual generalizations. For other purposes, however, the case study method may be the single most effective method. If one's purpose is to describe the experience of a single person [2], to develop interpretations or explanations of that experience, or to develop courses of action and to make decision appropriate for this particular individual, then the case study method is an extremely useful one (127). (p. 443)

[2]Or, for the purposes of this research, a single project community.

3.7.2 Ontic commitments of the investigator

It would be a gross oversight to propose that the ontic sets to which people subscribe, both the participants in the UMDL and DLI projects as well as describing a more general principle, give rise to blind spots and areas of occlusion without admitting to and examining my own. As I have attempted to advance in this work, ontic occlusions and exposure are neither good nor bad, advantageous or disadvantageous in their own right; rather, the context and moments that require access to the pertinent or removal of the extraneous are at the core. As for my own ontic commitments, I have consistently asked of myself, "Am I privileging a view or set of views?' Am I building the story out of what I've been given by my informants, or out of my own primitive objects? What are my biases? Am I being dispassionate and reasonable in what I am representing?" The simple answer is - yes, I have my own biases, but I attempt to make them transparent. I gravitate to the side of interdisciplinarity and combining traditions, methods, objects of study, and interpretive frames. I attempt to articulate and reflect the terms on which my respondents focus and accept them as they are. Through this dissertation work, I have learned far more than anticipated about coordinating world views, and I believe I have experienced more ontic exposure than occlusion. Of course, it is impossible to represent every detail of every viewpoint in a reasonably scoped work, so I admit to my occlusions, declare them a lifelong project to understand, and move ahead.

3.7.3 Missing data

When working with historical and archival data, it is difficult to know the extent to which significant data or artifacts are missing or unavailable. The negative spaces are usually the most difficult to define, and there are unknown unknowns that limit every study. Then there are the known unknowns, and this dissertation work has some data gaps described here.

Discarded artifacts

While searching for physical artifacts, it came to attention that a number of boxes that the project administrator assembled at the end of the project were missing. A short investigation revealed that in the course of a routine cleaning and space reorganization, the facilities staff had discarded a number of boxes in a storage closet. Among those discarded are quite likely a number of UMDL project records. Working with the project administrator, we were unable to recreate an inventory of what might have been in the boxes. This represents a potential gap in the project record that is unrecoverable.

Email archives

It should be no surprise that many emails were generated in the course of this project; however, these email archives remain solely with the project participants, if they were archived at all. Through the course of interviewing, there were some participants that referenced email, verified that they had, indeed, archived their messages from the project, or narratively referred to significant interactions over email. During the first few instances of hearing reference to email archives, I asked participants if they would grant me access to their email archives to learn more detail about the project. Each request was denied, and I quickly found that broaching the subject erected a barrier that took extra effort to overcome as the interview continued. As a result, I have been generally unable to gain access to a potentially rich archival dataset that describes the day-to-day and micro-level interactions, discourses, and work involved in the UMDL project. The problem of email archives in a project such as this falls into two categories. First, the range and reach of emails that may have been traded in reference to the project is inestimable. Thus, no matter how many emails or archives a researcher can access, there is no method to describe what percentage of the total corpus the sample represents. Second, within the sample collected, estimating or weighting the relative importance of content relative to the communications one does not have is impossible. As a result, this project was unable to access the micro-level analysis that could have been provided by email archives, and was limited to the narrative descriptions of interviewees to understand the day-to-day work of the UMDL project.

Operating committee notes

The collection of UMDL Operating Committee minutes, covering the entire three years of the funded project, have two potential sources of gap. First, it is possible that meetings took place where there are no minutes of record. Speaking with the various administrative staff responsible for the note-taking, there is minimal reason to suspect that there are significant, if any, gaps in the representation of actual meetings. The second area of missing data within the operating committee notes relates to the social network analyses based on meeting attendance. Of the 84 meetings recorded, 12 minutes did not make note of those attending. These meetings were omitted from the social network analysis as a result, introducing error of unknown quantity into the centrality measurements. From a more heuristic point of view, the attendance of the central players within the operating committee was quite consistent, as seen in the network representation of the strongly connected central component. My judgment is that the network representations do reflect reasonable centrality, participation, and influence of constituent members.

3.8 A reflexive note on research work and the dissertation

This was my first time producing this kind of work. Consequently, I had no understanding of what it would take. I have a much better idea of what it takes now, and will be able to scale more effectively the projections of work and estimations of effort involved in significant research projects moving forward.

Interdisciplinary literature reviews are more difficult than literature reviews in well-established disciplines. They do not conform to the instructions in the methodological or andragogical literature, and I did not find examples in existing literature that resonated with my project. Thus, the existing literature review was built out of the literature bases that directly led me to the ontic occlusion and exposure concepts. Every time I approach this work, I realize yet another discipline that might have something relevant to offer in interpretation. This project focused on literatures of ontology, large sociotechnical systems (LTS), digital libraries, and interdisciplinarity. There are other reviews that could have been written about schemata, discourse theory, infrastructure theory, collaboration, organizational behavior, project management, scientific epistemology, theories of power and control, requirements analysis, higher education, and the list goes on. These are all appropriate areas to address in the future, and are ways to make the ontic occlusion and exposure construct relevant to different communities of practice who actively use these literatures. Interdisciplinary literature reviews have the potential to sprawl infinitely, and my own tendency is to go down the literature "rabbit holes" all too easily. I did with this project, but have a better sense now of how to scope, put stopping rules into place, and articulate the boundaries I am setting on the literature review.

There is a tension between choosing a local site for research between convenience and availability of data, and being too close to the subject. Sociological and organizational scholarship advocates "theorizing ones own life and experiences" as a source of good scholarship, and this project developed out of an interesting story in my local context. Many of the people I interviewed had stories they wanted told, and I became caught up in feeling responsible for telling the stories they wanted in the world. For a while, I lost sight of what story I was telling amidst their wants and needs. I know now not to do this – to stay focused on my own research questions and keep the scope tighter. This is not to say that those stories are not important to tell. I am coming away from this project with better ability to recognize what story I am telling and being deliberate about my choices. From a research perspective, starting with the undefined or negatively defined (like the idea of occlusion) sets up a particularly nasty set of challenges. High proof and high paradigm science and scholarship are uncomfortable with ideas that start with "what is not there." I realize now that invoking the ontic (what is there) was my foil to show what was missing. This might not work as a strategy in the long run, and that may be the eventual lesson from this thesis work. I still think it can, at least as a conceptual tool to provoke examination and analysis. Simply prompting the question of “what aren’t we looking at or considering?” has heuristic value for inquiry. The thesis work contains some clumsy and unrefined approaches to attempt a difficult rhetorical and analytic maneuver. It was worth struggling with this, though, because the potential benefits are immense for interdisciplinary research to move fluidly between what is and is not being represented, to expand and contract at will and with an understanding of the mechanisms that allow us to do so. I learned that this kind of research is extremely messy, but necessarily so.

These are some of the things I have learned about research through this experience. I realize the value both of choosing research questions and methodological performances that the scholarly community will recognize and reward as epistemologically sound. I have also learned that early career research benefits by starting with smaller questions and scopes, motivated by personal interest and research passion but distant enough to be analytically dispassionate.

3.9 Summary

In this chapter, I detail the path to the UMDL case, sources of data, methods and tools used in analysis, and details about the approaches used to study the UMDL project. In total, I conducted 45 interviews with researchers and staff involved primarily in the UMDL project, but also with researchers other DLI-1 projects, as well as at national funding agencies. I also collected, converted into a readable format, and analyzed the meeting minutes of the UMDL operating committee meetings, in addition to project documents and artifacts produced by the various working groups on the UMDL project. These data are the primary inputs of the chapters to follow.

Chapter 4

Ontic Occlusion and Exposure in the UMDL Project

The University of Michigan Digital Library project (UMDL) took place in the context of rapid and significant change on the landscape of computing. Most notably, the commercialization of the World Wide Web and widespread access of the public to digitized information marked a transition for content providers and repositories, and the potential reach a new technology would bring to audiences, consumers, and new user bases. This chapter begins with a brief view of the larger social and technical dynamics in which the UMDL and DLI-1 projects took place, setting the context for the project narrative that follows. I then describe three relevant precursor projects that led to the UMDL project. The UMDL took place as part of a broad grant that funded the contemporaneous development of five other digital library projects, constituting the full Digital Libraries Initiative - Phase One. Descriptions of the sister projects at these institutions and commentary on the joint funding by the National Science Foundation, DARPA, and NASA provide an orientation to the UMDL project scope and activities. The chapter then proceeds with a narrative of the UMDL project itself, drawing out specific examples of ontic occlusion and exposure both at the local and global levels, and ostensibly leading to positive and negative outcomes.

4.1 Sociotechnical Context of the UMDL

While the scope of context for any story of situated-ness can be sprawling, two broader trends had significant influence over the UMDL project, one local and one global. In 1991, the National Science Foundation released a Project Development Plan to facilitate a radical shift in networked computing. Over the following three years, the primary network backbone NSFNET would be disassembled and private Internet Service Providers would take up the task of supporting an interconnected network - an Internet - that would be commercialized and available to the general public (1). With the commercialized Internet came the World Wide Web, graphically-based browsers like Mosaic and Netscape, and a new era of interaction and access. The launch of the World Wide Web in 1994 came between the writing and submission of DLI-1 proposals and the beginning of the award period for the selected institutions. How much did this impact the research of the UMDL, and how did the integration of such a burgeoning and significant set of technologies related to access - a primary focus of library and information services and studies - impact the direction of the project between its conception and delivery? Project investigators, upon reflection, were varied in their accounts regarding the level of surprise or disruption, as seen in two examples from a computer scientist and a library scientist, respectively:

> One thing that I think bears remarking about DLI as a whole – when these projects, not just UMDL, but all that were proposed – it was 1993, before the Web. Before Mosaic came out, or at least was widely distributed. So, all of these projects were conceived in a pre-Web world, and then, by the time they started in 1994, we were in the Web world. I think everybody had a hard time reconciling ideas about how to re-make things with what was happening so fast at the same time. I'm not sure we could have done better, given how fast the sands were shifting under us, but that definitely made it much more difficult to have a rational vision that you could actually execute under the terms of the project. (7DC)

> The people at the University of Michigan who were involved in the UMDL were involved in it because NSFNET was here, and they knew it was coming. Because the NSFNET project was one of the first places that created the digital

> environment, and the infrastructure that allowed the World Wide Web to perform in terms of all of the stuff with graphics and so on – in 1993, the NSFNET project worked out a deal with the National Science Foundation that ultimately led to the commercialization of the NSFNET - ANS co+re. So, we all knew that this thing was on track to becoming a really big thing. (T7Y)

While perspectives on the need to adjust or modify the project vary, the effects of the World Wide Web for general access to information, digital libraries included, cannot be overestimated. Within the UMDL story, then, there is a strong undercurrent of both ambiguity in rapid technological and social change around information access and consumption, as well as an excitement at the potential of such interconnectedness.

The second backdrop of the UMDL story, more local, is a shift in administration that led to the right environment to assemble the UMDL team. In 1992, University of Michigan President James J. Duderstadt shifted the dean of the College of Engineering, Daniel E. Atkins, to a position as the dean of the School of Library and Information Sciences (SILS). This was the first instance of SILS being led by a non-librarian, and signaled the beginnings of an agenda that, as shall be discussed at the end of the chapter, has now become a transformative movement for many academic institutions.

4.2 Precursor projects to the UMDL

Three projects directly preceding or developing alongside the UMDL were explicitly cited by interviewees as impacting the formation and delivery of the digital library project.

4.2.1 The EXPRES Project

In 1987, as an early development project to what would become the NSF's "Fastlane" grant submission system, the University of Michigan, Carnegie Mellon University, and NIST were involved in the EXPRES project (***Exp***erimental ***R***esearch in ***E***lectronic ***S***ubmission) (82). The UM team, including UMDP principal investigator Dan Atkins, worked to create a system that would automate the delivery, organization, and processing of digitized resources, including distribution and collection systems. In a foreshadowing of some of the infrastructural difficulties seen in the UMDL, a NSF- and OSTP-based recommendation of the project encouraged further research.

> EXPRES researchers discovered that major breakthroughs in technology were necessary before the basic concepts of EXPRES could be achieved. In 1987, the technology was not advanced enough to meet the objectives of the research program. Additionally, the university information technology infrastructure was uneven; quality varied significantly even on the same campus. The EXPRES program, however, did validate the NSF goals of electronic document exchange. Although full-scale implementation of NSF's concept was not possible, NSF committed to the pursuit of achievable components of the overall program. (114)

While the EXPRES project itself did not turn out a successful system, the involvement in this project laid ground for continuing production systems research at UM, leading directly into the formation of the UMDL project.

4.2.2 TULIP

Between 1991 and 1996, Elsevier Publishing engaged in a large-scale project with several prominent universities to explore the feasibility of institutional production systems to accelerate the distribution of electronically-based scientific publications. The TULIP project (***T***he ***U***niversity ***Li***censing ***P***rogram) was a significant precursor to the UMDL project in that it both established Michigan, along with several other institutions (Carnegie Mellon, Cornell, Georgia Tech, MIT, Tennessee, Washington, Virginia Tech, as well as the entire University of California system), as an active site of digital library production systems research. It also established the professional relationships with Elsevier to be a primary contributor seeding the UMDL with content. The TULIP project focused on three areas of development, which can be seen as building expertise for the activities pursued within the UMDL agenda. The goals of the project, paraphrased (81):

- **Technical:** To determine the technical feasibility of networked distribution to and across institutions with varying levels of sophistication in their technical infrastructure.
- **Organizational and economic:** To understand through the implementation of prototypes, alternative costing, pricing, subscription, and market models that may be 'visible' in electronic distribution scenarios.
- **User behavior:** To study reader usage patterns under different distribution (technical, organizational, and economic) situations.

According to the final report section on the University of Michigan project (Appendix VI), five Michigan faculty and staff (three primary researchers and two programmers) were also listed in the UMDL project proposal submitted to the National Science Foundation. A primary researcher, stated "With the UMDL, and with TULIP, and then with JSTOR, and there were others, Michigan rightfully could claim itself as the leading institution in the development of digital libraries at that time (SBE)," indicating several direct conduits of expertise and knowledge transferred from TULIP to the UMDL, as well as from other projects. Beyond institutional knowledge, the TULIP project contributed base code for early prototypes of the UMDL system (36).

4.2.3 Contemporaneous development of JSTOR

The JSTOR project, a not-for-profit endeavor initially funded by the Andrew W. Mellon Foundation to provide electronically the significant historical archives of scholarly journals, began as an idea in the same time period as the call for Digital Library initiatives closed and evaluations were being made by funding agencies (late 1993-early 1994) (132). The project-level relationship between the University of Michigan and JSTOR was established formally in summer 1994, just before the first regular operating committee meetings for the UMDL project began on August 31, 1994. The JSTOR project team included three members overlapping with the UMDL project - Randy Frank, Ken Alexander, and Greg Peters. Throughout the project, the UMDL and JSTOR shared programmers, some working part-time on each project, and physically located in the same space. Interviews with several project staff claim that while the specific code bases developed did not pass between the projects, that the experience of working on both, and co-location when discussing problems and solutions arising in both projects likely had (non-specific) influences in the development of the digital library production systems.

4.3 The Digital Libraries Initiative - Phase One Project

Based on a call issued in 1993, the Digital Libraries Initiative - Phase I (DLI-1) was a joint project of the National Science Foundation (NSF), Defense Advanced Research Projects Agency (DARPA), and the National Aeronautics and Space Administration (NASA). WIth a respective 3:2:1 proportional split in agency funding commitments, the DLI-1 project committed $24 million shared among six institutional sites, chosen out of 80 full proposals submitted to the RFP (61). The call for proposals expressed the goal of the project (111).

> To explore the full benefits of such digital libraries, the problem for research and development is not merely how to connect everyone and everything together in the network. Rather it is to achieve an economically feasible capability to digitize massive corpora of extant and new information from heterogeneous and distributed sources; then store, search, process and retrieve information from them in a user friendly way. Among other things, this will require both fundamental research and the development of "intelligent" software.

The call outlined three main areas in which research interest was peaking (though not an exclusive list, as stated in the CFP)

- Area 1
  - New research on systems for capturing data of all forms.
  - New research on how to categorize and organize electronic information in a variety of formats.
- Area 2
  - New research fundamental to the development of advanced software for searching, filtering, and summarizing large volumes of data, imagery, and all kinds of information.
  - Research on visualization and other interactive technology for quickly browsing large volumes of imagery.

- Area 3
  - Research on networking protocols and standards needed to insure the ability of the digital network to accommodate the high volume, bandwidth, and switching requirements of a digital library.
  - New research leading to simplifying the utilization of networked databases distributed around the nation and around the world.

4.3.1 Sketches of the DLI-1 Projects

In addition to the University of Michigan Digital Library project, the DLI-1 made five other awards for digital library development. The $24 million award was distributed among the six university sites, funding a variety of activities to build production systems for varying types of information (61). The DLI-1 project was, according to interviewees, one of the first NSF-funded projects to require awardee sites to share resources and findings, and actively work toward interoperability of systems. To achieve a measure of knowledge transfer, the project convened six "all-hands" project meetings, help every six months, and rotated through the six project sites over the three years of funding. Each site concentrated on different aspects of infrastructure development, and focused on work with different data types. Several interviewees independently described the six projects on a continuum from "most service focused" to "most research focused" with the projects ordered, respectively,

- Most Service Focused
  - University of Illinois-Urbana Champaign
  - University of Michigan
  - University of California-Santa Barbara
  - University of California-Berkeley
  - Stanford University
  - Carnegie Mellon University
- Most Research Focused

One highly correlated theme in this ordering is the extent to which respondents suggested that the library was involved in the project. Projects with more involvement from university libraries and library science faculty tended to be more oriented toward service and use. More specific details of each project's focus has been covered well by Ram et al, in a summary statement of late 1990s digital library projects in the US and Europe (122). Following are short descriptions, related specifically through interviews and artifacts, of the other five projects to give context to the UMDL project and frame some perspectives and comments about the UMDL.

Carnegie Mellon University

The Informedia Digital Video Library at Carnegie Mellon University, led by Howard Wactlar, was proposed in a stream of continuing research on image and video research that began before the DLI-1 and continues to the present. The project conducted under DLI-1 was focused on "Integrated Speech, Image and Language Understanding for Creation and Exploration of Digital Video Libraries"[1]. Claims in interviews were made that a number of the innovations achieved through the Carnegie Mellon project in subsequent years led to advanced image recognition systems, within-video search and retrieval, and voice recognition technologies that are now licensed by Nuance Communications, Inc. The Carnegie Mellon DLI-1 project was considered by many involved in the DLI-1 to be the project most straightforwardly focused on computer science and engineering research.

University of Illinois-Urbana Champaign

The University of Illinois-Urbana Champaign project was directed by Bruce Schatz and involved two primary efforts. The first, DeLIver, was a testbed repository and library production system to deliver physics, engineering, and computer science journal articles to the UIUC engineering community. This project worked with SGML conventions to produce contextualized search systems within text documents. The federated searching features we now consider standard originated in the DeLIver project – searching academic journals

[1] http://www.informedia.cs.cmu.edu/dli1/index.html.

restricted to particular fields (e.g., author, title, abstract, keywords, etc.). The DeLIver project also heavily engaged the library science faculty and had a strong social science team that focused on rapid iterations of usability and user testing within the library. The other project, InterSpace, was a pure computer science project aimed to develop semantic indexing techniques for multimedia information. Of the six projects, the UIUC DLI-1 project was the most developed and successful in terms of providing a working digital library within the project time frame.

University of California-Berkeley

The University of California-Berkeley project, headed by Robert Wilensky, focused on a digital library system for environmental and biodiversity databases and was administered by Berkeley Natural History Museums, Berkeley Digital Library Project, Department of Integrative Biology, and Information Systems and Technology. Two commonly noted episodes in interviews focused on "multivalent objects" developed in the project, which involved library users contributing to an annotation layer that would be coupled with PDF versions of documents. The second episode related to the *in-the-wild* viability of the Berkeley project, offered as a proof-of-concept for the work.

> There were major floods in California around that time. It must have been 1997 or 1998. Huge flooding throughout the state, and they had the infrastructure at that point where they could work with the California Department of Natural Resources to, in real time, put out emergency response information - video feeds, image analysis, and in very short order, became a very important resource for managing the flood situation state-wide. (V6F)

The Berkeley DLI-1 project work was continued through 2005 and the primary websites remained online until 2007. The archival material can be found on the current Biodiversity Sciences Technology (BSCIT) site[2].

[2] http://bscit.berkeley.edu

University of California-Santa Barbara

The Alexandria Map Library formed out of the University of California-Santa Barbara project, led by Terrence Smith. This project focused on providing distributed access to geospatial databases and information. The Alexandria Digital library is still an active project that spawned a number of innovations including the ADEPT digital library architecture, several metadata standards for sharing geospatial and geo-referenced information. Because of its sustainability as a research project, several interviewees considered the Santa Barbara project to be one of the more successful endeavors under DLI-1, particularly in terms of cross-departmental work.

> UCSB has a much clearer legacy with the Alexandria digital library and the GIS stuff they did, and the linking of their map library into the technology components from the computer science department. So, at UCSB, they may have had one of the more successful collaborations between the library and the computer science folks. (V6F)

Stanford University

Similar to Michigan's DLI-1 project, the Stanford project was considered by many to be one of the more abstractly defined research programs. The InfoBus project, headed by Hector Garcia-Molina, was targeted at developing technologies for digital library infrastructure interoperability. Many observers of the project described the Stanford project as funding a number of smaller graduate student projects that focused solely on computer science with no involvement from library science. That said, the most notable story associated with the Digital Libraries Initiative, the most often recounted by interviewees from all institutions, attributes the creation of Google to the Stanford project. At the time of DLI-1, Google founders Sergei Brin and Larry Page were graduate computer science students at Stanford working under Garcia-Molina. As retold, one of the side projects under DLI-1 funding called *BackRub* explored rank ordering the results of search queries over a sets of documents. Several researchers from the other projects explicitly recalled attending one of the DLI-1 "all-hands" project meetings and seeing the first presentation of the now-famous PageRank algorithm by Page. While others claim that the attribution of Google to the DLI-1 projects is a stretch, there is a strong suggestion that this creation story is shared my many who take part in digital libraries research.

The six DLI-1 projects tackled the problem of formative information infrastructure and digital library architecture at the most basic levels – standards, interoperability, fundamental search and retrieval protocols, conversion of resources into digital formats. The UMDL's artificial intelligence and agent-based research provided yet another view on what a digital library of the future might be.

4.3.2 Funding agency roles

National Science Foundation (NSF)

The direction and drive behind the DLI-1 project came from Steven Griffin, program director for the Division of Information & Intelligent Systems at the National Science Foundation. The primary architect of the original call for proposals, Griffin was the agency contact that remained with the project throughout its duration. (The DARPA and NASA program managers changed during the course of the DLI-1 project.) Throughout the project, Griffin remained an advocate for the projects to explore difficult, abstract, and high-risk questions when others would have preferred a more stringent and defined agenda for each of the project sites. Despite granting this general freedom, Griffin did ensure that the projects were consistently under review through quarterly, biannual, and annual reports; presentations and reporting at all-hands meetings; and assigning two liaisons to work directly with project teams at the institutions on an ongoing basis. The National Science Foundation then took the lead in releasing a call for the follow-on DLI-2 program, which shifted focus from the DLI-1's charge of developing foundational digital library technical architectures to a more library-based orientation in developing specific collections for digital production, distribution, and use.

Defense Advanced Research Projects Agency (DARPA)

During the early years of the DLI-1 project, DARPA was represented by program director Barry Liner, and then transitioned to Ronald Larsen as he assumed the position at the end of Liner's appointment. DARPA's interest in funding digital libraries stemmed from two main concerns. First, defense agencies have a need to identify, organize, extract, and summarize information in short periods of time. As the volume of information available for making time-critical decisions increased in the digital era, it was clear that tools and techniques for managing information would need to evolve in kind. Second, as more data needed for analysis was located in different agencies and produced through different systems, the ability to access and transfer information efficiently was a top concern. As pointed out by one agency interviewee, "We realized that among the services, and among the intelligence agencies, and among the federal government – a number of different types of systems had to interoperate and it was immense and growing. How can we contribute to an understanding how to make these things function better? The DLI-1 provided a nice forum for thinking about that. (V6F)" Notably, DARPA internal processes require six-month check-ins for assessment and goal setting on projects. While DARPA was unable to enforce the strict accountability protocol, as is its culture, it did impart the regular meeting requirements that led to the "all-hands" meetings convening the six projects biannually.

National Aeronautics and Space Administration (NASA)

NASA, as the contributor of the smallest amount of funding (approximately one-sixth), had a primary interest in the DLI-1 projects that focused on architectures, protocols, and standards for geospatial mapping and referencing. Program managers Nand Lal and Eugene Miya were the primary contacts from NASA. Since Miya was located at NASA Ames Research Center, involvement with the Santa Barbara, Stanford, and Berkeley projects was more consistent.

Interagency coordination and requirements

Although the three agencies entered into a co-sponsorship arrangement to fund the DLI-1, the locus of administrative power and adherence to procedure followed the lead of the NSF, who was providing the largest proportion (50%) of the total $24M budget. Unlike some arrangements where protocol adheres to the most strict, covering the needs of the less, the National Science Foundation required less stringent reporting and accountability structures, preferring to leave the innovation space wide open to the grant awardees. The coordination of the projects, since the institutions were clustered in the midwest and west coast, fell to two levels of oversight. In Washington DC, Griffin's and Larsen's offices were walking distances from each other, which promoted frequent contact and discussion about project agreements and agency requirements. Miya, the NASA project manager, was located on the west coast at NASA Ames Research Center, and made frequent trips to monitor the Stanford, Berkeley, and Santa Barbara projects, and had less frequent contact with his NSF and DARPA counterparts. More frequently checking in on the projects were Ben Gross and Susan Harum, two early members of the UIUC project who had been hired into NSF by Griffin to monitor and report back interim progress between the bi-annual "all-hands" project meetings.

4.4 UMDL Project Summary

While some of the more specific details of the UMDL project are covered through observations in the sections that follow on instances of ontic occlusion and exposure, a high-level narrative of the project can be divided into four phases: proposal phase and years one, two, and three. Throughout the three years of the project, the day-to-day work appeared to be unremarkable in the context of academic project work. Although all interviewees on the project were asked to recall details of the everyday practices in the project, few could recall specific details and were anchored mostly in the activity surrounding preparation for the all-hands meetings where the project would report progress to the other five institutions and funding agency managers. The exception to this lack of detailed memory came through references and anecdotes arising in the bi-weekly operating committee (OC) meetings. It became apparent the these meetings were the primary site of regular contact for the library science and computer science perspectives that explicitly addressed deeper issues of project construction, disciplinary assumptions and commitments, and was a focal point of the interdisciplinary experience in the UMDL.

The University of Michigan Digital Library project began in 1992, when newly-appointed dean of the School of Library and Information Studies Dan Atkins began a series of meetings inviting scholars from across campus to begin exploring mutual interests with digital technologies in mind. As a result of these meetings, a persistent group of scholars – some self-selecting and some specifically encouraged by Atkins – agreed to take part in writing a proposal for the NSF Digital Libraries Initiative Call for Proposals released in 1993. Knowing that the proposal would be highly multidisciplinary in nature, the team worked to avoid the approach of each group writing proposal pieces separately and submitting a "proposal by stapling." Instead, Atkins worked with groups from the College of Engineering (CSE - Computer Science and Engineering) and SILS, but also with faculty from the University Library as well as other faculty from units such as public policy, economics, and education (though no other departments had enough representation to match SILS or CSE). The resulting submitted proposal was an ambitious project to create artificially intelligent "agents" that would perform the functions of a digital library. The agent-based approach to digital library architecture necessitated several working subgroups to replicate various functions for finding, retrieving, and presenting digital resources for users. Figure 4.1 below describes the generalized architecture of the proposed agent-based library system.

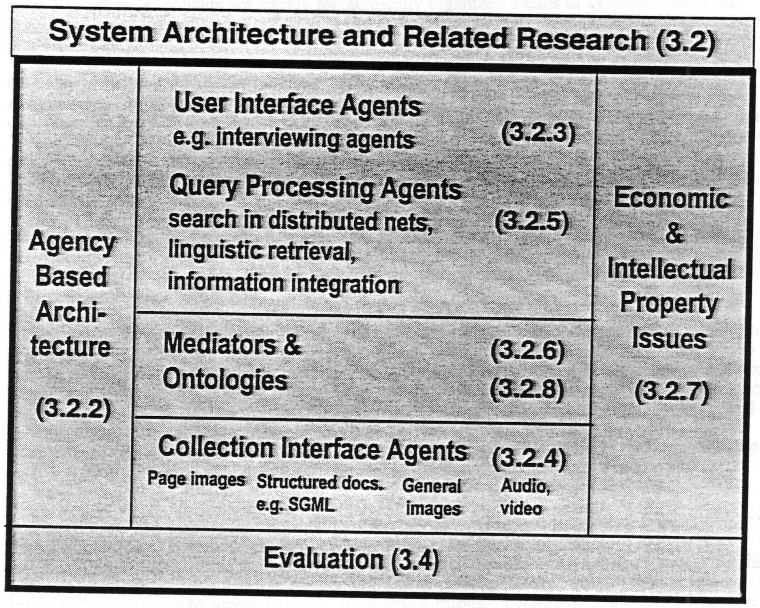

Figure 4.1 Fundamental UMDL Architecture (7)

Seen in the division of components, the project focuses on the engineering capabilities of the UM team. We also see a number of objects that would later be revealed as pivotal points of misunderstanding, such as *user, agent, ontology, collection*, and *evaluation*. The different epistemologies of library science and computer science describe substantially different ontological orientations, and thus different application of the ontic commitments to these terms through which the actual digital library would be constructed.

Figure 4.2 gives a more detailed picture of the proposed involvement and relative influence of the researchers on the UMDL project. A notable feature of this diagram is that the subgroups serve to mostly separate the library contingent (primarily Frost, Drabenstott, Warner, Durrance, Janes, Alloway, Lougee) and the computer scientists and engineers (Atkins, Birmingham, Durfee, Wellman, Rundensteiner, Soloway, Frank, Alexander, Peters). The library science contributions to the project, as seen in both Figure 4.1 and 4.2, were concentrated in the activities designated "Deployment, Use, and Evaluation". These were all activities taking place *after* the technological development, architecture design, and

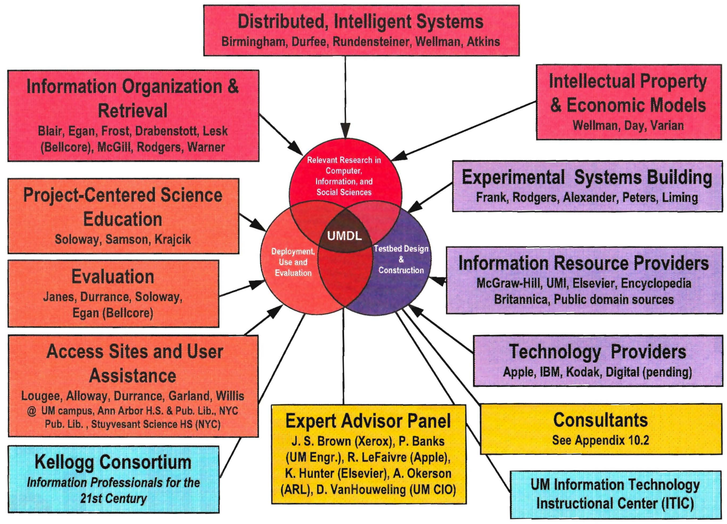

Figure 4.2 Research Components of the UMDL Project (7)

construction. Although the aim of the project was to work in a highly interdisciplinary fashion, interviewees described the work as taking place in traditional and "business as usual" disciplinary groups. The artificial intelligence group developing the agent architectures (Birmingham, Durfee, and Wellman) worked independently, though did collaborate with Varian and MacKie-Mason to build economic auction models to govern agent resource sharing and algorithmic decision behaviors.

Aside from the pure technological development, architectural work, and artificial intelligence research, the UMDL project also planned implementation of the digital library system itself – the user-facing side of the library – as a system for middle- and high-school science education. The Artemis Project, as it would be called, was planned for several Ann Arbor district schools, with initial plans to also pilot in Stuyvesant High School in New York City. Despite efforts, the New York connection did not prove fruitful, and the eventual implementation was limited to local education. As the UMDL proposal plan stood, the project would have two primary outcomes: a testbed for demonstrating the developed technology (a requirement of the call for proposals), and a working prototype that delivered digital content of a specified domain-based collection.

In broad strokes, the first year saw a significant marshaling of resources and managing relationships with outside vendors and industry partners. The project team, following an engagement through the TULIP project, approached Karen Hunter at Elsevier Publishing for seed digital content that would populate the testbed. Hunter agreed and provided content from digitized journals representing various disciplines. The User Study Group focusing on the school implementation worked through the first year to select sites and promote an "Internet culture" at the chosen schools. Since the World Wide Web was as yet unfamiliar territory for schools, the team saw a need to tend to the basic Internet literacy skills of teachers and students before a digital library implementation could take place. The technology group started construction of the testbed and worked with graduate student programmers to design the conspectus, ontology, and agents that would replicate the roles of reference librarians *in silico*. During this first year, Dan Kiskis joined the programming group (mostly professional programmers who coded projects for the CSE faculty and polished graduate student code to be ready for production releases) and gathered together the operating committee notes and technical group artifacts to produce a master requirements document for construction of the agent-based system.

The second year work saw the construction of the interface that would become the Artemis project implemented in the schools. In addition to Elsevier's more advanced content (useful for generating interest in digital libraries from the university audience), McGraw-Hill publishers also donated content for middle school science curriculum development, aiding in the implementation side. During this year, the AI and IPE (Intellectual Property and Economics) group also started more significant work in designing the auction systems that governed DL agent behavior. By the end of the year, the interface for schools had been built, and students were able to access content, but the core functionality of the agents proved to be problematic [3]. The end of the second year saw the University of Michigan hosting the

[3] During interviews that covered the technical aspects of the project, including the design and programming of the artificial intelligence agents, I probed about the requirements gathering process to define the activities and functionality of agents performing activities usually done by librarians. I was surprised to find that the computer science faculty garnered their understanding of library functions by asking the library science

bi-annual All Projects Meeting where the funding agency representatives and teams from the other five DLI projects converged to share updates. Meeting notes suggest that at the conclusion of the second year, the UMDL project was still in the proof-of-concept stage, having produced a number of posters and planning a video animation of how an intelligent agent-based retrieval system would work in a digital library, but had not produced a working prototype.

The third and final year of the project saw the production of the explanatory video, which was well-received. The implementation group was able to gather many hours of video data from the Ann Arbor public schools of middle schoolers using the Artemis system. This data was passed along to the evaluation group (primarily SILS faculty) toward the end of the third year; however, the frustrations of the group from waiting for two years to become engaged were significant, and interviews revealed that the full evaluation of the data never took place. The operating committee was engaged in a return to deeper questions about the role of a digital library in science, and began to reflect upon the work of the previous two years as two major milestones approached. First, the team began from the start of year three to strategize the final report to show the overall project contributions. Second, the DLI-2 project had been announced, and the University of Michigan group spent time putting together what would turn out to be an unsuccessful bid for a second round of funding. The third year and the project ended with a final All-Project meeting where the post-mortem notes suggest that the UMDL team felt that they were unable to deliver their vision of the project goals and outcomes clearly to the community. Despite the failure to produce a working digital library populated by intelligent agents, the team articulated some important lessons learned (selections paraphrased from UMDL Operating Committee Meeting Notes from April 23. 1997)

- The assumption that online resources are a library needs to be re-thought. There needs to be more than online replication of a textbook. More animations, graphics, and

faculty to describe the routines and operations of a library. When asked if they interviewed working reference librarians or spent time in a library shadowing librarians as they do their work, they replied that they had not.

analytical tools are needed.

- Where does the library stop and where do other things begin? We need to back to defining the digital library in terms of looking, finding, and reviewing.
- To really build a digital library system, you need a vision for useful services and what is needed or necessary to get them done. Accomplishments from the UMDL project would be hard to demonstrate to third parties. We have not shown how to project and bring services to bear on library-like tasks.
- There is no incentive for third parties (like content providers) to invest in services until an interesting infrastructure is in place. An interesting infrastructure cannot be built without content around which services can be built. This is a chicken-and-egg problem.
- Digital libraries need to support more than one-shot inquiries. They need to support advanced tasks and the knowledge work that people do.
- We learned how to locate, describe, and team agents. We discovered that issues of subjective meaning of service or content were harder than initially believed. There were issues of how difficult it is to price service. Issues of encouragement for others to build, describe, and deliver collaborative services.

Several interviewees at all levels of the project – researchers, agency contacts, administrators – pointed out that while the stated goal of the project was to develop a working prototype of digital library architecture that would deliver seed content, the larger goal of the NSF was to foster innovation into new areas that would eventually address the need to manage an impending explosion of digital content. As we will see in the following sections, the failure of the project to produce a library may have occluded some of the more important and sustainable contributions of the UMDL project.

4.5 Local Occlusions and Exposures

Applying the interpretive lens of ontic occlusion and exposure, two relevant levels of scale emerged from the analysis. The first level is the local context of the UMDL project. In particular, the activities taking place through the operating committee as a consistent site where disciplinary researchers confronted and choreographed ontic differences.

To engage a discussion of mechanisms and change, a useful approach is to examine

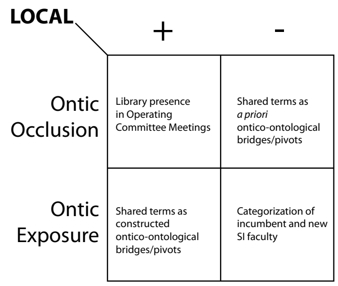

Figure 4.3 Range of Local Ontic Occlusions & Exposures

outcomes[4]. Cast as oppositional states and processes, we can separately examine occlusion and exposure, each leading to interpretively net positive and negative outcomes, as expressed by project researchers and interview participants. At the first, more proximate level, we find examples of each category relative to the UMDL project and its first-order connections and results. Briefly (and detailed more in the sections that follow), the UMDL project showed positive occlusions through the inability to overtly discuss or take action upon a decisive shift to the engineering perspective due to even diminished presence of library researchers in the operating committee. The project saw a shift from negative occlusion to positive exposure with respect to discovering misalignment with the operating ontic sets and commitments of the different disciplinary cultures through articulating a number of terms and concepts in need of negotiation. Finally, the local UMDL case experienced negative exposure by keeping present-at-hand the socially valent differences between epistemic cultures collected together in the new School of Information.

[4]Keeping with the observations of multivocality and the Rashomōn Effect, I recognize that using broad categories of *good* and *bad* outcomes are dependent upon the interpreter's perspective. The general approach to discussing outcomes here does not aim to be disrespectful of any one person's position relative to the project. At the same time, outcomes can have common or communal evaluations or judgements regarding their positive and negative effects.

4.5.1 Occlusion as Positive Effect

Since the UMDL project was an early encounter of researchers from library science and computer science, there were bound to be negotiations of the type detailed in literature on interdisciplinary formation. In the UMDL case, however, the language of engineering was dominant from the start, and representation from the library side appeared marginalized.

Throughout the project, the representation of the library was constant but diminished, and generally was moved to the periphery of participation. To explore the nature and dynamics of participation in the operating committee meetings, I chose to represent them as a series of networks based upon data found in committee meeting notes. The social network approach here is useful because the representations reveal another window onto a complex phenomenon. While they are intermediate products of the research and not answers or "proof" in themselves, they are strong indicators of where another type of data support or contradict constructed narratives, or provide an alternative window into the phenomenon where additional insight is found.

In the UMDL case, the network representations happened to support most of the interview data from project participants, and there was no significant contradiction or incommensurability between the attendance data and participants' recollections. It is important to note that the network analysis is not given too much weight, and that the limit of interpretation is that these networks corroborate the details uncovered in the qualitative interviews. Still, the social network analysis did contribute to this study in two ways. First, a more robust understanding of the change in operating committee relationships over time (and as the nature of the project work changed),. Second, the network indicated that some figures were more central to the operating committee than conveyed in the interviews, leading to deeper exploration of topics with participants, as well as an unforeseen aspect of ontic occlusion as participation maintained the power and legitimacy of the library in the project, as seen in the following diagrams.

Note: In all network diagrams, yellow squares represent meetings and circles represent participants (Blue: Computer Science tribe; Red: Library Science tribe).

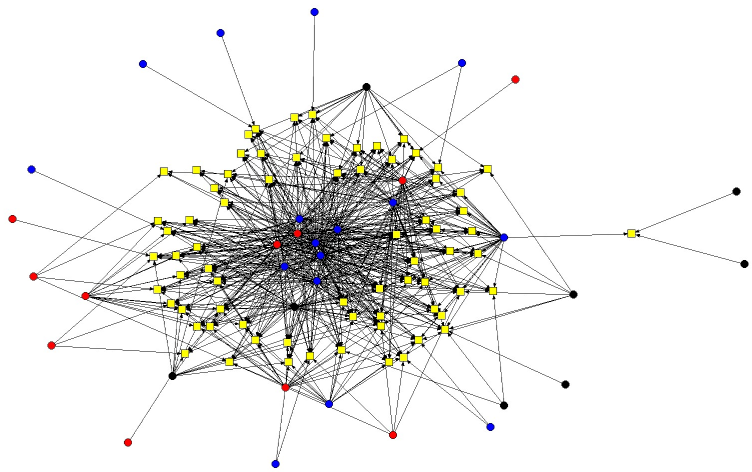

Figure 4.4 UMDL OC meetings and attendees 1994-1997

In Figure 4.4 above, we see a force-directed network representation of all attendees of the UMDL operating committee meetings over the three-year funding period. There is a clear ring of square nodes which represent specific meetings. Two groups of circular nodes, the attendees, emerge here. First, there is a group of attendees inside the ring. This group represented a core set of researchers and staff who attended a large proportion of the meetings throughout the project. The nodes on the outside represent associated researchers who had a lower attendance or involvement in the operating committee. This criterion was used to identify the primary group of researchers on which subsequent network analyses would be based. Lammers suggests that participation in formal meetings within organizations is correlated to the power that an individual can exert over the decisions and processes (94). I have interpreted this work in the context of the UMDL project that attendance at operating committee meetings and levels of centrality are associated with levels of influence and representation in the discourse of the project. Looking at the arrangement of meeting attendees by tribe, it is clear that the inner circle (meaning those who were central to the entire project cycle in terms of attendance) has more than twice the number of computer science and engineering researchers than the library researchers. Though this may be in part a function of the project framing provided by the NSF call, as well as by the RFP designed by the UM team, the respective roles of the library and engineering perspectives in the overall project implies that the construction of the UMDL was more digital, less library.

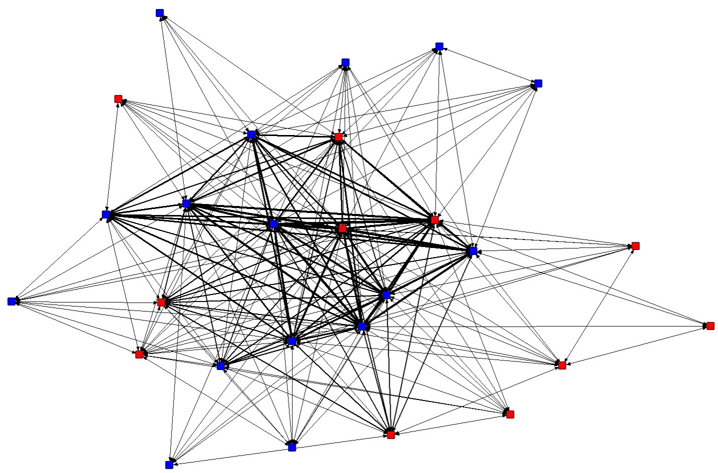

Figure 4.5 UMDL OC attendees 1994-1997

Figure 4.5 above represents a one-mode network derived from the previous network of meetings and participants. In this network representation (as in all others that will follow), the nodes represent meeting attendees (again, with the same tribe designations) and the ties between them indicate co-attendance at meetings. Thicker lines imply more common co-attendance and increased discourse between the represented individuals and tribes. This figure, which represents the relationships among all non-isolate participants in operating committee meetings over the entire three-year period of the project, shows that there was a core of participants with a stronger representation of computer science and engineering researchers. It also indicates that three library researchers in particular (seen in the upper right of the core group) had much more frequent contact with other team members and each other, and the remaining two more centrally involved library researchers (in the lower left) had weaker ties overall with the core group. Alternately, all of the CSE researchers in the core tended to have stronger ties with each other, as well as with the three more frequently involved library researchers. Overall, this suggests that the there was, in fact, a core group of researchers who frequently attended the same meetings (as opposed to adequately high meeting attendance, but at different meetings.) Given the higher levels of attendance by this core group in both tribes, we can better imagine how ontic occlusions took place by finding common concepts and signifiers to share knowledge in the group meetings, as well as occasion to realize the consequences of such occlusions and engage the process of ontic exposure to realize deeper misalignments between the two tribes' use of and approaches to work as a result of different ontic subscriptions.

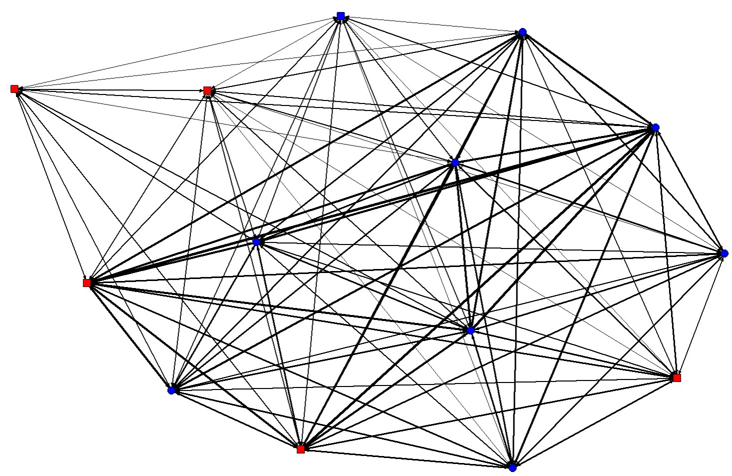

Figure 4.6 Core UMDL OC attendees 1994-1997

Figure 4.6 shows a network diagram generated out of the same data as Figure 4.5 – UMDL operating committee co-attendance for the full three-year project period – but removing all people who attended less than 10% of the meetings. For the purposes of this study, I considered this subgroup as the "core" of the UMDL operating committee. In this diagram, we can see that CSE researchers are at the center and have stronger interconnections, and the library researchers are around the margins of the network.

In this diagram (Figure 4.7), we see a co-attendance network representation for the core group during the first year of the DLI-1 award. The node most central comes from the CSE

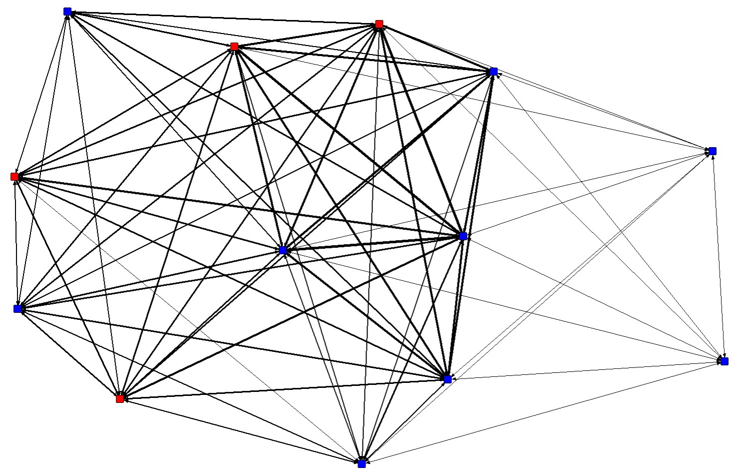

Figure 4.7 Core UMDL OC attendees AY1994-1995 (DLI Year 1)

tribe, and there is a slightly stronger interconnection among the group of CSE researchers to the right. The Library tribe here has less than half of the attendance representation; however, those that did attend regularly did so at a similar rate to the CSE attendees. The Operating Committee meeting notes indicate that the efforts during the first year were concentrated on securing school sites for the eventual launch of the prototyped interface to the UMDL system and running focus groups to gather information for interface design, negotiating agreements with content providers to populate the UMDL, and development of a conspectus document that described the proposed digital library architecture and testbed. The library science researchers were linked most closely with the first task, while the remaining tasks were primarily linked with the names of CSE researchers.

The second-year network (Figure 4.8) of the UMDL project operating committee meetings show a stronger push of the attending library faculty to the outside of the network. Meeting notes indicated that the activities during the second year became more compartmentalized with subgroups working independently on developing the agent-based testbed (CSE), working with the schools for upcoming deployment and designing evaluation criteria for the launch (SILS and Education), and pursuing content (University Library and IPE). The

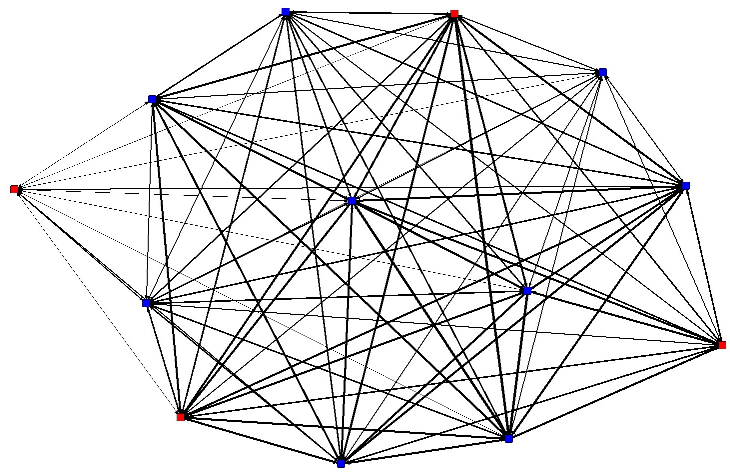

Figure 4.8 Core UMDL OC attendees AY1995-1996 (DLI Year 2)

operating committee members themselves were also quite active this year in visiting other sites, sponsors, and funders to The year began with content contracts still in negotiation with several providers. The primary two signing on during this year were McGraw-Hill and Elsevier. As a result, this year saw increased activity from the IPE (Intellectual Property and Economics) subgroup, composes of members from the CSE Artificial Intelligence team along with an addition from the economics department.

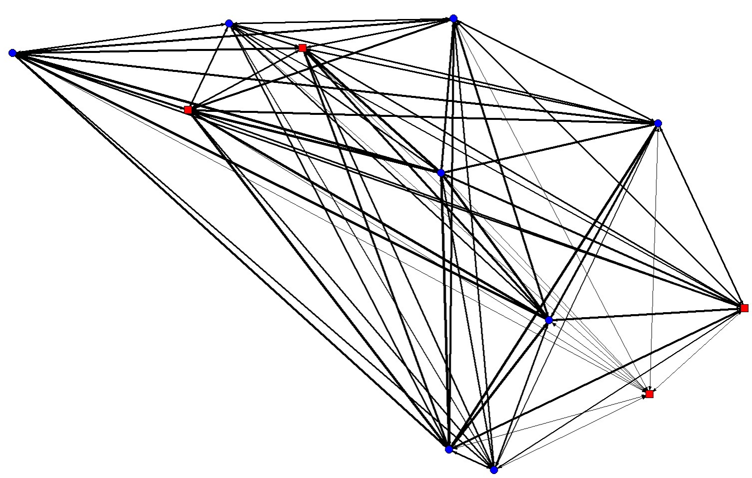

Figure 4.9 Core UMDL OC attendees AY1996-1997 (DLI Year 3)

In the final year of the project, we can see that the committee exhibits some polarizing associations with a strong computer science presence on the left, and a library science figure on the right (Figure 4.9). As a reflection of the work, the library figures to the left worked closely in the last year with the computer scientists on implementation issues within the university library and local Ann Arbor public schools. This may account for a strong association between these individuals during the final phases of the program. From meeting notes and interview data, the discussions around this topic were primarily targeted toward specific technical issues with production systems and adjusting programming, interface elements, and available content for in-classroom use.

The right side of the diagram shows two librarians, one with much weaker ties and co-participation overall, and one strong presence. This more densely connected node also kept the second-highest centrality and dyadic constraint measures throughout the project. This suggests that although the strong library presence moved away from the center throughout the project, the underlying influence remained strong.

Comments from both library and computer science researchers, when recalling the operating committee meetings, suggested that the fact that the library presence declined in the meetings and in the project as the end of the funding drew near did not go unnoticed or unappreciated. In the face of difficult conceptual negotiations, the need to prepare final reports of the project in a unified and consistent language understandable to funding agencies, and a drive to pull together the resources to generate a proposal for the upcoming DLI-2 grant competition, engineers understood that the process would be easier if the project could adopt a consistent disciplinary voice. The language of computer science and engineering was most available, given the representative expertise of project participants attending the operating committee meetings.

Despite the shift in the project toward more representation and disciplinary dominance by the engineering side, and the often singular treatment of the technical aspects of the project recorded in the operating committee meeting notes, the library presence never disappeared fully. Throughout the project, one member of the library faculty attended almost every meeting and was among the top project participants in measures of degree and betweenness centrality, as well as measures of dyadic constraint (both in terms of being the least constrained by, and most constraining of other members in the network), as seen in the following table.

ID	Tribe	Deg Centr	Betw Centr	Constrained	Constraining
N6R	CSE	0.941	0.058	0.0067	0.0358
7C4	LIB	0.941	0.058	0.0068	0.0301
YQR	CSE	0.882	0.044	0.0070	0.0250
UEV	LIB	0.882	0.048	0.0070	0.0242

Table 4.1 Network Measures for Most Influential Committee Members

What we may infer from this set of measurements is that although the engineering focus was prominent in the project, proposal, reports, and meeting notes, there was a persistent and significant parity of influence from the library side. Participant 7C4 attended almost every meeting. Why, though, do project participants attend meetings? Three primary possibilities are:

1. There is a relationship between attendance and importance to the project
   (a) People attend the meetings because they are important to the project.
   (b) People are important to the project because they attend the meetings

2. The person's job is primarily administrative in nature and attending meetings is the primary activity

3. Attending the meeting ensures enablement or constraint
   (a) Attendance ensures that particular items are discussed or actions taken

(b) Attendance ensures that particular items are not discussed or actions not taken

To disambiguate the analysis, I returned to some of the interview participants and inquired about this interpretive scheme. A few participants revealed that category 3b was important with respect to the influence of the library in particular and important ways. The UMDL project faculty were also part of the core group responsible for the transformation of the UM School of Information and Library Studies (SILS) into its new institutional form, the School of Information (SI). During this time, significant debates about the new school's curriculum involved discussion about the role of traditional library studies in the remediated program. Interview participants suggested that if the library faculty had stopped attending the UMDL meetings altogether, many of the ensuing, ontically exposing discussions that brought to light the different communities understanding and use of core terms would not have taken place [5]. In short, the continued participation of the library faculty occluded a short-tem dynamic that might have discarded the library science disciplinary viewpoint from the UMDL project, and by extension, the new school's curriculum which integrated many of these exposed ontic tensions and differences. This occlusion, then, was a survival mechanism for an important continuing contribution at the intersection of library and computer

[5]The apparent disappearance of an influence or causal factor in a diverse environment of actors appears both *in vivo* and *in silico*. Agent-based simulations provide an analog to the resurgence or re-assertion of a dormant or presumably extinguished factor. A popular and simple multi-agent simulation of predator-prey models shows the dynamics of competitive populations. A typical scenario involves foxes and sheep. There are three agents in the modeled world – grass that auto-reproduces, sheep that eat grass to reproduce, and foxes that eat sheep to reproduce. Two typical outcomes (sensitive to initial conditions) are seen in the scenario: (1) the populations of foxes and sheep reach a cyclical equilibrium where the diminishment of one population serves as a control on the other, or (2) too many foxes eat locally available sheep and the fox population dies due to lack of food. Because the population is based on a spatial grid, there may or may not be remaining sheep lucky enough to be too far away from a fox to be eaten. Under this scenario, the sheep multiply to fill the entire available grid. There is a special case described by Rick Riolo, lab director at the University of Michigan Center for the Study of Complex Systems, as the "nano-fox" problem. In one unpredictable form of the simulation, fractional representations of the fox agent remain unseen on the grid (since the representational unit of analysis in the simulation is 1 fox). These fractional nano-foxes float on the board un-noticed until enough anneal to "spontaneously" form a new fox, who then has an ample supply of food to resurrect the fox population. The underlying analogical suggestion here is that elements of a dynamic field (especially of ideas or residual ontic/ontological elements) can remain unnoticed or occluded not by inattention or intention, but simply by being too subtle, small, or dilute. They may, however, coalesce and exert influence after a period of dormancy. A potential lesson for the study of ontic occlusion and exposure here may be that although the presence of an ontic set seems to have disappeared completely, it may be a nano-fox that later brings the system back into equilibrium if we wait and watch: our time scales of evaluation, in many cases, may simply not be long enough to observe the nano-foxes of our dynamic social systems.

sciences, and worked toward a positive outcome in a successful and sustainable information school vision and curriculum.

4.5.2 Occlusion as Negative and Exposure as Positive Cyclical Effects

Considering the ontic as a set of discursive objects lends itself well to casting as a variation on a theme of boundary objects (141; 25), and in the context of discursive objects that have strong community connotations or are semiotically attached to further disciplinary processes or interactive contexts, boundary objects with agency (57; 58). I believe that the ontic occlusion and exposure mechanisms do have a relationship with the boundary object concept, but not as a sub-class or variant form of boundary objects. Instead, the ontically occluded may be a reflection of the boundary object, but through a mirror darkly. The ontically exposed is rendered visible to the viewer, and the embedded systems in which they find their roles and contexts become clear and present-at-hand. The ontically occluded is more difficult to interpret in its ready-to-hand state. We can make reasonable claims that if the exposed appears structural in nature when it is rendered, then it is likely structural when it is invisible [6] However, the ontics privileged in dominant narratives continually re-inscribe particular views and understandings of structures. Specifically, we tend toward a functional definition of *structures of enablement* which either allow us to function, or must be addressed when systems break down. The other, more difficult structural conditions are the complementary *structures of neglect*. The ignored, silent, or otherwise residual is not necessarily unorganized or isolated, and the occluded may indeed have equal organization, power, agency, and causality. An apposite case returns us to Vaughan's Challenger analysis, where the occluded communication hierarchies leading to cultures of production and secrecy had strong systemic and organizational features: elaborated systems with the quality of neglecting critical communication paths (155). In the Challenger case, the occluded on-

[6] The general idea being that which is invisible, ready-to-hand, and working below the level of cognitiion – infra*structure* – is indeed structural in nature when unobserved.

tics were not revealed until the catastrophic events had passed and analysts from different disciplines took intentional pains to examine the root causes of the problem.

In the UMDL operating committee there was a similar cycle of ontic occlusion (though certainly not implying that the UMDL was a national catastrophe) that led to a sticking point in the work, and the group was able to expose on its own through examination of the project's progress. The operating committee, as the primary site of discourse between the library scientists and computer engineers working on the project, engaged in joint interpretation and construction of what had been proposed to funding agencies. The project artifacts reflect different sets of details, objects, and primitives associated with these constructions. Depending on the issue at hand, many of the operating committee notes are more procedural; for example, person X should follow up with person Y, or be sure to hire a new programmer, or prepare slides for the upcoming site visit. Because the project had a physical set of objects – technologies, the testbed, prototypes in schools, code – the recorded details tend toward describing actions performed on these objects, and the represented ontic of engineering is further advanced by the dominance of the CSE faculty as detailed in section 4.5.1. These details are less important to interpreting the more interesting ontic story of the operating committee that arose from the interviews, which indicate that the discussion, never entering into the official record, was much different than the matter-of-fact progression contained in the documentation.

The activity of constructing a digital library began, in the discursive sense, with writing the proposal. Since the team was set on providing an integrated project (and not simply several smaller projects proposed by different departments and stapled together), Atkins and his team collected the ideas of interested parties and sought to synthesize them in the proposal.

> We didn't speak each others' language at the beginning, and so as we were writing the proposal, we were still at the beginning of trying to understand each other. We got to understand each other better after we got the money and were actually doing the project, but I don't think there was a sufficient amount of

> real appreciation, on either side, during the proposal writing process of what the other side needed. I'm trying to be fair because I don't think in any sort of dysfunctional relationship that one party is all right and the other is all wrong. It's just a misunderstanding.
> ...
> I think that would have really helped because we did a lot of the, "When I say 'this', I mean 'this', but when you say 'this', you mean 'that'." We did a lot of that after we got the money. And it wasn't that it was too late. It was just that we should have done it before so we could hit the ground running.(87D)

Upon beginning the work, the operating committee used the proposal as a starting point for putting the plan into action. The proposal, generated documents about the work plan, test bed, and conspectus (a document describing how artificial intelligence agents would pass information describing library objects back and forth), all employed terminology that both library and engineering worlds use frequently. As they began the work, the documents serving as boundary objects and the shared vocabulary through which they passed information back and forth facilitated the progress of work, but not without tension.

> During the UMDL, we came from different tribes, and we didn't speak each other's language. That was another difficulty with UMDL because it was truly as though we were different tribes. Each of those tribes had their own cultures. Each of them had their separate languages. They shared some common words, but those words didn't mean the same thing. So, the UMDL was really – there were many, many cultural and technological things that the UMDL was attempting to do that – it probably couldn't have done any better than it did, and I would not say that it was a smashing success. We may not speak the same language still, but we aren't totally different tribes anymore. (4Q3)

As the project progressed, though, the operating committee members began to realize that although they were speaking through the same words, their languages and understandings of the objects – their intentionality – was quite different. When asked about whether progress was made in resolving the early tensions of language differences (and of ontic sets), one project member remarked:

> No. No, there wasn't. That was kind of sad because every six months we'd get together to try to figure out where we were, and what everybody understood

> about the project, and it just never gelled. Part of it was that we didn't speak the same language, and part of it was that we had proposed something that wasn't possible. In that case, I don't think that the computer science folks really understood how hard some of this stuff is to model computationally. I don't think that the library folks were sufficiently articulate or stressful. (87D)

The vocabulary problem turned out to be a regular feature of interviewees' narratives about why the UMDL project experienced challenges in producing a digital library product. I describe these terms, in the context of the project work, as *ontico-ontological pivots*. Each tribe came to the table with ontological commitments and understandings of what a digital library might be or become, framed by the synthesized language and objects represented in the project proposal. To bring a library into being, to manifest, the group needed to cross collectively what Heidegger refers to as the "ontico-ontological bridge" (46). Whereas Heidegger's conceptualization of the bridge was focused on the individual moving from understanding the experience of being in the world (the phenomenological) to understanding his own particular situation of existence within it (Being), I co-opt this term to describe a collective and negotiated process by which a group progresses from the abstracted concept of what they might bring into the world (the ontological) to what they commit to making manifest (the ontic). As it would happen in the UMDL project, the two tribes shared referents – vocabulary – that made the impossible (as described above) seem possible. These words, though, served as occluding "pivots" that allowed the groups to communicate without being aware of the difference between an aligned ontic sense, and orthogonal ontological subscriptions. When asked for specific words that eventually arose as terms of contention, several were given. A compiled list from operating committee interviewees includes:

Other questions surrounding this list came to the fore in interviews as well:

- What are the settings of scholarly and non-scholarly use?
- Does a digital library contain just text? Images? Anything digital?
- What parts of the library are digital? What makes them digital by definition or by nature?
- Is it a digital library if it is like an OPAC?
- Do we only use digital libraries to find digital objects?

- access
- agent
- architecture
- artifact
- catalog/cagaloging
- centralized
- collection
- content
- data
- digital
    - digital artifact
    - digital collection
    - digital library
- distributed
- index/indexing
- information
- knowledge
- library
- metadata
- ontology
- scholarly
- service
- use
- user

Figure 4.10 Ontico-Ontological Pivots in the UMDL Operating Committee

- To what extent is a library an institution with people and staff? How are these balanced with AI agents and technologies in a digital library?

These terms and questions are not peripheral to the conceptualization and construction of a digital library. The contention of the most basic terms became more apparent as the project progressed. When asked to describe the differences and what each tribe understood to be the nature of the term and how it might have differed (what was the nature of the occlusion), interviewees were still unclear on many of the differences. A typical response, when asked how these tensions were resolved:

> We didn't. We really didn't. We said, "Gee. That's interesting." It's really hard. I'm being overly harsh, but it's very hard to do interdisciplinary work. These two fields – they were on North Campus and we were on Central Campus,

> and we had never even met each other before, so it wasn't surprising that it was hard on either end. To be fair, I think I should say that. There was no bad guy and no good guy. It was just hard. We didn't pull it off very well. (87D)

The inability to agree on the most basic terms, the misalignment at the ontico-ontological pivots, made it difficult to communicate within the operating committee, but also was pointed out by agency contacts as a difficulty in communicating the progress and products of the UMDL project outside.

This occlusion may appear to be solely negative, but the operating committee did not simply walk away from the tensions, challenges, and hard work of examining these fundamental (and as interviewee's admitted, uncomfortable) differences. One member sums up the fate of these debates elegantly.

> They didn't speak our language. We didn't speak their language. They didn't care about learning my language. I didn't care about learning their language. We couldn't figure out what we had in common, and where we had common words that did not mean the same things. So, it was those types – engineering types. The computer engineers. In fact, there was a layer of people who didn't talk to us at all, but they built things. It was important for them to build things. There was - what we realized, I think individually, but not as a group, was that this project was showing is that even within our own areas of specialization, we didn't understand each other. We didn't understand our own area of specialization. Everyone would figure, "Oh, those AI guys all understand each other. Those LIS people all understand each other. They're the same. " I don't remember an archival presence at that time. What the UDML did was to stretch our minds so that we realized, "Oh, we don't even know – we don't even have within our own tribes – there are sub-tribes that, if we're going to get this thing done and do this digital access thing for a bunch of people, then we're going to have to understand better what it is that we do." (4Q3)

Several members went on to point out that many of the UMDL project members who were aware of these tensions went on to teach the first foundations courses at the transitioned School of Information. They claim that these scholars were intrigued and bewildered enough by the mismatches in ontologies, and realized that there was significant work to be done in this area that would need continuation after the DLI-1 projects had ended, that the questions above and negotiation of the terms became the basis for the new master's and doctoral curricula at SI. By report, it is not incidental that the first questions new students in the school encounter are “what is information?”, “what are libraries?”, or “what is the nature of the relationships among people, information, and technology?” The ontic tensions, through the agency of mindful and interested researchers and teachers, underwent an institutional transference, finding new life and continuation as a positively-oriented and ontically exposed mode of inquiry through the curriculum, and in newer generations of information professionals and scholars.

4.5.3 Exposure as Negative Effect

At times, keeping ontic details in a present-at-hand state may lead to particularly negative effects for some. Interdisciplinary work is often continuously reflexive, and the novelty of encountering disciplines other than one’s own remains in sharp focus. With this focus comes the politics of power, and potential for horizontal violence perpetrated between disciplinary affiliations. In the case of the UMDL, the “culture war” (8TU) that emerged between the engineering and library factions spilled over into the formation of the new School of Information. As the school formed, a potentially beneficial ontic occlusion could have been communal agreement to an undifferentiated title such as “School of Information faculty.” In the actual formation, though, the differences between disciplines, and between those who had been a part of the previous incarnation of the school, were kept in the foreground and became the source of tension.

> The project itself was essentially run by computer scientists and programmers in this vision that [Atkins] had of creating a digital library. It would be interesting to find out if any librarians continued to participate. To me, it became clear that this was an engineering project, not a library project. Then, of course, the behavior in the school was essentially treating the library program - what were called the “legacy faculty”, the faculty inherited from when it was a library school - essentially with benign neglect, or not so benign neglect, and let it atrophy by attrition, and no one was hired for many years, or very few people were hired, and so the school - the library component of the school - has continued to shrink to this day. (MWK)

The explicit separation between the faculty that had been, as stated here, inherited from the time before Atkins took leadership of the school were designated by an alternative term that would hold their difference, and in this case, perceived inferiority, as a consistent element of identity within the department. Another library faculty member describes a feature of the "not so benign" neglect.

> I felt that I was increasingly being given the message that, "Well, you're not a computer scientist, so you're not worth as much." You can only live with that for so long. It was coming from everybody [Dan Atkins] brought in from the outside. I co-taught a class with [a new faculty member] and it was just awful. [Another new faculty member] was pretty nice to me when she was in front of me, but not so nice when she was with other people. They just didn't feel – they just had no respect for what we did. One of the faculty members referred to us as "bottom feeders." (87D)

Again, the application of power through holding one group as "other" is effective, and in this case, interview participants of both cultural camps acknowledged the difference in the treatment and labeling of the existing library faculty. More often, the engineering narratives presented this as an admission of an attitude which has since been softened; however, most interviewees also acknowledged that keeping this divide in view has played a role in a persistent categorical difference between SI faculty who draw lineage from the engineering and mathematical traditions, and those who practice qualitative research. The consistent exposure of these existing differences then engages a culling cycle that institutionalizes what was once only an interactional practice, as noticed here.

> Dan, and the rest of the new faculty ultimately agreed – they had a much stronger perspective regarding publication in prominent scholarly journals. I think that's why certain faculty did not receive tenure – because of that ratcheting up of standards for promotion. My sense was that there was deep disappointment among the faculty that were pre-Dan [Atkins]. (TQD)

Several interview participants commented that the incoming faculty, mostly from fields grounded in quantitative analysis, modeling, computational sciences, and mathematics or statistics, did not see the qualitative or professional nature of the library profession as sufficiently rigorous. However, as pointed out by Dillon et al, the formation of interdisciplinary work moves through stages of accepting epistemic cultures and practices foreign to one's own (104; 103). This early stage in the formation of the School of Information involved an ontic exposure that had visibly negative effects for several participants.

4.6 Global Occlusions and Exposures

In the previous sections, we looked at specific instances of ontic occlusion and exposure, both with positive and negative effects. We also considered both static and dynamic or cyclical states at the local and level of the UMDL project and and contemporaneous projects that were associated with it. through examination of meeting attendance, project artifacts, and the observations of interviewees with connections to the work performed during the funding period, the work identified examples where the ontic occlusion and exposure framework can lend an alternative explanatory framework.

Since the UMDL project took place 15 years before this dissertation study, the ideas and technologies addressed have grown and made their way in the world. Digital libraries are now commonplace. The respondents in this study identified not only events and details of the UMDL project during the time research was being conducted on DLI-1, but also stories and explanations for the legacies of the DLI-1 projects. Considering the narratives of scaling effects in sociotechnical systems, the growth from system to infrastructure, we can concurrently scale the ontic occlusion and exposure mechanisms to frame activities at various levels. Following is a similar organizational structure to the previous local section, but instead considering the outcomes of the DLI-1 projects in the broader temporal and influential spheres.

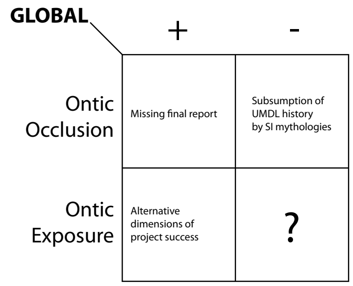

Figure 4.11 Range of Global Ontic Occlusions & Exposures

4.6.1 Occlusion as Negative Effect

In Chapter 1, I discussed the research context of choosing the UMDL as a case. In particular, I relayed a common narrative passed on at the School of Information about origin myths as relayed by George Furnas. I didn't recall the mention of the University of Michigan Digital Library project, or of the libraries at all in these myths. The injection of the library as a relevant object in the story was solely through referencing the faculty of the School of Information and Library Studies.

Contrary to what this omission might suggest, interviews with University of Michigan DLI-1 researchers, without exception, drew upon stories of the UMDL project and the School of Information, particularly the transition and transformation to the new institutional form, often in equal measure. The claims of influence and causality varied: some felt that the UMDL project was directly causal, as in the following statement, frequently echoed by others.

> Part of Michigan's story is that [the UMDL project] was also part of the transformation of the school itself. So, there were other people in a number of dimensions – in both constructive and destructive ways, arguably. At Michigan, the DLI-1 project was – as someone astutely put it – was the midwife of the school of information. They were all tied up together, so part of it is teasing the stories apart, if that's even possible. Part of me is tempted to let them remain that strongly connected. (8TU)

It was impossible for the UMDL story to be told in the absence of the SI story, and vice versa. The following statement from one interviewee was perhaps the most cautious in assigning causality, but clearly draws a strong relationship between the two.

> There was a lot of overlap. I guess, in that sense, UMDL was partly, unintentionally, I don't think it was created this way, but it became a testbed for whether this group of people with different disciplinary backgrounds could find enough in common in an important information problem that they could productively work together and would want to keep doing that kind of thing. It was a trial for doing collaborative research on information problems across disciplinary boundaries. Who knows, since we can't run the experiment again differently: if there had been no UMDL, would there be no SI? Would it be different? Who knows? But, it certainly influenced who were the key thinkers and participants in the beginning. There was a natural group who were already talking to each other, getting to know each other, and already knew that they had this common interest. It wasn't the whole group. Not everybody who was a charter faculty member at SI was part of the UMDL, and not everybody on the UDML came to SI. It wasn't exactly the same group, but there was a lot of overlap, and they clearly co-evolved. There was definitely interaction and feedback between the two. (Y7D)

Even the most conservative individual story about the origins of the School of Information draws significant relationships with the UMDL, yet the UMDL is not a part of the common or vernacular narrative, nor is it accessible in official documentation. A (July 5, 2010) search performed on the University of Michigan School of Information web site (http://si.umich.edu/) tool yields ten results, each of which results in a *404 Error: Page Not Found* return. Traces of the UMDL are all but expunged from the current representation of the School of Information, and details are absent altogether. For a project that core faculty acknowledge as an integral foundation of the new school, the first iSchool of its kind and the beginning of a contemporary institutional movement in the information sciences, this important aspect of history is lost both in the official record and in the oral culture. The various mythologies, and the monolithic identity of the School of Information, as it sought to gain legitimacy through its infancy and growth, subsumed the UMDL narrative, important as it may be. Similar stories were told by members of other DLI-1 projects. Most notably, and pointed out by many, the Stanford *InfoBus* project led by Hector Garcia-Molina is subsumed by the origin stories of Google; however, a number of interviewees recalled Larry Page demonstrating the first versions of the PageRank algorithm at one of the DLI-1 "All Hands" project meetings while he was a graduate student. Similarly, federated searching has become such a invisible part of our searching habits and of information retrieval infrastructure that it goes unattributed to the UIUC project undertaken through the DLI-1.

Following the same arguments at the beginning of this dissertation, losing important elements of history in major projects can be detrimental if the occasion arises to interpret, change, repair, or otherwise remediate sociotechnical systems. As Benjamin and Arendt so passionately point out, the fragmentation of historicity leaves us with no choice but to fill in the gaps with our best guesses, to linearize with projections of our own (flawed, faulty, and biased) desires to remember and reconstruct the past as we wish it were (15; 5). The exclusion and subsumption of the UMDL as a constituent object in the School of Information story robs new students who will become alumni a true sense of their legacy, and also serves as one more instance where *library* fades or disappears from view in the reconstructed vision of Information as a field of study.

4.6.2 Occlusion and Exposure as Positive Cyclical Effects

The University of Michigan Digital Libraries project was a failure: This statement was one of the common initial statements made by the majority of researchers and staff taking part in the UMDL project, as well as members of other DLI-1 projects and related organizations. As interviews gave way, moving from opening statements to more descriptive personal narrations of the projects, interviewees consistently began to shift from the narrative of failure to a more elaborated accounting of nuanced successes.

The dominant narrative of failure is not wholly incorrect. The UMDL, like most of the DLI-1 projects, failed to produce a working, sustainable, and usable digital library or robust library prototype at the end of the three-year funding period. In this case, the ontic commitments of the NSF, DARPA, and NASA as vested funders became those of the institutions receiving the money. The DLI-1 call for proposals was open enough to include objects of the library world (library, archives, repositories, access), but described products in the realm of computer science and engineering (testbeds, architectures, routines, code). The response of the UMDL team mirrored the language of the proposal, but may have fallen victim to the unforeseen lack of ontic choreography that would later manifest in the workings of the UMDL operating committee.

Returning to the easily accessible and pervasive failure narrative, the following statements are representative of common sentiments of related project participants.

> The fact was that none of the participants in the digital library project had any institutional or professional involvement with libraries or librarians in the traditional sense. They understood computers and they understood information retrieval, but they didn't understand – it's not a matter of whether they were stupid or foolish, it's just that they came from different backgrounds. They just didn't have any involvement with it. I think it showed in the project. I think that may be why it was considered by many as a failure. The fact that it was considered failure might have been a reading of people who didn't have an involvement with libraries and librarianship. I don't know what objective measures were used to determine the failure, but people were constantly reporting it by word of mouth. I heard that in the aftermath of the project. (MWK)

> I remember thinking at the end of the nominal period for [the UMDL project], "We never did anything." My impression of the whole thing was, from our perspective, was that it went nowhere and did nothing. I'm not saying I didn't get reports, but I don't remember being actively involved, or anything done from our side, because I remember very distinctly saying, "This fizzled out. This sure didn't do anything." I remember being disappointed. Nothing more than that. (SBE)

> I think it failed. I think it definitely failed. They didn't produce a usable library. I think they may have been able to, from their perspective, build a toy architecture that demonstrated that they could do some basic things. But, that's not what NSF wanted. NSF wanted a real library. The other teams at the other four or five universities built real libraries, as far as I can tell. (87D)

As the question of outcomes beyond the immediate UMDL project success criteria, as mapped onto the NSF program, radically different statements came to light that were in direct opposition to the failure narrative. When re-framed as “legacies of the DLI-1 project”, participants were able to identify specific categories and dimensions that they considered successes of this stream of work. In the following list, I draw not only from interviewees’ perspectives on the legacies and outcomes of the UMDL project, but of the full suite of DLI-1 projects. Since the evaluation criteria for all six projects were generated by the same call for proposals, the evaluations and results at the conclusion of the DLI-1 funding period were comparative and relatively consistent. What I aim to highlight in this following list are dimensions of success in the more general instance of a large sociotechnical set of projects that were not aims of the original call (which was to produce architecture for a sustainable digital library), but were acknowledged through interviews with participants from all six DLI-1 projects when asked “What are the legacies of the *X* project, or of the DLI-1?”

Academic publications

As seen in *Appendix A: Scholarly Output*, the UMDL project spawned a large number of publications that are directly claimed by the research team. This category, though not specifically listed in the NSF DLI-1 Call for Proposals, nor specified as individual deliverables in the UMDL response, publication is traditionally, and remains for the foreseeable future, one of the most tangible, immediate, countable, and accepted measurements of project outcomes and effects. During one interview, a project member commented on the relationship between publications and evaluation.

> From the NSF’s point of view, what is the general metric? As crazy as it sounds, the number of papers published that reference NSF support. At the end of the day, that’s how they’re counting. For better or for worse. There are a lot of subjective metrics like whether it’s being used by others. At the end of the day, one of the objective metrics, and maybe “objective” is the wrong word, one of the easily quantifiable metrics – “metrics” implying the ability to count with precision – it certainly generated lots of publications. (XDU)

This is the clearest sense of evaluation in which the UMDL project outcomes conform to the general academic standard of a successful project.

Specific technologies and computer architectures

While the downstream effects of the UMDL's intelligent agent architecture was difficult to track down, there was evidence that a long-term project based on the work done had application. Most of the interviewees believed that the project had no direct technological products, quickly dismissing questions about tangible outcomes.

> The fact that there really is no software legacy to it isn't surprising to me. I'm not sure that was ever an explicit goal. From one point of view, that failed miserably. It never turned out anything that could be considered an operational product. But, it did explore some of the issues, and I think that it also, once again, was too much too early. (XDU)

Reported within the interviews, though, were two projects pursued by DARPA that capitalized directly on the agent based approach taken by the UMDL artificial intelligence team. TIDES (Translingual Information Detection, Extraction, and Summarization), and GALE (Global Autonomous Language Exploitation) ran for 10 years of continuous development and funding to develop systems for military field personnel needing to marshal quick translations for encountered scenarios.

> [TIDES] came right out of DLI-1. Within two years it became the largest technology program DARPA was running at that time, and it ran for about five years before it morphed into a program called GALE – Global Autonomous Language Exploitation – which ran for another five years or so. So, both of those programs were very large programs, and they flowed directly out of the Digital Library Initiative. (V6F)

Digital collections

The DLI-1 projects resulted in a number of significant collections, especially in the early context of institution-scaled production and delivery systems for digital content. The image and video archives at Carnegie Mellon's InfoMedia project and the map libraries at Santa Barbara have continued to grow throughout the ensuing years. The Berkeley biological data projects have given way to a number of new collections ranging from amphibian and moth databases to storage for academic journal articles and photographs.

Beyond the digital collections continued through the DLI-1 project, the apparent success of the overall DLI-1 project toward its conclusion gave justification for a second round of funding – DLI-2. The focus of the DLI-2 project shifted from innovation of novel digital library architectures to casting a broad net for digital collections to be curated and submitted for inclusion in the new library models. Through the DLI-2 as a continuation of the promise seen in several DLI-1 projects, over 50 teams developed digital collections (61).

New institutions, organizations, and industry entrants

Already mentioned elsewhere in this dissertation, the DLI-1 projects spawned two high-profile institutions that have continued to grow and flourish. Commonly cited by interviewees, Google was far and away identified as the most luminary result of the digital library projects. As both a technology and an industry entrant, Google is frequently invoked as the crowning contribution of the DLI research stream. Also detailed in several places, the emergence of the University of Michigan School of Information as a contemporaneous institutional development, was the first instance of the modern "iSchool" movement, a consortium now enrolling over 30 programs and schools in North America.

> The University of Michigan School of information was a shining example of what could be done. Now, of course, there are iSchools all over the country who are producing the current and next generations of people who work in libraries and other memory institutions. (P8J)

Intra-disciplinary transformation and Inter-disciplinary formation

To say that the field of library and information science has changed since the DLI-1 projects is a gross understatement. Although information and library science is an established disciplinary institution with a long and established history, the combination of computer science and engineering with library science, and a number of other relevant disciplines taking part (economics, education, psychology, history, business, etc.) was a bold re-formation of the field to adapt to the changing digital landscape. The work done under the DLI-1 brought the burgeoning field of digital libraries – a movement already begun in several places in academy and industry – onto the scene as a research activity legitimated by significant federal investments. From there, the "new information science" seen in the curricula of many reformed schools, both former traditional library schools like Michigan, Toronto, Rutgers, and Washington as well as interdisciplinary departments created from other combinations like the program at Penn State, marks a significant and often contentious phase transition from the long-standing trajectory of the library field.

Even within this movement, identifiable interdisciplines have been fostered and are creating identities independent of the iSchool interdisciplinary phenomenon. Throughout the interviews, participants made reference to research streams taking place under the auspices of iSchool and digital libraries research in the post-DLI research environment that were anecdotally linked to work done during and as a result of the funded research period. One example is the advancement of the Incentive-Centered Design (ICD) field, formed and developed through the efforts of Jeff MacKie-Mason (UM School of Information and Department of Economics) and Michael Wellman (UM Computer Science and Engineering). This combination of behavioral economics (already an interdiscipline) and computer science has seen the emergence of new approaches to markets and allocations, system design to align with agents' incentive structures, and new ways of thinking about pricing, provisioning, and distribution. Another example is an interdisciplinary movement in "Values in Design of Information Systems and Technology", in part developed at the University of Washington's Information School through the work of Batya Friedman, as well as another strand of research pursued through the efforts of Geoffrey Bowker at the University of Pittsburgh and Helen Nissenbaum at New York University. Consistent successful rounds of funding from federal agencies (similar to the ramp-up of digital libraries as an interdiscipline) show promise that the downstream effects of earlier interdisciplinary investments can, with time, produce further interdisciplinary differentiation.

Productive and sustained research relationships across disciplinary boundaries

By its nature, the UMDL project fostered research relationships between individuals and among small groups because it involved multiple academic units, as well as connections to other institutions, government, and industry. It is also not unusual – more appropriately expected – that those who then formed the core faculty of the rechartered School of Information would form research relationships that extended beyond the project duration. What the project did, however, was encourage collaboration between researchers who did not end up joining the school, and the common interest has given rise to productive and sustained research relationships that have endured across disciplinary, departmental, and institutional boundaries. One of the most formalized examples of this happening was the meeting of professors MacKie-Mason and Wellman, mentioned in the previous section. After first meeting on the project, MacKie-Mason joined the School of Information faculty while Wellman chose to remain in the College of Engineering with no formal ties or appointments to SI. For a continuous 12 years after the project, the two worked continuously on co-written and funded grants from various institutions. One of the most successful has been the STIET (SocioTechnical Infrastructure for Electronic Transactions) training program: the first social science IGERT (Interdisciplinary Graduate Education Research Training) program funded by the National Science Foundation at the University of Michigan. Over two rounds of funding, the program has had a generational effect of bringing together doctoral researchers from the School of Information, Ross School of Business, Industrial and Operations Engineering, Economics, and Computer Science and Engineering. In the most recent round of funding, the STIET program has branched out to many more departments, as well as to Wayne State University, further broadening the reach and scope across boundaries. These faculty and funded graduate students have gone on to combine and recombine their knowledge across disciplinary boundaries with each other. As a consequence of two researchers meeting through the UMDL project, a sustained program to generate interdisciplinary scholarship, as well as an identifiable and active community that crosses traditional boundaries as a matter of routine.

The positive effects of exposure in the global case, then, are primarily methodological. In the course of this dissertation research, it became clearer that the evaluation structures in place for the DLI-1 were tightly constrained by time scales. The funding period was three years – an inadequate amount of time to see the development of working systems that may become infrastructure, or even to develop the infrastructure required to build a digital library in the first place. As we will cover in more detail in the next chapter, the process led to an insight that evaluation methods have ontic occlusions of their own - in this case limited by time, disciplinary orientation, and ability to trace second- and third- order effects that would would later take place. Instead, a narrative of failure arose, which gained a certain inertia. The qualitative approach – interviewing those who would understand the project best – yielded several dimensions of evaluation criteria not represented in the way history casts the project. The interview process exposed variant ontics – concrete, realized, and manifested objects and relationships in the world – that can be used to develop more contextual and reasonable evaluation metrics. This form of ontic exposure through qualitative methods has potential for an improved approach to evaluation for large technical systems.

An Incidental Occlusion

A side story of this project involves ontic occlusion as a possible positive for some, and negative for others (harkening back to the familiar Rashōmon nature of occlusions and exposures). As with all National Science Foundation projects, many reports were generated to communicate progress and evaluation. For the UMDL, assessing progress was a commonly expressed difficulty, as indicated by the following perspectives.

> I think we were always skeptical that the Michigan project would actually

> result in anything useful. I think it was recognized within the agency that – at least certainly among the program managers – that the Michigan project was the most speculative of the six. I think that's probably why it was awarded. In fact, there was a program that followed DLI-1, but preceded DLI-2. I don't remember the name of the program. It was specifically [information redacted to protect interviewee] I don't know if that was inspired by the Michigan project, or in response to the Michigan project, but I think part of the fascination with, and our interest in the Michigan project was that it was so uncertain and so unknown. (V6F)

However, issues of evaluation were not solely because of the ambiguity and cutting-edge nature of the UMDL project. Even within the project, the teams found that the operationalization of evaluating the digital library system was problematic because of unforeseen contingencies.

> There was discussion about evaluation and assessment, and my recollection of those discussions was that they were largely fruitless and not taken terribly seriously by the people who were running the project. It was an afterthought, at best. The evaluation thing was always, "... and then a miracle happens, and then we will evaluate this. We'll do this in month six, and we'll do that in month nine, and", but a lot of it was that we had to wait because we didn't know what collections would be in it, or what the thing was going to look like, and you can't evaluate something if you don't have a really clearly vision of the point. You can't evaluate something you can't see. You can only go just so far in planning an evaluation for something that doesn't exist yet, because you don't know the details of it. So, we'd have meetings, but it didn't go anywhere, because we were waiting. And waiting, and waiting, and waiting. By the time I left, we were still waiting. (XPY)

The collision of epistemic cultures and competing disciplinary systems of evaluation gave rise to problems as well.

> The evaluation, I don't think, was as rigorous as it could have been. This is where you probably had a lot of people's hands in the pie, and when you have a lot of people's hands in the pie, it's difficult for anyone to find where the pieces are. So, I think we maybe had one article that came from the evaluation. That's too bad. We probably should have produced a lot more out of that. (7C4)

Among all of the interim evaluations – memos; quarterly, biannual, and annual progress reports to funding agencies; PowerPoint presentations and all-hands meeting slide decks; etc.

– one key report is missing in this project: the final report submitted to the National Science Foundation, DARPA, and NASA. This came as a shock which grew more incredulous as the project wore on. After asking over 60 members associated with the project, the NSF head librarian and archivist, Bentley Historical Library, and physically inspecting every box of project data made available, the final report was still nowhere to be found. To be sure, there was a final report written. Administrative staff on the project remember compiling and submitting it. The project PI recalls writing the final draft. Agency contacts admitted that they did not remember the report specifically, but that submission of a final report is required to close the project file, and the UMDL project file was closed; thus, a satisfactory final report was written and submitted. The report's absence began as a curious anomaly that grew to a mystery story: a curious event, and especially so when thinking about the role of a final report in the context of ontic occlusions and exposures.

Narratives can be captured in many formats. Verbal accounts and oral histories are one source of identifying perspective and the objects that an individual includes in their ontic sets or commitments. These, however, change over time as people change. What was once outside of purview is now legitimate and incorporated into the narrative, and as we forget things, in the other direction as well. Written documents, though, capture the ontic and give it durability through time and space. Archivists and historians know this situation well, as terms and objects are representative of a contextual understanding not our own.

To draw a distinction, then, between the types of narratives, we can consider the written durable forms to be *official accounts* and the transient verbal narratives to be *vernacular* accounts. In the absence of a final report, a final statement of the UMDL project as is drew to a close, we are left without an official account. As a result, details of the project are left to rely upon distributed memories. The Rashōmon effect is in full force in this situation, and plays directly into the failure narrative. There is no solid or identifiable report to articulate the outcomes and successes; thus, there is no official or legitimated documentary form that can mediate conflicting narratives. In the absence of official accounts, vernacular accounts grow, change, combine, linearize, forget, emphasize: in short, they grow into mythologies of infrastructure as the systems themselves sink into their invisible working states.

One project team member suggested that the fact the report could not be found was interesting in that a final UMDL report would not reflect well on the overall performance of the project. This person implied that the final report may have been intentionally buried to hide project failures, or that people may have been withholding the final report when asked. While Occam's Razor would suggest the simpler explanation that no one thought to keep a copy, as opposed to a conspiracy to bury the perceived frailties of the UMDL project, the issue raises an important question about the nature of ontic occlusions and exposures, particularly for future research: intentionality. Is the nature of occlusion and exposure different when it is motivated by intention?

There is, of course, the possibility that the final report does exist, perhaps in a file folder or a storage box in an office. After more than a year of focused search for this document, and requesting every available project member to check their records, there seems little hope of finding a copy. For the purposes of discussing the ontic representations at play in the social life of a sociotechnical system, I will claim that should a copy exist, it is inaccessible enough that the official account is missing or occluded by the vernacular accounts in this case, and the resultant mythologies of infrastructure have given rise to discussed examples such as the UMDL failure narratives and the creation myths of the School of Information.

4.6.3 Exposure as Negative Effect

Although exposure resulting in negative outcomes clearly has a place in the categorical structure of the ontic occlusion and exposure analysis, there was not a clear set of incidents or interpretations from interviewees that suggested this outcome in the UMDL case, or with the transition to the School of Information. We can easily imagine, however, cases in which exposure can arguably have negative consequences at the global level. Stepping away from the case at hand, and to fill in an example of this phenomenon, we can consider the general case of classified information and the practice of redacting sensitive passages from documents and other archives. The common assertion behind classified and redacted materials is that introducing the content – the objects, relationships, and contexts described therein – would be damaging, difficult, or inappropriate for general consumption. This category does directly speak to issues of control and power. Who has the authority to decide what ontic sets are globally relevant? How are decisions made regarding which voices remain silent and which become active carriers of discourse. While a deeper exploration into the philosophies, ethics, and power of classified materials is out of the scope of this discussion, the connection to global ontic exposure and project outcomes remains an area of potential future study.

4.7 Summary

In this chapter, I have presented a short history and background of the UMDL project, as well as some detail about the related transformation and emergence of the School of Information. I examined details extracted from archives and meeting notes of the UMDL operating committee, interviews with associated project researchers and staff, and observation of the pervasive local effects of the project within the University of Michigan. Through these inputs, I described how the ontic occlusion and exposure framework may be applied to render interpretations of the project that may run counter to the dominant narratives, or may be unrepresented in accounts altogether. To give a consistent structure to the examples, I presented interpretively positive and negative outcomes of identified occlusions and exposures at two levels. First, I present the phenomenon at the local level or on the scale of first-order effects of the UMDL project and early formation of the school. I then describe the same categories related to the second-order effects and beyond that have scaled upward and outward in the interim years since the conclusion of the DLI-1 project.

Chapter 5

Discussion

5.1 The UMDL as Reverse Salient

The UMDL project may have been an idea whose time had simply come – an example of Hughes' *reverse salient* – and the encounter among the researchers taking part was engineered by Atkins – a man who sensed the burgeoning tensions in the larger sphere of information management and knowledge stewardship (79; 80). Considering the pairing between computer science and library science, there is the possibility that these two disciplines coming together and forming a new interdisciplinary endeavor were seeking to expand the ontic sets or repertoire for deep transformative reasons unto themselves. Through Duderstadt, Atkins, Van Houweling, and others who were recruited into the efforts, both fields were able to embrace and synthesize important approaches to understanding and changing the world that were previously missing. That is to say that with particular developmental and infrastructural goals in mind, library science and computer science may have been apposite complements. Library science, as seen in the early 1990s closing of prominent library schools like Columbia and University of Chicago, was experiencing a crisis of relevance in the academy. Still, the library tradition is firmly anchored in the real world. Its epistemic infrastructure includes buildings, books, and other material objects that proclaim the existence or Being of the library. Computer science, on the other hand, is one of the newest significant fields (speaking in relative terms, compared to physics, chemistry, economics, linguistics, literary fields, etc.) and to a much larger degree is theoretical, abstract, and disembodied. Computer science and engineering have clear claims to be sciences with rigor, however, early developments of computer science move from the theoretical to the applied involved adapting and augmenting existing fields (i.e., augmenting physics with computational services, providing faster and cheaper ways to calculate ballistics tables, etc.). Computer science needed a corporeal site of its own to do developmental work independent of high paradigm fields' expectations and demands. In this case and context, the library provided that site: an institution with unchallenged legitimacy and history in the world, an academic field that was in perceived jeopardy, a reasonable argument to make about the commonality in addressing information issues (though I feel compelled to point out that "information" was and remains one of the most contested terms in the information science field.) The disciplinary encounter between the fields, though, was the forcing function for two radically different epistemic and ontic cultures to work through the growing pains of an interdiscipline – sometimes horizontally violent, arguably colonial with engineering arriving to occupy the library's spaces (both intellectual and physical), and discursively ambiguous and difficult. The realization of committee members that they were speaking through similar terms and objects, but needed to appreciate the nuance and context in which they applied these terms was important. Though, the lack of clear resolution and institutional transference of these ontic debates to the School of Information curriculum advances the interdisciplinary encounter in important ways. As pointed out by Page, the diversity of approaches to a problem yields more robust solutions (119). Taking the difficult problems of decoding terms such as *information, data, knowledge, library, user, access, collection, archive, document, learning,*, and so forth – the exact terms that the UMDL researchers, experts, wrestled with – and making them the primary orienting images for new generations of information science practitioners scholars by inserting them into the introductory curriculum of the School of Information enterprise: this process of repositioning previously occluded concepts in a way that continually exposes them for debate, development, interpretation, and discovery allows the concerns to scale fluidly between the local contexts to the universal generalizations.

The fact that the UMDL did fail as a sustainable digital library, yet played a critical catalytic role in a number of other dimensions, suggests that there is something to be learned in this encounter and others like it about the effects of interdisciplinary efforts and system building beyond the proximate. One way to approach discussions of defining that broader interpretive space is by engaging the ontic occlusion and exposure mechanisms in the different stages of the development cycle – design, monitoring/maintenance, and evaluation.

5.2 Interpreting Sociotechnical Lifecycles

Of the various insights provided by interviewees throughout this project, one of the most striking aspects was the consistent surprise when recounting passages of the failure narrative at the outset of the interviews, and the moment of revelation when people began listing the legacies and significant downstream effects of the projects. The mechanism of exposure brought to light a frailty in the ways we evaluate large sociotechnical systems in development. The ability to turn away from the dominant narrative, to remove some occlusions if even momentarily, shifted the perspective enough to postulate causal links between work done under the DLI and currently existing programs, technologies, and interdisciplinary developments. Our methods of evaluation, it would seem, are not always well matched with the cadence of development for the systems we build.

The National Science Foundation set the funding period for the DLI at three years, at the end of which an evaluation took place. Several interviewees commented that with exploratory research at the scale of architecture, it wasn't until several years after the funding period that technological capability began to match the envisioned forms of the digital libraries as they had been conceived. There was a general sense of lamentation that, in retrospect, it was impossible to build a library in the allotted time given the state of digital technologies, but that 15 years has been enough for the seeds planted during the project to have broader effects. As discussed in Chapter 4, these dimensions are not necessarily obvious and take some guidance to articulate. Ontic exposure can be used as a method to develop evaluation plans that are more suitably matched to the development cycles of large sociotechnical systems, which generally take place over the course of decades or centuries. Having such an evaluation plan in place, patiently watching for the emergence of outcomes and benefits, and developing tools and inspection regimes to identify outcomes as they happen: these are some of the potential benefits of mastering the dynamics of occlusion and exposure.

Consider a general project at the large systemic scale. As Star and Ruhleder discuss, first order problems and effects within sociotechnical systems are generally easy to identify, and we are far less apt to identify second-order (unforeseen contextual effects) and third-order (broader issues of structure and dynamic stability) issues that arise and become visible in times of change or flux (142). As an evaluative society, we are notoriously resistant to assigning causality to second- and third-order influences, effects, and outcomes. This is not necessarily because we do not understand or intuitively know that there is a relationship between the antecedents and outcomes, but because the high-proof paradigm of evidence precludes us from mapping a particular numerical or statistical predictive regime onto highly complex phenomena (51). As our built sociotechnical systems become more complex, we it becomes more difficult to keep track of the connections they make. As they sink to the level of infrastructure, we are unable to account for the rich network of relationships, maturation of subsystems and gateways, or the innovations that take place as downstream results.

For the sake of classification, imagine three different classes of designing and evaluating systems. We will call the simplest process a Class I system. In this scenario, the straightforward engineering approach. There is the initial state at point A, and the solution state at point B. A process is designed to move directly and efficiently from A to B, and upon evaluation, we find that the plan has been successful as designed. We are quite comfortable with Class I evaluations, as our matched evaluation systems. A second class of system building is more complicated, Class II. In this scenario, there is the initial state at point A, the solution state at point B, and the designed plan to get from A to B. Upon evaluation, however, we learn that although we arrived at point B, it was not according to the plan. The outcome is generally what was expected, but the journey, process, or design were unforeseen [1]. Class II systems exhibit a quality of *equifinality*, where the final product or state can be identified and evaluated according to the original plan – an "end justifies the means" post-hoc explanation – but the path is highly variant. We are less comfortable with evaluating these scenarios, as the established metrics do not necessarily conform to analyzing the unforeseen. Still, the articulated outcome desired is the outcome manifested, so we perform the necessary occlusions and narrative linearization to make sense of our systems. The third class, moving beyond simple and complicated (both primarily linear in concept), encounters the *complex*, meaning that outcomes are emergent and could not necessarily be predicted at the outset. Class III systems come into being and evaluation systems and established metrics run off the rail. It is not only that we have failed to predict or control the path to a solution, but the solution is not necessarily recognizable as a solution (since the system may have gone into the world and proven to be a solution to a different set of problems, as systems are wont to do (117; 143). In the perspective of the designed plan, complete with its own sets of ontological expectations and ontic commitments, the outcomes of a Class III system may be completely residual and go unidentified or unaccounted. These residual categories have, in many cases, comprised a significant and critical piece of a system's history and effect (140). The processes of ontic occlusion an exposure, if employed as a mechanism and tool for decoding such systemic outcomes, can bring some order, sense, voice, and potential legitimacy for these alternative outcomes. Because systems and evaluation regimes go hand-in-hand for the context of this discussion, it bears mention that unlike the equifinal outcomes of Class II systems, the identified outcomes of a Class III system are not necessarily equifinal or even equibeneficial. Since the outcomes are emergent and may

[1] As a former advisor would often say, "If you want to gamble, there are many roads that lead to Reno. Doesn't matter much which one you take – you end up losing your money all the same."

belong to varied problems, other environments and related systems, or have moved to other levels of scale, they must be evaluated on their own terms after uncovering the ontic and epistemic details of the new evaluation context. Systems showing qualities of emergence are most often categorized, referenced earlier, as complex, which is often associated with sensitivity to initial conditions and intractability (77).The high-proof argument easily dispenses with the intractable, which makes it a convenient foil when interpretation becomes difficult or ventures into unfamiliar territory. Harkening back to the historical problematics described by Arendt and Benjamin, fragmented historicity exists everywhere. It is simply what we have because there is no alternative to remembering some details and dispensing with others. It is a feature described in the human condition (124; 125) as well as through the construction of sciences (24). Infrastructural systems sprawl. They have fragmented histories and accounts. They are difficult to interpret and resistant to high-proof causal evaluations. They are also quite real and patent in aspects of the functional world at all levels of scale. Thus the difficulty of off-the-shelf evaluation and the hard work of surfacing the ontically occluded to develop context-sensitive metrics and evaluation regimes – these challenges are not compelling reasons to turn away from evaluating large sociotechnical systems in more useful and meaningful ways than the predictable categories of "success" and "failure." This initial work introducing the ontic occlusion and exposure mechanisms provides a framework to engage this discussion in alternative ways.

5.3 Ontic Occlusion and Exposure: Choices in Representation

The UMDL case provides an instantiated example of a more general class of dynamics in interdisciplinary work. The choices we make in our representations – approaching the ontic with intentionality, both exposures and occlusions (since it is useful to know what we are removing from view, as we later know to reproduce it) sets up a cycle that oscillates between the two states of concealment and unconcealment, of blindness and revelation. In the figure below, we can see a general form of this cycle, understanding that our relationship with knowledge and discovery moves from one to the other, and can also change scale (as seen in the move from local to global occlusions and exposures in the DLI case.)

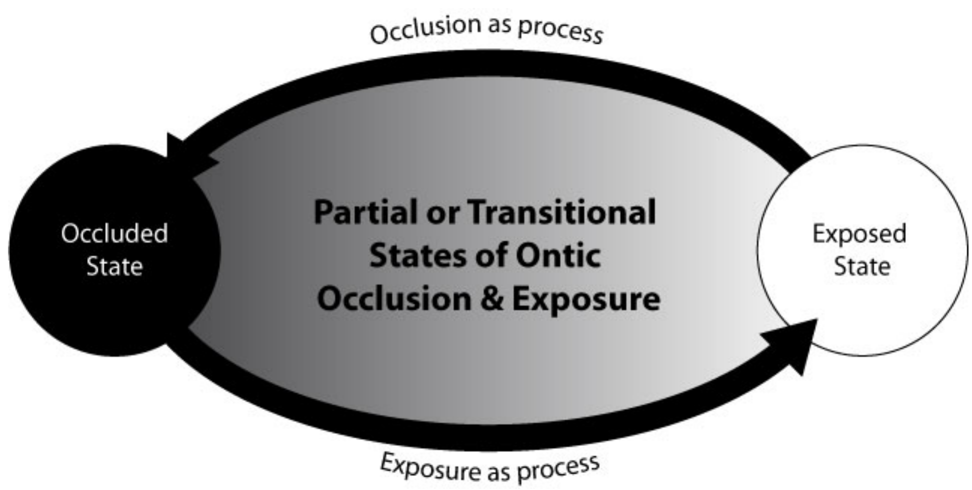

Figure 5.1 Ontic Occlusion & Exposure Cycle

The ontic occlusion and exposure framework will render more robust interpretations for planning and enacting systemic change. As a set of exploratory and explanatory mechanisms, it can be adapted to many situations where transformation is involved in sociotechnical systems. As a consequence, the outcomes of this research are not specific sets of conclusions or recommendations, but more appropriately a set of provocations; a way to look at what is in front of us differently so we can detect our own blind spots, a slight turn so that a difference in the degree of our perceptions and understandings might produce a difference in kind, a deliberate pursuit of a Gestalt shift in looking at complex and heterogeneous systems and revealed infrastructural elements.

As a set of provocations, ontic occlusion and exposure have potential for practical use in many domains. In the case of large sociotechnical systems, it seems rare that we would encounter a significant system *de novo*. Most transformation at such scales involves change, re-engineering, re-configuration, or migration of existing systems and and institutional components into a different arrangement. Shifts in the morphology of systems and infrastructures typically render new things visible, and familiar things are out of view. Changes in structure alter the flow of power. The discourses and narratives through which we express our work involves significant choices of representation. How do we choose to build the world discursively? What objects are important and which are cast aside? Our ability to make choices with intention, to resurrect or recall the set-aside or residual, and to design systems that reveal necessary knowledge to us in the moments of need: the ability to move fluidly between the ready-to-hand where we employ the knowledge we have to engage the world, to the present-at-hand where we discover new knowledge and are deliberate or intentional about understanding the nature of the world. The tension between these two states serves as an engine for production and discovery.

5.4 Summary

In this chapter, I make the move from the specific case of the UMDL and DLI-1 projects to discuss the more general case of considering ontic occlusions and exposures in the dynamic and evolving roles of sociotechnical systems and projects. I discuss how the interdisciplinary encounter of technology and traditional information practices was likely an inevitability. The need for the field to evolve and diversify drove the vision to create change, and the first instantiation of a transformative institution and intellectual enterprise was the result. I also describe the general need for a broader ability to encode ontic occlusions and appropriate revelations into our built systems, and the inadequacies of current evaluation regimes to account for second- and third- order effects of innovations that take longer time scales to develop. Finally, I present a brief model of the cyclical nature of ontic occlusion and exposure, suggesting that the tension between the two states is a fundamental driver of knowledge creation.

Chapter 6

Conclusion and Future Directions

This chapter reviews the key findings from this dissertation study by providing a summarizing overview. I then present four areas for potential further development and study after the completion of the dissertation work. I conclude with reflexive commentary on lessons about the nature of scholarship gained through engaging the doctoral process and performing the work of producing a dissertation.

6.1 Overview of Key Findings

This dissertation project introduces ontic occlusion and ontic exposure – a set of complementary analytic mechanisms to describe dynamics regarding the objects and relationships that enter discourses and representations.

The ontic refers to the set of objects and relationships that are concrete and manifest in the world. Where ontology refers to the abstracted set of all relevant objects and relationships within a specified domain, the ontic is what is present, invoked, engaged, or realized. In the context of disciplines and scholarship, a discipline discursively invokes an ontic set to render explanations of the world (i.e., a physicist's explanation of phenomena is constructed out of masses, forces, particles, particular expressions of their relationships, etc. A sociologist will render the world in terms of people, social groups and movements, classes, laws, deviances, and the like.) In the case of interdisciplinary projects, these communities must engage and choreograph competing ontic sets to perform collaborative work. In the ideal scenario, the contents of discursive practices and enactments would map across disciplinary boundaries easily, consistently, and transparently. As is the more typical case, described by current research on interdisciplinary work, there are significant discordances and incommensurabilities during the early stages of collaboration. Often, depending on issues of power, legitimacy, and context, one account or narrative may crowd out, block, delegitimate, or completely dismiss another from the discourse. I call this mechanism – one narrative blocking the view of another – ontic occlusion. The reverse of this mechanism – re-introducing or re-legitimating alternative objects, relationships, and explanations into the discourse – is ontic exposure.

Sociotechnical projects and systems, by their nature of addressing both the social and the technical, typically enroll multiple disciplines to design and implement, and necessarily imply the intersection of disciplines to interpret and evaluate. I have made the following case for introducing ontic occlusion and exposure into the study of sociotechnical systems.

1. **Assumption:** Where there is change or transformation in sociotechnical systems, there is accompanying discourse.
2. **Assumption:** Where there is discourse, choices are made to include and exclude existing objects and relationships.
3. **Definition:** When objects and relationships are excluded from discourse, ontic occlusion occurs. When objects and relationships are introduced into discourse, ontic exposure occurs.
4. **Implication:** Where there is discourse, ontic occlusion and exposure occur.
5. **Implication:** Where there is change or transformation in sociotechnical systems, ontic occlusion and exposure occur.

By understanding better what we choose to include and exclude in our accounts, how we leverage our own ontic commitments as well as attend to those of others, we can better decode transformations and understand contextualized evaluations of sociotechnical systems.

Considering the digital library as an example of a sociotechnical system, the University of Michigan Digital Library project (UMDL) was selected as a case study to develop and explore applications of the ontic occlusion and exposure framework. The UMDL was one of six projects conducted from 1994-1997 to build foundational digital library architecture. Michigan's project focused on an agent-based approach to resource allocation and information delivery that brought together researchers primarily from Computer Science and Engineering (CSE) in the College of Engineering, and the School of Library and Information Studies (SILS). While much of the day-to-day work did not require close collaboration across disciplinary lines (e.g., the AI lab exclusively did agent-based design work. The library science faculty worked on evaluation of services and user studies), the bi-weekly meetings of the UMDL Operating Committee were sites of consistent encounter between the communities. Through examination of the Operating Committee minutes, social network analysis of meeting participation, and interviews with UMDL and DLI-1 researchers and staff, I discuss episodes of ontic occlusion and exposure in the project that explain positive and negative interpretative outcomes of the project at two levels of scale – local and global.

The analysis of this case through this proposed framework leads to alternative and contrasting explanations of UMDL outcomes. At the local level of the project, the Operating Committee found that a base set of vocabulary was common to both the CSE and SILS researchers . While design and development work took place in various groups through what was understood to be commitment to and enactment through a shared ontic set, later assembly of built components and realized artifacts gave rise to tensions, frictions, and frustrations when differences in the deeper disciplinary understandings of each community arose. The occlusion of the *a priori* understandings of fundamental definitions, and later exposure through negotiating constructed definitions, allows us to understand particular difficulties of the project in a different way. In a related thread, the UMDL was also the initial occasion or joint work for a large number of the researchers who would form the founding faculty of the re-formed School of Information. As a form of continuing ontic exposure, the set of terms that proved to be so problematic for the UMDL project found continued debate and development by explicit insertion into the foundational curriculum of the SI graduate program.

At the global level, the ensuing years since the UMDL project's end have produced a common narrative that the UMDL was a failed project – it did not produce a sustainable digital library architecture in the funding period, and was one of two DLI-1 projects that failed to win a DLI-2 grant for continued research. The Operating Committee and research community were unable to resolve the revealed discursive tensions regarding fundamental vocabularies and terms. Interestingly, an important enduring artifact of the official project narrative – the final report to the NSF – is missing entirely. Despite the missing official account, and the enduring vernacular account of failure, project interviewees (who notably supplied the failure narrative) went on to describe perceived legacies and second- or third-order outcomes and effects of the UMDL and DLI-1 project that are considered successes. In particular, interviewees provided instances of identifiable, and often significant and transformative progress in the following areas:

- Academic publications
- Specific technologies and computer architectures
- Digital collections
- New institutions, organizations, and industry entrants
- Intra-disciplinary transformation and Inter-disciplinary formation
- Highly productive and longer-term research relationships across disciplinary boundaries

The articulation of six significant categories of success in the context of this project, none attributed initially or significantly to the UMDL project upon first approach, was occluded by the dominant failure narrative. Many project participants remarked that they had not thought about how much impact the project had in the longer term until taking part in this thesis project's interviews. The positive story of ontic exposure here is that coordinated qualitative methods such as interview, ethnography, and archival work may be used to suggest more robust dimensions of sociotechnical project evaluation.

Moving away from the specifics of the UMDL project to the more general discussion of ontic occlusion and exposure as they relate to understanding sociotechnical systems, the cycle between states of inclusion and exclusion, and the tensions that drive them, can be used to reveal alternative and overlooked objects and relationships, or subtract extraneous or noisy objects and relationships. Intentional engagement of the mechanisms can then open opportunities to new narratives, understandings, scales, metrics, and measurements, and discourses of our built environments. Moving from evaluation and feeding back into philosophies of design, we can also build systems to reveal more easily the alternatives or de-emphasized ontic elements, should scenario planning or understanding of future contexts make need for their recollection likely.

In summary, the thesis work contributes perspective on a theory of discourse development in interdisciplinary projects where shared language is important to design, execution, and evaluation. It combines perspectives in philosophy, digital libraries, and interdisciplinarity studies. The complementary mechanisms of ontic occlusion and exposure are useful devices to decode and describe change in sociotechnical systems, and highlight the need to examine more closely both what is rendered in accounts of sociotechnical systems, and residual categories often left unaddressed.

6.2 Ideas for Future Research

6.2.1 Further development of the Ontic Occlusion & Exposure concept

The concept of ontic occlusion and exposure as explanatory mechanisms for sociotechnical change arose from the synthesis of examples observed over a number of years. Most of these examples were of the perspicuous type described in the opening chapter – catastrophic failures, high-profile and well-reported breakdowns of systems, obvious gaps in communication or representation. These mechanisms, though, are ubiquitous and permeate most acts of representation and control when more than one perspective is in play. I think that this set of mechanisms has potential as a provocation for better design and analysis of sociotechnical systems, but also has potential as a more generalized framework for understanding discourse, negotiation, and situational change.

Since change happens in all contexts and situations, at all levels of scale, I look forward to refining ontic occlusion and exposure by finding other case studies and pushing the limits of how and when this framework is useful. Like the concept of “boundary object”, a broad mechanistic explanation can be overused. Conversations with Leigh Star frequently addressed the issue of not just *what* is a boundary object (since arguably anything could be), but *when*. The consistent conclusion drawn was that the framework is invoked when doing so lends analytical traction. In the same spirit, most situations can be cast as a difference in understanding, perspective, and resultant choices in discourses and representations. Further work may explore different subtypes of ontic occlusion and exposure, as well as cases and classes of analysis where the framework is particularly useful.

6.2.2 Understanding the Role of Discursive Coordination in Interdisciplinary Work

As Miller and colleagues at Harvard’s Project Zero discovered in examination of high-performance interdisciplinary teams, the process of building effective bridges between disciplines is a process of gaining trust, respect, and understanding of others’ contexts (108). As a form of collaboration, Cussins and Mol each invoke the metaphor of *choreography* in addressing ontological issues between two disciplinary groups that must pass knowledge between (37; 109). I believe that in the context of highly interdisciplinary work, not only must the ontological (and ontic) be coordinated, but also the epistemological and phenomenological. This complicated “dance” which leads to stunning interdisciplinary performance relies on what I see as *OEP choreography*, whereby agreements and differences are made explicit in each of these areas to negotiate terms and expectations of collaboration. The commitment to developing a mutually useful set of discursive practices for all involved, possibly through using the framework of ontic occlusion and exposure, may improve this type of coordination, leading to more reasonable expectations of project outcomes at appropriate scales.

High-paradigm[1] fields have reached an advanced level of closure on many OEP issues, and are adept at choreographing the dynamics among them. Low-paradigm fields may find it difficult to do the same. The reasons for high- and low-paradigm status are varied (historical path dependencies, maturity of the field, disruptive or transformative technologies adopted by practitioners, separate ideological factions, etc.)

OEP are not just abstract philosophical concepts. They are fundamental elements in the practice of science. They define disciplines' identities. When pursuing interdisciplinary work that requires multiple viewpoints, complementary methods and expertise, new and hybrid theories and models, and management of knowledge in complex environments – the need for agreement on the fundamentals is critical from the beginning. The more convergent disciplines' understanding of OEP, and the skill in choreographing these areas, the stronger the confidence in conducting joint inquiry.

6.2.3 Developing New Metrics for Evaluating Cyberinfrastructure through Coordinated Methods

The outcomes of this research suggest that evaluating cyberinfrastructure projects and investments is a complex, multidimensional, and difficult task. Moving past the dissertation work, I am interested in a next research phase to explore questions about improved and grounded evaluation of cyberinfrastructure that combines historiographic and ethnographic techniques to identify and distill relevant dimensions and time scales for evaluating large sociotechnical systems and projects in a more contextualized way. Continued research of this type would pursue avenues and questions such as:

[1] "High-paradigm" and "Low-paradigm", based on the work of Thomas Kuhn, refer to the consensus within a scientific community on the "academic law" within that field (93). High-paradigm fields are thought to have clear and unambiguous ways of defining, ordering, and investigating knowledge. Low-paradigm fields are characterized by a high level of disagreement as to what constitutes new knowledge, what are appropriate methods for inquiry, what criteria are applied to determine acceptable findings, what theories are proven, and the importance of problems to study. Further, the work of Anthony Biglan suggests that high-paradigm fields show greater social connectedness, more focus on research than teaching, and more orientation toward service activities (18).

- What are the correct units of analysis to evaluate cyberinfrastructure?
- How can we migrate from the *multi-disciplinary* (meaning, each discipline has a different sensibility and set of success criteria) to the *trans-disciplinary* (meaning, a meta-evaluative evaluation approach that represents more than the sum of constituent disciplinary viewpoints) in discussing and evaluating cyberinfrastructure projects?
- What are categories of first- and second-order cyberinfrastructure effects we know to be of transformative and substantial value to the progress of science, industry, education, governance, etc.?
- What are reasonable and commensurate metrics for evaluating cyberinfrastructure projects?
  - In the short term (3-5 years, typical duration of an agency funding period)
  - In the medium term (10-15 years, period to show evidence of portability and standardization, adaptation to localized contexts outside of the original site(s) of development.)
  - In the long term (20-50 years, reasonable duration for a technology to show deep integration into larger systems and achieving an invisible state of infrastructure)
- How are lessons learned about scientific cyberinfrastructures formulated and communicated to prepare other cultures and institutions for high-impact and successful cyberinfrastructure transformation?
  - Education – e.g., Transformation of the Research University; Inclusion of polytechnics, junior, community, and teaching colleges; Non-institutional continuing adult and vocational education (CAVE); K-12; Augmenting special education (both Gifted/Talented and for People with Disabilities)
  - Commercial
  - Service and Non-profit
  - Military, defense, and security
  - Government and policy
  - Regional, state, and community initiatives
  - Improvement for under-represented or traditionally disadvantaged/excluded groups (orphans of infrastructure)
- What are the respective boundaries and requirements of accountability (looking backward) and responsibility (looking forward) in designing, implementing, maintaining, and reporting on research and work in large sociotechnical systems and cyberinfrastructures?

6.2.4 Further Interrogating the Terms "Success" and "Failure"

I find the categories of *success* and *failure* to be problematic, and increasingly so as I experience more project descriptions *post mortem*. Starting this journey to ontic occlusion and exposure through so many stories of catastrophic failure in systems, networks, and infrastructure – seeing how an incomplete or askance narrative could miss critical or causal factors completely – I have become sensitized to hearing about failure, and equally about success, as they are blunt instruments. Until further along in my interviews, when participants began to give name to successes within the UMDL projects despite the overarching narratives of failure, I was at a loss to explain what might be problematic about these terms. Success and failure designations are often anchored in elliptical or omitted sets of standards, expectations, and criteria. I am interested in doing further work developing methods and tools to interrogate and challenge these terms, to unpack them quickly and responsibly, and to give due consideration to the complexities that are hidden by the binary nature of these often-used terms.

6.3 Reflections on scholarship gained during the dissertation work

Research is one kind of craft, and takes development of some significant skill. Writing is a completely different kind of craft and requires skills that are usually not explicitly addressed in doctoral training. I will be learning for the rest of my career in both areas, and realize that they take a lot of time and effort to develop independently, and even more effort to integrate.

I am reminded by mentors that I have made life difficult for myself as a doctoral researcher in several ways: they were necessary choices despite the anguish caused. I think that the School of Information is a tremendously successful interdisciplinary endeavor, and that the students it produces will go on to make great contributions to information sciences. Yet, the projects and dissertations produced still tend to be conducted along strong disciplinary lines. When I first started working with John King, I told him that I did not want to focus in such a way: I wanted to work on an "Information" dissertation and pursue research in a deeply interdisciplinary way. At the time, I had no idea what the tradeoffs would be making that decision. With disciplinary commitments come clear sets of theories, methods, and communities of practice to guide the work. Rejecting disciplinary boundaries altogether, especially for one in training, is a dangerous game. My advisor has never pushed me toward a disciplinary orientation. In some ways this was a continual act of deep respect (accompanied by, I am sure, equal measures of vexation) for my self-determination as a scholar in an emerging interdiscipline. In other ways it was the rope with which I could hang myself. I know several different configurations of noose knots now, and am better at recognizing when I am tying them instead of working on what is important and productive. I have come to this point and am more convinced than ever that multi-/inter-/trans-disciplinary work is the future of our relationship with new knowledge. I am also deeply convinced that we are very early in our understanding of how this kind of work is done and this type of scholarship is produced – both in the context of combining existing disciplines and working across their boundaries, as well as giving name and legitimating what have previously been interstitial or residual spaces of scholarship. The difficulties I encountered in the thesis work, and some of the current challenges in articulating it in a traditional, linear, documentary form, reflect working with the ambiguities of interdiscipline. The dominant practice in the information science field as an interdiscipline is to start from the center of established disciplines and work toward the boundaries where they might meet. Since the field is still in its early days, and most active researchers were trained in constituent disciplinary fields, how could it be otherwise? I saw myself as a different type altogether, and felt I needed to try a different kind of work that started in the spaces between the boundaries. Again, how could it be otherwise? I was not getting the same degree as those training me. There wasn't a map, but someone has to be willing to strike out. Time will be the judge of whether that was ultimately a wise choice. I currently think it was, and although this kind of scholarship is ambiguous and unrecognizable to a number of paradigms right now, it won't be forever. I am part of that change. Scholarship is hard. Interdisciplinary scholarship is hard in its own ways that are becoming apparent now – for me personally, for information science as it matures in its new incarnation, and for the academy and research communities in general as we face more "grand challenge" types of problems. These are some of the things I've learned about scholarship through these last stages of the doctoral experience. It's terrifying and exhilarating to be faced with the darkness where our knowledge doesn't yet shine. It's also addicting to try and turn those spaces from dark to dim, and on to illumination. I'd like to continue trying to do that, knowing more for this experience, and knowing that I'll never reach the limit of learning.

6.4 Summary

In this concluding chapter, I have provided a brief recapitulation of the dissertation work and described what I believe to be some of the contributions of this project. An overview of the key findings and context of the project gives a sense of the nature and scope of the work done. I briefly discuss the possible relationships of ontic occlusion and exposure to existing theory in information science and related fields, with hopes that the concept is portable and may be picked up and found useful in a variety of contexts. Next, I present some fields and topics of immediate application for the ontic mechanisms, primarily in the area of higher education and requirements analysis for large sociotechnical systems. As the University of Michigan continues its leadership in defining the future institutional forms of academic enterprise, more tools are needed to reconcile the multiple voices, demands, needs, and requests of varied stakeholders and constituencies. Further, as the university population grows more diverse in many dimensions, employing tools and frameworks like ontic occlusion and exposure may help ensure that the future design of higher education accounts for those who have traditionally been unseen, unheard, or otherwise residual or unacknowledged.

To continue my own work, I have described four immediate areas in which this work could be continued. These ideas range from the purely theoretical (e.g. further development of ontic occlusion and exposure as concepts, interrogating success and failure categories) to projects with high potential for empirical and pragmatic applications (developing new metrics for sociotechnical systems, studying coordination in interdisciplinary formations.)

Finally, I end with a reflexive turn on the experience of scholarship gained through the doctoral and dissertation process. With these thoughts, I conclude the dissertation.

Appendices

Appendix A

UMDL Scholarly Output

Lists taken directly from http://www2.si.umich.edu/UMDL/pubs.html#pubs and formatted.

A.1 Primary Publications

- Alloway, G., Bos, N., Hamel, K., Hammerman, T., Klann, E., Krajcik, J., Lyons, D., Madden, T., Margerum-Leys, J., Reed, J.,Scala, N., Soloway, E., Vekiri, I., & Wallace, R. M. (1996, July 25-27). "Creating an inquiry learning environment using the world wide web." Proceedings, International Conference on the Learning Sciences, Northwestern University, Evanston, IL.
- Alloway, G., Bos, N., Hamel, K., Hammerman, T., Klann, E., Krajcik, J., Lyons, D., Madden, T., Margerum-Leys, J., Reed, J., Scala, N., Soloway, E., Vekiri, I., Wallace,R., (1997) "Creating an Inquiry-Learning Environment Using the World Wide Web", Journal of Network and Computer Applications, Academic Press Ltd., in press.
- Atkins, Daniel E., Birmingham, William P., Durfee, Edmund H., Glover, Eric, Mullen, Tracy, Rundensteiner, Elke A., Soloway, Elliot, and Vidal, Jose, Wallace, Raven and Wellman, Michael. "Toward Inquiry-Based Education Through Interacting Software Agents", IEEE Computer, May 1996, p. 69.
- Atkins, Daniel E., Frank, R., Lougee, W., and Willis, K. "An Overview of Digital Library Initiatives at the University of Michigan", March 6, 1996.
- Birmingham, W.P. "An Agent-Based Architecture for Digital Libraries", D-Lib, July, 1995.
- Birmingham, W.P., Drabenstott, K.M., Frost, C.O., Warner, A.J., and Willis, K. "The University of Michigan Digital Library: This is Not Your Father's Library". In Digital Library '94 Proceedings, June 1994, 53-60.
- Birmingham, W. P., Durfee, E. H., Mullen, T., and Wellman, M. P. "The Distributed Agent Architecture of the University of Michigan Digital Library." AAAI Spring Symposium on Information Gathering in Heterogeneous, Distributed Environments, Stanford, CA, AAAI Press.

- Bos, N., "Student publishing of value-added resources in a WWW digital library." Paper presented at AERA, 1997.
- Bos, N., Krajcik, J., and Soloway, E., "Student publishing in a WWW digital library: goals and instructional support." Paper presented at AERA, 1997, symposium Artifact-building in computer learning environments: supporting students' scientific inquiry. Chair: Philip Bell.
- Crum, Laurie. "University of Michigan Digital Library Project." Communications of the ACM, Vol. 38, No. 4, April 1995, 63-64.
- Crum, Laurie. "University of Michigan Digital Library Project, Final Report, Volume I," Telepublishing Survey, TFPL Ltd., June 9, 1995.
- Durfee, E. H., Kiskis, D. L., and Birmingham, W.P., "The Agent Architecture of the University of Michigan Digital Library", IEE/British Computer Society Proceedings on Software Engineering (Special Issue on Intelligent Agents) 144(1), February 1997.
- Glover, E., Park, S., Arora, A., Kiskis, D., Durfee, Ed., "A Case Study on the Evolution of Software Tools Selection and Development in a Large-Scale Multiagent System", submitted to AAAI-98 workshop on software tools for developing agents, 1998.
- Hoffman, J., Kupperman, J., and Wallace, R., "Online learning materials for the science classroom: design methodology and implementation." Paper presented at AERA, 1997.
- Jackson, Jay. "Enhancing access in a national digital library federation, New Edition", School of Information and Library Studies, University of Michigan, Spring 1995.
- Jackson, Jay. "Update: The U-M Digital Library Project, New Edition", School of Information and Library Studies, University of Michigan, Winter 1995.
- Kiskis, D. "UMDL Architecture Requirements Analysis. School of Information and Library Studies", University of Michigan, August, 1995. (Internal Report)
- Lee, A., Nica, A., and Rundensteiner, "Surviving in an Evolving Environment: View Preservation", Technical Report, Electrical Engineering and Computer Science Department, Computer Science and Engineering Division, University of Michigan, Ann Arbor, Michigan, 1997 (submitted for publication)
- Lougee, Wendy P. "Beyond access: new concepts, new tensions for collection development in a digital environment." Collection Building, vol. 14, no. 3, 1995, p. 19-25.
- MacKie-Mason, Jeffrey K. and White. Kimberly. "An Axiomatic Approach to Evaluating and Selecting Digital Payment Mechanisms."
- Mullen, T. and Wellman, M.P. "Market-based negotiation for digital library services." Second USENIX Workshop on Electronic Commerce, November, 1996.
- Mullen, T. and Wellman, M.P. "A Simple Computational Market for Network Information Services." In First International Conference on Multiagent Systems, June 1995.
- Nica, A., Lee, A., and Rundensteiner, "View Sychronization under Capability Changes of Decoupled Information Sources", Technical Report, Electrical Engineering and Computer Science Department, Computer Science and Engineering Division, University of Michigan, Ann Arbor, Michigan 1997.

- Nica, A. and Rundensteiner, E.A. “DIIM: A Foundation For Translating Loosely-Specified Queries into Executable Plans in Large-Scale Information Systems”, in the Proceedings of the Second IFCIS Conference on Cooperative Information Systems (CoopIS-97), Charleston, South Carolina, June, 1997.
- Nica, A. and Rundensteiner, E.A. Uniform Structured Document Handling Using a Constraint-based Object Approach, Advances in Digital Libraries (ADL’95), A Forum on Research and Technology Advances in Digital Libraries, Virginia, May 1995.
- Park, S., Durfee, E., Birmingham, W., “Emergent Properties of a Market-Based Digital Library with Strategic Agents“. In proceedings of the Third International Conference on Multi-Agent Systems (ICMS98), July 1998.
- Park, S., Durfee, E., Birmingham, W., “A Stochastic Strategy for Multiagent Contracts and the Impact of Deliberation Overhead” (abstract), Proceedings of the Fourteenth National Conference on Artificial Intelligence (AAAI-97), p. 840, July 1997.
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Appendix B

Interview Protocol & Consent

Semi-structured Interview Questions

- What was the purpose of the DLI-1 project?
  - How did the call come about?
  - What were the goals?
  - What were the criteria for success? Were they met?
  - What were the outcomes?
- What was the purpose of the UMDL project?
  - What were the goals?
  - What were the criteria for success? Were they met?
  - What were the outcomes?
- How did you become involved in DLI-1 / UMDL project?
- Can you give me a brief narrative of the project from your perspective?
- What do you think were the central figures of the UMDL story? Who (the same or different people) were the architects of the reports/narratives/official story?
- Can you tell me about what the term *digital library* meant at the time? What was revolutionary about the term? What does the term mean now, 15 years later?
- How did the composition of the project team change over time? How did that affect the project, if at all?
- I have been unable to find a written history of the DLI-1/UMDL project at any significant depth. As someone who was involved in the project, what do you think would be the most important events, objects, people, and artifacts to include in such a history?

Consent to Participate in a Study

Ontic Occlusion and Exposure in Infrastructural Narratives: The Digital Libraries Initiative-Phase One and University of Michigan Digital Libraries

Investigator: Cory P. Knobel, Doctoral Candidate, University of Michigan School of Information

Description: This research project is investigating the Digital LIbraries Initiative-Phase One (DLI-1) and University of Michigan Digital Library (UMDL) projects, focusing on the ways in which disciplinary-based language and ideologies contribute to constructing infrastructure project narratives. This study has implications for those involved in research, development and management activities that span existing boundaries of professional research and infrastructure practice. It is relevant to those involved in information science, science & technology research policy, and (cyber)infrastructure studies.

Procedure: If you agree to participate, you will take part in a semi-structured interview about your motivations, perceptions and observations of participating in the Digital Libraries Initiative-Phase One projects. I will take notes and, if you agree, make an audio recording of the interview. A transcriber will then create a transcript of everything said during the interview. I will analyze interview transcripts in order to generate findings for this study. You can expect the interview to take about 60-90 minutes. If you agree, I may also contact you through email with brief follow-up questions to clarify or extend your comments from this interview.

Expected Benefits: Although you may not receive direct benefit from your participation, others may ultimately benefit from the knowledge obtained in this study.

Confidentiality: In all reports and publications associated with this research, I will report data in a way (using generic descriptions or pseudonyms) that does not disclose your identity. After completing the data analysis, I will erase the audio file of this interview and any email messages you have sent me in response to follow-up questions. I will also dispose of any information that identifies you as an individual.

Right to refuse: Your participation is completely voluntary. You may skip questions that make you uncomfortable, and you are free to withdraw from participating at any point.

Questions: If you have any questions about this study, please feel free to contact:

Principal Investigator:
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Should you have questions regarding your rights as a research participant, please contact the Institutional Review Board, Kate Keever, 540 East Liberty Street, Suite 202 Ann Arbor, MI 48104- 2210, (734) 936-0933, email: irbhsbs@umich.edu

Documentation of consent: One copy of this document will be kept with the research records of this study. You will also be given a copy to keep.

Consent to Participate:
I understand and agree to all of the above. Cory Knobel has offered to answer any questions I may have concerning the study.

Name: ____________________ Email: ____________________

Signature: ____________________ Date: ____________________

Audio Recording:
Please sign below if you are willing to have this interview recorded on audio tape. You may still participate in this study if you are not willing to have the interview recorded.

Signature: ____________________ Date: ____________________

Follow-up Email Correspondence:
Please sign below if you are willing to be contacted later with questions I might have about your comments from this interview. You may still participate in this study if you are not willing to engage in follow-up email correspondence.

Signature: ____________________ Date: ____________________

Disclosure to Prospective Interview Participants that you have Participated:
In order to recruit additional interview participants for this study, it can be useful to inform them that someone they know has already taken part. Please sign below if you are willing to allow me to inform prospective interview participants that you have already participated in an interview. No reports or publications associated with this research would disclose your identity, and I will not provide any information to other participants about what you have said during the interview. You may still participate in this study if you are not willing to share your name with prospective participants.

Signature: ____________________ Date: ____________________

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