When Technology and Business Collide
Sheltering Novelty as a Source of Innovative Products

By

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Submitted to the MIT Sloan School of Management on May 9, 2014 in partial fulfillment of the requirements for the degree of Master of Science in Management Studies.

ABSTRACT

The notion of innovation as a source of long-term growth is an attractive and familiar one, yet there is no set formula for guaranteed innovation. This paper examines the idea that novelty and novel ideas lie at the heart of innovation, but more importantly, are sometimes overlooked or prematurely dismissed given pressures at the interaction at the boundary between the intended audience and the representation of novelty by objects with universal comprehensibility. The examination of flows from the transition of novelty to boundary objects suggests that the interactions and organizational conditions surrounding the boundary object—the relational construction—compete and thereby influence the interpretation and adoption of new technology. Using the case of Xerox PARC, this paper examines the factors occurring in a highly-novel research setting, wherein the interaction between technical, social, and business/financial concerns yield many sources of potential conflict. A conceptual model of understanding these categories of interactions is introduced, and its use is suggested to encourage higher receptivity to developing sciences and technologies.

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When Adam Smith first came up with the idea of an "invisible hand," I am sure behind him was a [non-degree] thesis supervisor with a great wisdom beyond Smith's own comprehension. As Xerox PARC plays such a prominent role in my thesis, it is only fair that I quote Butler Lampson:

> The master often speaks in somewhat inscrutable fashion with a deeper and more profound interpretation than his humble disciples are able to provide. In retrospect you can really see that the path has been plotted years in advance, and you've been following his footsteps all along. (Hiltzik, 1999, p. 7)

And so it was with my experience with Professor James Utterback. He dropped breadcrumbs of academic research that helped solidify the conflict of novelty roiling around in my own brain. I am deeply indebted to his support and to the support of the chair next to his desk for leading me down paths of exploration that I would have otherwise been entirely ill-equipped to find—paths important for not only this thesis, but also my understanding of the world.

I would also like to thank Professor Paul Carlile at the Boston University School of Management. Having been pointed his way by Professor Utterback, I soon found myself in his office, in deep dialog about the finer points of boundary objects, novelty, relational construction, and his academic theories. That conversation helped broaden my mental framework and strongly influenced this paper.

I thank Professor Michael Cusumano, Faculty Director for the MSMS program; Professor Fiona Murray, Associate Dean of Innovation at MIT Sloan; and Professor Sarah Kaplan, visiting from the Rotman School of Management, for speaking to me at various points during my thesis exploration, helping me to find and refine my direction.

I owe MIT and Sloan a great deal for the courses and events with faculty, visiting speakers, and students that afforded me an opportunity to listen to fresh new ideas and to ask questions that clarified issues I had been thinking about. To that end, Chanh Phan, Julia Sargeaunt, and Christine Bolzan have just been an amazing part of my experience at MIT, and it is a literal fact that I could not be here without them—they just happen to be incredibly wonderful people as well.

When I went to Tsinghua in China for the first time two years ago for the first part of the two-school MBA/MSMS journey, I had but the much-appreciated support of my family and my former co-workers—no knowledge of what it meant to live in China, a vague idea of desired career path, a dream to see how the other side of Cambridge lived, and a glimmer of hope that it would all work out. Today, somehow, it has, and the experience has given me more friends and family, an unthinkably ideal career path, a fuller appreciation for business and the innovative process, and a healthier appetite for the joy of discovery.

All along, though, I'm sure my grandmother knew what I was in for. She made this all happen for me, and so these two years have been dedicated to her.

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1. Introduction

The question of how to facilitate innovation is one that has taken on iteratively different forms over the years. From the nature of encouraging innovation and Schumpeter's creative destruction (Schumpeter, 1983) to knowledge sharing across the corporation (Nonaka, 1994), each facet is important in its own way. This paper will focus on the nurturing of innovation during the generation process by examining the forces that impact novelty solidification into boundary objects, and reception thereof.

Under the premise that novelty is often equated with innovation, novelty itself often challenges an organization to go beyond its knowledge base, particularly within and between departments or teams. Corporate cultures tend to dictate how people work in a broad sense, while specific methods of cooperating and communicating are worked out over time as groups interact and grow accustomed with each other. Bringing in new people unlocks new skills and possibilities, and those soon integrate and assimilate into the broader organization.

In this way, the inertia of business can be thought of as a pace of movement: different corporations and different teams move at different paces, and when forced to integrate and assimilate in short order, internal strains and incompatibility may contribute to failure, or they can result in more integrated teamwork norms. The scale of interaction involves three large facets: technical expertise and representation by boundary objects; social norms and preconceptions; and financial or business interfaces involving a view of markets and consumer demand.

This paper will focus on a the research and development side of innovation, in which actors come with a novel idea, and the team works on it to iterate and create a new product; this team is considered an entity, as is the corporation at large, represented by strategic exogenous

financial or strategic priorities. While the team is within the organization, it has goals and priorities that may be inconsistent with those of the broader organization, and their novel work is represented to the broader organization in the form of boundary objects, or things understandable by people with different backgrounds. In order to turn the idea into a viable product, the corporation may have to change and accommodate the innovative idea.

Understanding that these flows are often in conflict, then, can lead to defining failure frameworks within an organization—why do a group's contributions or new technological advances go underutilized or ignored?

1.1 Thesis Overview

This thesis is designed to be a study in making explicit the flows affecting innovation. In so doing, it is my hope that this will benefit a more meaningful dialogue about capturing and nurturing the long-term value of smaller and nascent units of innovation. Chapter 2 examines how companies create the "corporate" part of the infrastructure involved with the interpretation and evaluation of novel technologies or ideas. Chapters 3 and 4 extend the conversation to think about what novelty and innovation are, and Chapter 5 defines how the two interact. Together, Chapters 2 through 5 help outline the scope of what innovation is for the purposes of this thesis. Chapter 6 addresses how meaning travels across the corporation, given the infrastructure and boundary objects. Chapter 7 uses the case of Xerox PARC to illustrate different types of interactions between novelty, innovation, and infrastructure in a highly-novel research setting. Chapters 8 and 9 integrate the interpretation from the first half of the paper with the Xerox PARC case to create a model of interaction between technical, social, and business/financial areas in order to identify sources of potential conflict for application to the management of innovative companies.

2. Companies and their Organizational Influence

As much as scientific or technological achievements are the work of dedicated individuals or teams, the structure of the organizations or companies supporting these efforts are equally, if not more, important to the end result. In aggregate, organizational interactions are necessarily more complicated as they involve a larger number of actors and artifacts along the way. Given practical difficulties in enumerating the varied interactions between technical research and development and business considerations, this paper focuses on the types of issues companies encounter at boundary interactions (corporate scope of this paper highlighted in yellow).

Figure 1: Scope of Paper from a Corporate Innovation Management Perspective

<table>
<tr><td rowspan="9">Innovative, R&D-based teams</td><td rowspan="5">Management methods</td><td>Spurring innovation</td><td colspan="2">Unlocking creativity</td></tr>
<tr><td>Best practices</td><td colspan="2">Design thinking</td></tr>
<tr><td rowspan="3">Team selection</td><td rowspan="3">Team structure</td><td>Cross-disciplinary</td></tr>
<tr><td>Competing teams</td></tr>
<tr><td>Leadership styles</td></tr>
<tr><td>Communication</td><td>Interaction dynamics</td><td>Frequency/form</td></tr>
<tr><td>Cross-departmental</td><td>Situation parameters</td><td>Integration of team</td><td>Reintegration</td></tr>
<tr><td rowspan="3">Spinning off innovation</td><td>Seeding new products</td><td colspan="2">Dispersion of (new) technologies</td></tr>
<tr><td>External-in</td><td>Corporate VCs</td><td>Integrator role</td></tr>
<tr><td>Internal-out</td><td>Intrapreneurship</td><td>Catalyst</td></tr>
<tr><td>Business operations</td><td>Resource allocation</td><td>R&D financing</td><td colspan="2">Innovation KPIs</td></tr>
</table>

2.1 Corporate Motivations Influence Culture: Time Horizon

Companies formulate a set of norms and goals that guide the culture and behavior desired in employees. It is not always the case that the resulting culture was intentionally created, but a successful company will have a culture that is closely aligned with its strategic goals. From the

strategy standpoint, it is suggested that there are survival and advancement strategies, a dichotomy recognizing the difference between sustaining the viability of a business and developing future expansion opportunities for the business (Von Krogh, Ichijō, & Nonaka, 2000, p. 71).

Applied to this dichotomy of priorities, Mintzberg's work (1975) recognized the disconnect between the manager as a reflective planner and the reality of being the manager being prone to action, with particular reliance on verbal information stored in his or her memory. As it acts to gain a competitive edge in the market, the company recognizes *achievements* of the manager—a discrete cause-and-effect relationship—and the manager is rewarded. Such action reinforces the behavior and propensity of the manager to seek out these action-oriented wins, or at least, measures by which the company remains competitive in the marketplace. When information is not actionable, it is easy to gloss over its significance simply because it possesses few of the benefits offered by information that yields clear strategic conclusions.

The broader implication of this, then, is that the time horizon of many managers is reinforced and trained to be more oriented to the short-term and that the valuation metrics relied on are clear, quantifiable benefits to the corporation. On the other hand, a focus beyond the numbers and validity of projections could lead to a consideration of what new strategic possibilities or revenue opportunities are enabled by innovation (Kaplan & Orlikowski, 2013).

2.2 Interaction between Team and Corporate Priorities

Despite the pressure for corporate culture and managerial incentives to align the priorities of managers and their groups to corporate strategy and goals, it is still possible for corporate goals to differ from department, team, and individual goals. With this view of variability within the top-down management approach, it appears that "the real goal of formal organization is the

structuring of communication patterns" (Allen, 1977, p. 211). In this sense, an organization can rely less on micromanagement by higher levels of management and strategy-setting, and trust in the employees to create and expand the boundaries of expected achievement.

Given the ability to do so, though, it is still up to the company to commit to ceding control. With public companies, there are external factors such as shareholders and publicity that may reduce the amount of leeway given to projects and to team discretion. Indeed, even with discretion, research and development efforts must balance the degree of multidisciplinary requirements and knowledge with communication methods and the latest information updates (Allen, 1977). Unless the act of study or research is done by an individual, there are still coordination issues that lie at the heart of any organization—be it a company of twenty thousand or a team of two.

Corporations address this issue by creating an infrastructure, norms of interactions between actors and objects, included in which is culture—only by making sure all levels understand the mission and purpose of the company can they reduce the resource expenditure on "managing," and instead create a self-reinforcing and self-regulating environment. The core competencies of meaningful and repeatable corporate interactions become autonomous: effective cultures and value systems combine with technology system, and are reinforced with proper organizational structures to improve the results for customers (Quinn, 1992, p. 316).

2.3 Organizational Design

Given these issues of coordination and communication, then, organizational design can be considered important in some sense at any size of organization. For companies of a large enough size to have multiple sub-teams or departments, organizational design selection is

important for internal processes and for the end results: there is a choice of functional or project management organizational models (Allen, 1977).

Functional management focuses more on the processes and tasks assigned, which necessitate the correct qualifications, particularly technical or skill-based ones. In popular terminology, functional management is often described in terms of "silos," in which groups operate independently or in some degree of isolation in order to more effectively finish area-specific tasks. The limitation of this approach becomes clear when cross-functional tasks occur, and a number of siloed skill sets need to come together: ownership of the project is uncertain given this paradigm (Allen, 1977).

Project management, then, focuses more on the end result and the product desired, particularly as these may require a more integrated, cross-functional approach to arriving at the desired goal. In this configuration, a project manager takes ownership of the task and facilitates the coordination of necessary interactions, distribution of information, and communication of goals. By removing control from multiple managers across multiple silos (which would have required communication between individual teams and their managers, as well as between teams through managers and/or technical specialists) and centralizing it under one leader, the difficulties in aligning efforts is significantly decreased.

The deeper question at the heart of this paper, then, is how can the alignment of priorities and efforts normalize and/or discourage tangentially-related, not-well-understood, or narrowly-specialized alternative solutions to stated goals?

2.4 Assimilation of Ideas and Organizational Framing

The work of a development group may be considered design- or engineering-based, but the focus is on the work and modes of interaction less so the specific "type" of worker; for

example, an engineer can be considered a designer, and a designer could be an engineer. A wider look at organizational structure with respect to communication within a team introduces a need to evaluate or validate the contributions of that given team. Successful implementation of a team's contribution can be defined as the adoption of the group's idea, innovation, or product by the broader organization. In effect, with an understanding of corporate motivations as described in Section 2.1, the work itself can be considered secondary to the recognition and adoption of the work by others beyond the immediate team.

With an understanding that the knowledge used in innovative processes can be about the users, technological opportunities, or product languages, the greater integration of those three results in in a vision about a possible future (Utterback, 2006, pp. 165–166). Because of its intrinsic nature of exploration, design-inspired innovation—particularly of the technical variety—can place demands on communicative methodologies and semantic contexts. In other words, from a practical perspective, novel exploration of needs may result in technologies that can only be as useful as the language used to describe them.

Everett Rogers discusses five factors affecting the rate of adoption (in this case, adoption of a generic "innovation," which could be an artifact, process, or idea): *relative advantage*, or how much better the innovation is compared to alternatives and to what came previously; *compatibility* of the innovation to the existing infrastructure and usual processes in which users engage; *complexity* of the innovation, particularly as it relates to real-world use; *trialability*, or the ability of potential users to quickly and easily gain access or try out the innovation; and *observability*, which affects how quickly others see and share the innovation with others (Rogers). These factors speak to how the benefits of an innovation can be understood and

communicated in turn, but they also describe more of the intrinsic qualities of artifact, process, or idea.

The extrinsic influences of the organizational framework connect back to the diffusion and adoption of innovation in very real ways. New concepts are most likely first described in terms understandable to others, as "collective technological frames only emerge from interactions" (Kaplan & Tripsas, 2008, p. 802) and as communication network cohesiveness has a strong positive impact on project success (Ebadi & Utterback, 1984). Without explicit intent to do so, organizational memory and framing—in effect "cultural lock-in"—takes the past processes and products that inform the company's experiences in success or failure and applies those to the evaluation of the new (Foster & Kaplan, 2001).

Because of this, even something that may be understood as a good innovation (in spite of the limits in existing language or semantic contexts) may not actually fit in with a company's culture, infrastructure, or knowledge base. In this sense, something completely novel and incompatible with a company's past and current operations may be dismissed by other individuals, teams, or the broader organizational management. Assimilation of technological ideas and breakthroughs in multidepartment corporate settings, therefore, becomes an issue of how to deal with the organizational uncertainties and strains resulting from novelty and knowledge management.

3. Novelty

Novelty is the creative spark that lies behind innovation and concurrently describes a phenomenon in which the corporation may be unable to reconcile the technology with its operations, at least at present. Due to a lack of resources, organizational infrastructure, technical knowledge, or ability to comprehend the strategic benefits, organizational memory or

organizational framing encounters something that has not been part of the company's history. Novelty is a source of tension impeding a company's willingness to take risk and impeding its ability to effectively communicate—it represents the unknown.

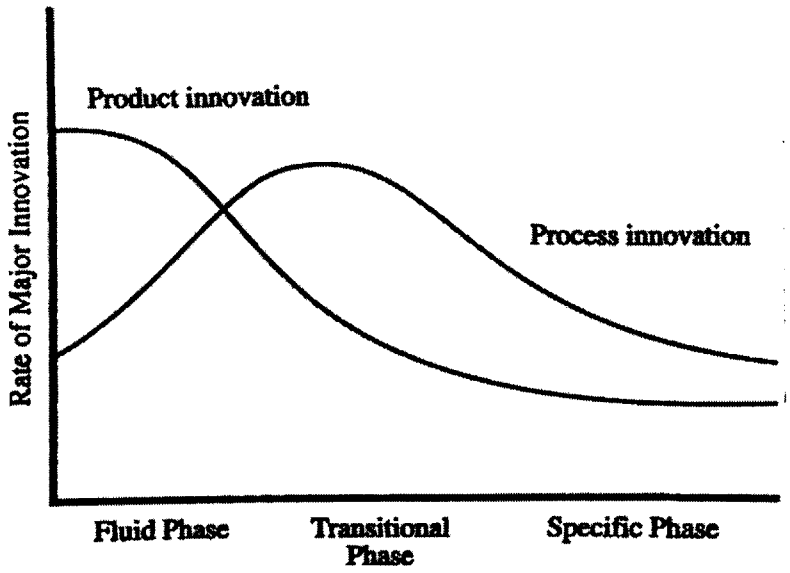
At the point at which business needs change and in turn necessitate a change in the underlying processes or organization, the very flow of operations is disrupted. In other words, novelty in the system requires a different pace in the working structure.

3.1 Pace as Operational Parameter

As many managers focus on technology with known markets with well-known and well-understood customers, as a "planned, researched approach to evaluating, developing, and marketing innovative products is not only possible, it is critical to success" (Christensen, 1997, p. 165). In other words, a routine, or a "normal" pace of business operation and interaction develops in order to maintain profitability and success. Here, pace is not simply the rate at which tasks are completed (though that too plays a part: there are key differences between daily financial transactions and long-term basic research, for example), but also the degree to and methods by which information is habitually communicated and presented.

From a lifecycle standpoint, understanding how the rates of innovation vary is part of the reason why novelty forces organizations to stretch. As the relative pace of new product churn does not occur at the same rate as company adaptation and change, these rates can illustrate some of the incompatibility (Utterback, 1994, p. 91):

Figure 2: The Dynamics of Innovation (Utterback, 1994, p. 91)



From a non-temporal phase view, the high rate of flux in periods of uncertainty shows a disconnect between the rate of product and process innovation—organizational novelty really reflects an inability to accommodate novelty given the current internal infrastructure and capability, and the organization may have to struggle in order to regain control over movement and change. The corporation can adapt in the long run.

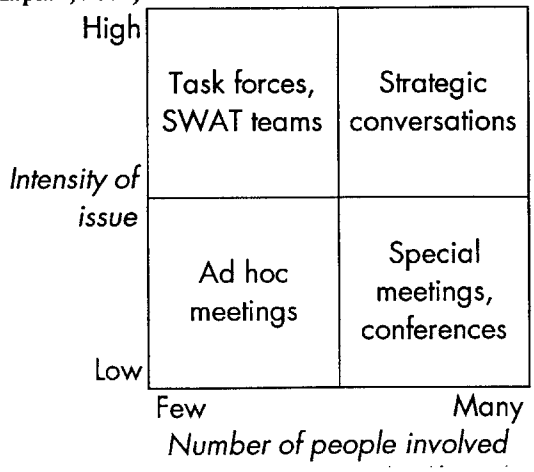
Carlile and Lakhani (2011, p. 5) put a finer distinction on the interactions between novelty, innovation, and knowledge by thinking of innovation as reconciling sources of novelty with existing knowledge "to determine the consequences or the value of that novelty for innovation to occur." There is a crucial judgment made in the transformation from novelty to innovation—the pace of the new must be understood in relation to the pace of the old, a mental gearing to understand the connection between the two and the power behind the novelty.

3.2 Corporate Responses to Novelty

From a practical perspective, the corporate pace is one of established inertia. To put into visual terms, a small gear spinning at low speed introduced to a large gear spinning at high speed fails to generate meaningful pairings, and the interaction may even damage one or both of the gears (Carlile, 2014). When faced with the need to shift gears or use some form of differential gears, a company can understand and respond to the challenge of novelty from three different perspectives: scale, internal capabilities and sub-teams, and external opportunities and expertise.

In terms of scale, the firm and actors may begin by trying to define how meaningful the uncertainty is in terms of bottom line or effort required in the exploratory transformation from novelty to innovation. Recognizing novelty to begin with may be a challenge with smaller-scale ideas, because existing mental models or methods of examination may not capture the nuances of change. At the most basic level, there is a need to understand both novelty and the forms that novelty takes—what are the parameters that make sense for a given firm or a given industry at a certain point in time, and how do those change?

Figure 3: Top-down Creativity (Beinhocker and Kaplan, 2002)



Once novelty is discovered and recognized, the firm and actors can begin responding in accordance to individual and collective capacity and ability, the combination of which form the capability (Carlile, 2014). The consideration of capacity, ability, and capability forks at internal and external dimensions, and is subject to decision-making based on ambiguity and mixed signals (Kaplan, 2008). Assuming that there is sufficient ability to

make technical sense of novelty, when there is a breakdown in internal capacity, the gap can be addressed with project-based structures in the form of special task forces or innovation teams to focus on determining the potential of future innovations. (Of course, for larger problems affecting the viability of the firm, a single team would be an insufficient response to the situation—again, scale is a highly variable modifier to "appropriate" responses.)

Sub-teams cannot recreate the natural functional isolation and specialized work present at outside organizations. Qualcomm is a current illustration of how internal and external dynamics take pacing into account with respect to innovation. Qualcomm encourages many types of structured innovation (employee suggestions that are evaluated by experts and voted on by the corporate community), but it also addresses unstructured innovation—unstructured innovation being a side, after-hours project of a given employee. When the side project begins attracting multiple other collaborators and becomes visible to managers, then it becomes managed. This may mean linking to similar projects within the company, or building out to a larger team. (Jacobs, 2014)

At a certain point, though, corporate influences begin to come into play. From a resource perspective, when the budget gets tight, non-core projects with names get cancelled, because it is seen as a non-essential line of business (a non-essential *potential* line of business at that), even if it may result in long-term revenues. Conversely, the company also recognizes when a promising small project does not provide sufficient incentive for proper traction and progress (that is, the comfort of a large balance sheet shelters the employee from a need to focus on speed to market). At that point, that project may be spun-off as a separate company with the blessings and financial backing of Qualcomm. (Jacobs, 2014)

3.3. Implications of Responses to Novelty

This natural reaction to annex the exploration of novelty is to recognize the incompatibility of pace between novelty and the established "normal" business operations. Organizational culture and methodologies put in place to reduce the load on managerial resources further entrench the existing process. Internally, a project may be cancelled and novelty snuffed out even before it yields boundary object representations. If novelty has already grown into a viable innovation, a research or business operation, though, management can think about how to move forward with the *innovation*, rather than with *novelty*. In other words, when put into context of broader organizational commitments and direction, product innovation with effective boundary object representation begins to match process innovation on a more comparable basis. If the mismatch is too great, an innovation can begin to live within the organization as a separate entity or unit and not impede the normal workings of existing groups.

Separating into a project groups is to suspend meaningful work from the possibility of creating internal turmoil and/or from organizational resistance or change within the confines of some form of a single silo. With freed capacity to explore and understand the business implications of novel technological frontiers, keeping management engaged, invested, and willing to integrate the proposed solutions may be another challenge if the company is unaccustomed to such measures: in effect, technological novelty may result in organizational novelty as well.

As Christensen says, a larger company can "right-size" the project by putting it with an organization small enough to focus on and care about it, an isolated company more so than just a sub-team, or by acquiring a smaller company with which to incubate the project (Christensen, 1997). In either a corporate spin-off or corporate venturing approach, the recognition of a radical

difference in pacing requires a similarly radical break with normal business patterns and customs, but may yield value by tapping into additional innovation networks (Calia, Guerrini, & Moura, 2007).

Empirically, Qualcomm illustrates the realization of such pressures, albeit with a certain degree of speculation on the part of corporate leadership as to what sort of behavior is being incentivized within a firm (Jacobs, 2014). Value capture of a firm is reduced with a spin-off, but the overall value of innovation creation is increased. Assimilation of new information from acquired companies or assimilation of more complete innovations and ideas at a later point in development can help reboot pacing to a desired state and put the benefits of internal contributions in context, but even so, acquisition is done at tremendously greater cost and may later impede progress given potential organizational mismatch. (Jacobs, 2014)

4. Innovation

In recent years, much has been made of Christensen's idea of disruptive innovation, and for good reason: the rapidly changing context of maturing and evolving technology and their intended applications and actual consumer use has resulted in obsolescence of many companies and devices. Indeed, Qualcomm is an example of that: even as processor market leader Intel created increasingly more powerful chips for application in personal computers, Qualcomm created smaller and more power-saving chips appropriate for use in handheld and wearable devices. As the landscape has shifted, Intel has found itself behind the curve and struggling to overcome the momentum of Qualcomm as new waves of devices are developed and released. (Jacobs, 2014)

Having an understanding of the technical world and of the markets be refreshed in ever quickening cycles requires a consideration of innovation, the driving force of change. In

describing innovation, Christensen constructs a dichotomy of sustaining and disruptive technologies. In contrast to sustaining technologies, which involve improvements to existing products, disruptive technologies offer new value propositions than previous products. While initially offering a lower level of product performance, disruptive technologies catch up to and exceed the performance of previous technologies over time—though not without some degree of additional development and market support. (Christensen, 1997) On the other hand, this is not to say that incremental improvements (sustaining innovations) are unnecessary and futile, because they are often expressions of gained insights about user needs and experience, which may influence or benefit the creation of disruptive technologies.

Christensen writes about disruptive innovation from the viewpoint of market reaction, but the same issues apply to an inward-facing corporate ecosystem: because many new technologies or potential technologies offer non-obvious future benefits, the management focus on shorter time horizons mentioned in Section 2.1 means a focus on sustaining technologies. In other words, with respect to Rogers' framework, adoption is greatly impeded by the lower relative advantage at the very outset—this in conjunction with the investment necessary to elucidate the complexity or compatibility (which may ultimately prove low)—shown by an observable, trialable prototype artifact or demonstration of practice.

Because of the fundamental tension in uncertainty, this discovery period is one of risk-taking for the corporation, and a prime reason why novelty causes organizational disruption.

4.1 Tacit or Explicit Information as Competitive Advantage

Given that there are different ways in which a single disruptive innovation may be communicated, innovation adoption may depend on the skill, knowledge, and/or experience of the demonstrator, and may or may not be easily reproducible at scale without an understanding

of the value-added breakthrough. These types of knowledge form the basis of competitive advantage going forward, but in the formative discovery period, it is imperative that companies capture all the knowledge involved. With an increasing quantity of knowledge, certainly the assets required to implement the knowledge must keep pace as well (Teece, 1986)—this may require change on the part of the corporation.

Just as a recipe for a soufflé can yield vastly different results when in the hands of the originating pastry chef than when in those of an average college student, so too can the knowledge of individuals result in variable outcomes in companies. In knowledge management literature, tacit knowledge (that of individuals) is recognized to be much more difficult to capture than the explicit knowledge typically represented in corporate documentation and manuals (Von Krogh et al., 2000, p. 75). Both types are important, but it is also important to recognize the level of innate variability within the firm, such that the contributions of an isolated innovation team may be difficult to implement broadly without closer interactions between groups. Methodology aside, initial success also depends on the ability of the technology originator to clearly communicate the promise of the novel direction, or at least to do so sufficiently well to an advocate in a gatekeeper role who can make the pitch on his or her behalf with sufficient technical and communicative abilities (Brown & Utterback, 1985).

Recognized, utilized, and widely-shared tacit knowledge can yield positive benefits for the broader technical capability of the corporation. What may be thought of as competitive advantage—knowledge dwelling exclusively within the firm in the form of specialists or specialized teams—may also be seen as a barrier to effective utilization throughout the firm, because the competitive advantage of information rests on high reproduction cost or difficult (Barney, 1991). These difficulties can be resolved internally, but the resolution thereof is directly

dependent on the context of corporate culture and organizational structure. Together, organizations and individuals iteratively expand the amounts of tacit and explicit information through socialization, combination, internalization, and externalization (Nonaka, 1994).

Anything that can be done to better transmit and share information across teams with backgrounds of differing disciplines and skill levels is highly valued. Moreover, only with successful methods of information sharing and transmission can the nature of the knowledge or contribution be realized.

5. Relating Novelty to Innovation with Boundary Objects

The transmission of information across disciplines or departments can be done in numerous ways and through various interfaces, but a translation or interpretation step is often included—at the heart of common understanding is a need to understand the viewpoint of other parties, given current or individual frameworks of knowledge. At these boundaries of understanding lie boundary objects, which are artifacts or representations that can bridge the knowledge gaps and communicate meaningful content.

5.1 Boundary Objects: Representations of Understanding

A common way of understanding boundary objects as mentioned above is that of things with "interpretive flexibility," or the ability to be comprehensible to two groups of people with different knowledge backgrounds and frameworks. Credited with introducing the idea of boundary objects along with Jim Griesemer, Susan Leigh Star later revisited the concept and clarified the definition and architecture of boundary objects with respect to two other qualities of boundary objects that had been largely underemphasized: "scale/granularity" and "material/organizational structure of different types of boundary objects" (Star, 2010, p. 602).

Understanding that boundary objects are use- and interpretation-dependent, boundary objects must also be considered as "at once temporal, based in action, subject to reflection and local tailoring, and distributed throughout all of these dimensions" (Star, 2010, p. 603).

In other words, a boundary object entails more than an interactive object itself, rather a context of qualities to be considered. Scale is a quality of boundary object-ness in the sense that anything presented or residing between two people could be considered a boundary object and can be used or useful as such, but the consideration of relevance to broader organizational goals and tensions pushes the examination of boundary objects to a broader level.

Categorizations of boundary objects proposed by Star were intended to be a starting point of understanding the use of boundary objects "based on particular forms of action and cooperation," and the materiality of boundary objects "derives from action, not from a sense of prefabricated stuff or 'thing'-ness (Star, 2010, p. 603). So, a theory may be a powerful object." In a research and development setting, then, those novel ideas are in themselves boundary objects insofar as they hold potential interpretive flexibility; however, the greater consideration of form and use in the context of surrounding conditions may render them incomplete or useless.

5.2 Infrastructure and Relational Construction as Context

Star (2010) framed boundary objects as temporal, based in action, and subject to reflection and local tailoring, and Carlile (2002) framed knowledge as "localized, embedded, and invested in practice." The realm of understanding boundary objects, then, includes not only the object that has a universality—at least commonality—in interpretative meaning, but also the all the components and framework constituting that understanding. Generalized, it can be seen that time and place, practice and application, and individual knowledge and preconceptions are factors that are linked to boundary objects—in other words, the context matters. More than that,

this suggests that much of the interpretive and application power rests with those people or environments separated from the originating individual.

Star and Ruhleder (1996) examined the "infrastructure," defined above as the interaction between actors and objects, as affecting the shift from an understanding of an object to the use of an object. They defined the characteristics of note as embeddedness; transparency; reach or scope; learned as part of membership; linked with conventions of practice; embodiment of standards; built on an installed base; visible upon breakdown; and fixed in modular increments. The examination of and elaboration upon these dimensions results in a possible description of why and how boundary objects fail—in many respects, it is very similar to Rogers' factors affecting adoption: relative advantage, compatibility to existing infrastructure and processes, complexity, trialability, and observability. There is a strong component of the human experience and subjective framing that colors the infrastructure surrounding boundary objects.

If the context surrounding a boundary object is incomprehensible from a *social dynamic* perspective, then the boundary object faces difficulty in adoption.

5.2.1 The Syntax, Semantics, and Pragmatics Surrounding Boundary Objects

Jantsch (1980) introduced syntactic and semantic approaches to knowledge. At the level of syntax—simply the words and terminology used to describe an object—the binary condition of having or not having a "shared and stable syntax," or a common language, is imperative for accurate communication.

For example, the phrase "the sky is blue" is understood to describe the layer above Earth, and that its color is blue. When the words and techniques used to communicate are as understandable as this basic scenario, information is shared and communication is normalized. It is possible and often necessary to co-develop a common set of terminology that can be used to

describe novel ideas and innovations (if the concepts have not already been established and learned prior); the co-development process naturally provides alignment in the resulting mental frameworks. The categorization of boundary objects can be thought of as an integrating device, as it describes a form of aligned information expression, but it is not immune to misinterpretation (Carlile, 2002).

The next level of knowledge—the semantic level/approach—considers that the way in which one person understands language may be different from that of another. For example, the "sky is blue" may indicate a bright light blue to one person and a deeper royal blue to another, or perhaps the observation could be alternatively interpreted to mean "the weather is nice." Therefore, increasing layers of perceived understanding and comprehension here muddy the communicative power of words or objects.

The implication of this from a team perspective is that the words and terminology used to describe the contributions and potential greatness of a novel idea may be insufficient to convey the meaning to an outside audience. Furthermore, the pace and methods of communication can be not only different, but also unpalatable to the unaccustomed. The communicative process can negatively impact the interpretation and reception of even generally-accepted terms and concepts. The possibility of in-group/out-group dynamics is a part of how organization structure and interactions between team and corporate cultures affect the conversion from novelty to innovation to successful products.

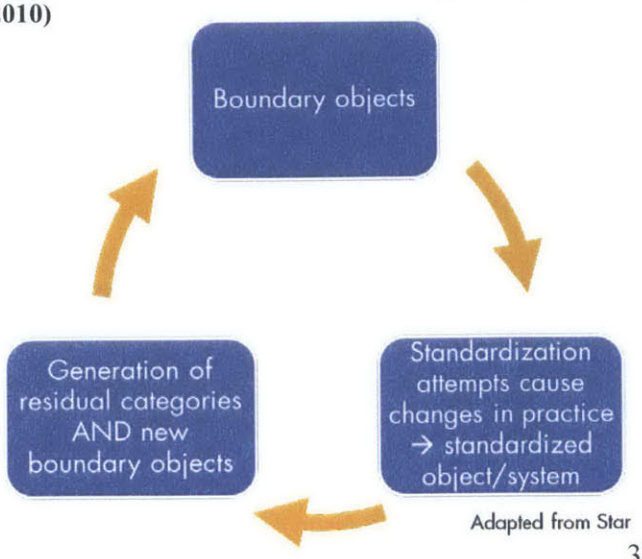
The acknowledgement of these differences begins to lead to a way of standardizing, rationalizing, or solving the need to translate novel ideas into "locally"-understandable terms. The infrastructure of knowledge is part of the social construct of daily interactions and stays at a subconscious level until characterized and discussed. Carlile's pragmatic view of boundary

objects (2002) recognizes that knowledge transformation is necessary for others to fully comprehend the message, given all the social structure and factors affecting the interpretation of the knowledge conveyed by boundary objects. In other words, how tacit knowledge can be communicated and accommodated from all parties involved creates an understanding of *how* to communicate; transferring knowledge is really the first a four step process of pragmatic boundary capabilities, with the follow three steps being translating and transforming that knowledge, and iterating to better effect (Carlile, 2004).

The recognition of organizational structure plays into an understanding how groups of people may have internally-similar but externally-conflicting ways of understanding and evaluating. By making the implicit aspect of knowledge infrastructure explicit, the dialogue surrounding the representation of novelty by boundary objects includes not only *what* is being conveyed, but also *what is necessary* in order to adequately convey the idea. In many respects, this paper can be considered a pragmatic analysis of converting novelty into innovative products.

5.3 Standards and Standardization Leading to Intercategorical and Residual Categorization

Figure 4: Standards and Residual Categories (Star, 2010)



In order to convey ideas from one group or department to another, the differences codified by standardized practices and processes must be realized. Co-development can happen within and between groups, but without regular interactions, independently-existing syntactic and semantic

frameworks develop. The simultaneous coexistence and incompatibility of multiple categorizations of understanding can lead to a dynamic change in the standardized form of boundary objects, as shown in the Figure 4.

As certain boundary objects are repeatedly recognized as either intercategorical or residual categories, they may begin new boundary objects or categories of boundary objects (Star, 2010). The influence of these changes yields not just changes in boundary objects and categories, but in the infrastructure as well. The explicit understanding of infrastructure relates to the relational construction of the dynamic system. When spread between groups across an organization, this can result in entrenched understanding and frameworks that collide with negative consequences on a changing basis over time. Moreover, categories, cognition, and actors to change how these contexts exist—it is a dynamic process (Kaplan, 2011). Reference points shift and realign understanding in the long-run, just as an organization can create product-driven process changes, but short-term friction can persist.

The relational construction—the understanding of infrastructure—necessarily describes the changes of the boundary object over time, from recognizing the potential of a novel idea and its communication; to boundary object representations and innovative applications; to multidisciplinary projects yielding iterative improvements with prototypes; to finalized and approved products; and to commercialization of the use case. This conceptual view of the infrastructural components involved with innovative development is not to be interpreted as a stage-gate approval process. Relational construction is not simply what the intercategorical boundary objects and resulting classifications are, but *how* the needs and form of boundary objects change over time in order to be compatible with existing processes and corporate culture, or to overcome embeddedness.

6. Addressing Relational Construction and Knowledge Transfer

At the heart of the idea that novelty is valuable is the assumption of being able to recognize useful innovation. Given the limitations of technological expertise in unexplored areas of study, though, real-world confirmation of the value of novel ideas is not guaranteed. Again, in cases of novel technology, it is not simply enough that a boundary object communicates what it is—it also has to suggest what it can become. Furthermore, the co-development of common syntactic and semantic frameworks strengthens social bonds and degrees of mutual understanding within between individuals, but outside that group, communicative power may be limited by such specialized language.

Objectively, there is no "correct" standard or framework of evaluation, simply one that makes the most sense given available information and requirements, and generally agreed upon by stakeholders in the process. For example, it is perfectly okay to measure things by smoots instead of meters if everybody does it; in an environment in which meters have been scientifically determined to be constant and measurable, measuring length by the height of an MIT students seems arbitrary and irrational—essentially outside the framework of normal measurement categorization. However, the meter came about as a result of people realizing the need for a constant and universal system of measurement, then trying to figure out adequate representation under those conditions; multiple actors came together to develop a system of measurement—a boundary object is also defined by a set of social actions and norms.

Howard-Grenville and Carlile (2006, p. 474) describe the situation in terms of created knowledge regimes, or "nested connections between the material reality engaged by work practices, the work practices themselves, and the larger collective conventions that reflect and account for the appropriate use of such practices." In an organizational environment of codified

standards and habits, classifications help frame an understanding of team achievements. However, those classifications are strongly experience-dependent—they live on implicitly as mental frameworks, and these influence the metrics of evaluation used.

Knowledge regimes, then, delineate the components of "confirmation," such that the imprint of past successes and understanding informs the value of the novel (Carlile & Lakhani, 2011). When a novel idea or innovation fails to fit into that framework, it becomes an intercategorical object, fit into the residual category of "other"-ness (Star, 2010). Because of the subjective nature of classification, what otherness represents is an admission of reserved judgment based on insufficient information at best (in other circumstances, outright rejection may be experienced). Therefore, for otherness to become accepted, it either has to change or has to be accommodated through joint transformation of that knowledge (Carlile & Rebentisch, 2003).

Confirmation and subsequent (re)categorization is functionally important because it serves to change the global scope of dialog and understanding over time, but it must be examined at a pragmatic level; in other words, the challenge is in the confirmation and it is dependent on the nature of human behavior and interaction.

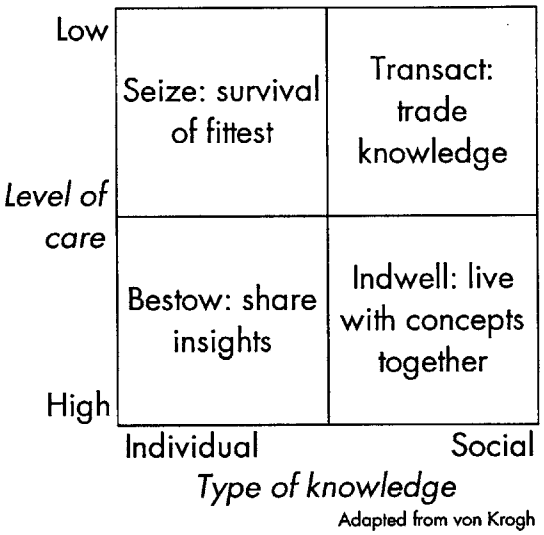
6.1 The Scale and Pace of Interactions

The framework of understanding the challenge of confirmation—why infrastructure and boundary objects in innovative processes are important—ties back to the reason why great ideas can fail to make it to market, or make it to market at firms other than the firm of origin. Infrastructure necessarily includes corporate boundaries in place and the dynamics affecting cross-departmental communication—it relates to the structuring of communication patterns

(understood here to be proxies for knowledge transference in whatever transformative steps it takes).

In general, priorities change across the company and these shape the pace of their actions and interactions. Short-term solvency concerns force management to focus on balance sheet financials (actionable metrics), while various groups within a product or research and development department diverge between short-term and long-term projects. Individual knowledge sharing changes based on the general environment. In Figure 5, expected channels and forms of knowledge sharing are illustrated. For example, in high-pressure, task-driven research environments in which many projects occur simultaneously (the upper left quadrant), scientists or researchers toil on without care to others around them. The one-actor change nature of this interaction, should it be sustained, conceptually results in a boundary object with semantically-flawed context—that is, there is a risk is that no one else will support a project, even if its importance is understood.

Figure 5: Knowledge Creation with High or Low Care (von Krogh et al, 2000, 55)



Adapted from von Krogh

On the other hand, even in organizations in which there is cooperation among many individuals or groups, a categorization and knowledge regime codify as frequent interactions and trading of knowledge occurs. Depending on the actors involved, even this multi-disciplinary group effort may still fail to easily translate into novelty value confirmation when facing a broader group. Since the regulation and normalization of knowledge transfer pace is affected by the scope of knowledge transfer relative to the entire company, from the top down,

organizational clout and ability to get things done can strongly affect individual or group contributions and knowledge transfer at smaller units of interaction. (Spin-offs may also occur to eliminate the pacing mismatch.)

Interestingly enough, the challenge of novelty confirmation in relation to knowledge transfer can also hang up on inter-office political issues. Dick Brass, a former vice president at Microsoft, described the internal struggles at Microsoft over ClearType, an alternative way of interacting with liquid crystal displays to clearly reproduce text on computer, as illustrative of why Microsoft is no longer innovative. Brass stated that the reception of ClearType, initially designed with the intention of improving e-book sales but providing widespread benefits and implications for other Microsoft products, met with cool and even actively-political responses screens (it should be mentioned that ClearType is widely used in Windows today):

> Engineers in the Windows group falsely claimed it made the display go haywire when certain colors were used. The head of Office products said it was fuzzy and gave him headaches. The vice president for pocket devices was blunter: he'd support ClearType and use it, but only if I transferred the program and the programmers to his control.

A decade of critical praise and internal publicity passed before ClearType was implemented in Windows. (Brass, 2010)

As this example with Brass and Microsoft shows, pace does not just relate a given group to the broader organization, but also from group to group, and from group-to-organization to group-to-organization. For job security, for credit, or for other social reasons, truly beneficial technical innovations may trigger comparisons of present and future pace of operations and growth between groups, particularly as it relates to individuals. In some sense, this may be inevitable, but designing interactions to take into account such concerns is a nontrivial task.

6.2 Bonds and Barriers: Inspiration from Bell Labs' Jack Morton

The intermediate gearing necessary to normalize the interactions at different paces and scale was suggested in spirit by Jack Morton, vice president of electronic technology at Bell Labs during the transformative discovery and development of the transistor. Morton saw the manager as the interface between the group and the organization, and between current and future market trends as well. By dynamically changing and incentivizing meaningful development interactions with infrastructure, a piece of technology can be adequately explored, built out, and pay off before its obsolescence. (Morton, 1971)

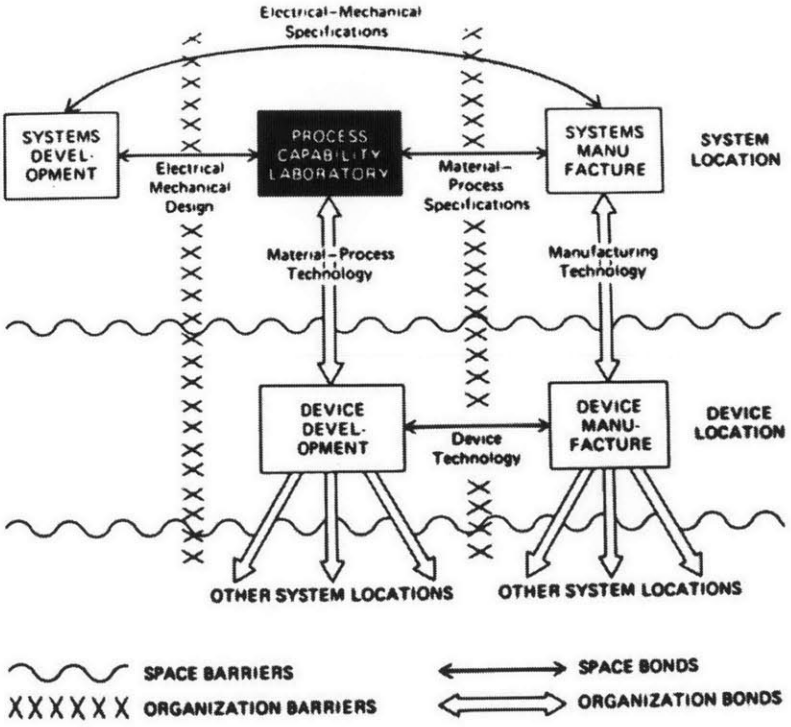
This view connects to the exploration of knowledge enablers and barriers. Five knowledge enablers include "(1) instill[ing] a knowledge vision, (2) manag[ing] conversations, (3) mobiliz[ing] knowledge activists, (4) creat[ing] the right context, and (5) globaliz[ing] local knowledge" (von Krogh et al, 2000), and these speak to the environmental factors affecting a high-care, high-interaction social infrastructure. While the benefits of knowledge enablers are understood, Morton takes a step further by recognizing the impedance of communications as a beneficial counterpoint.

Selective prevention of "*destructive* domination or influence of one specialist group over another" is seen as beneficial in producing "synergistic couplings" (Morton 62). While knowledge management scholars my list communication impediments such as "(1) the need for a legitimate language, (2) organizational stories, (3) procedures, and (4) company paradigms" (von Krogh et al, 2000) as negatives, Morton welcomes these as managerial choices to protect independent thought and understanding of person-to-person, group-to-person, or person-to-person coupling dynamics.

Coupling is Morton's view of organizational barriers in physical space or departmental separation, and it coincides with an understanding of relational construction regarding boundary objects. A representative diagrammatic construction of Morton's ideas is shown in Figure 6.

The context of incomplete or in-process boundary objects can be just as prone to failure as independently-developed syntactic or semantic understandings, albeit in different ways, and coupling can facilitate and shelter as necessary.

Figure 6: Representative Morton Diagram (from Bell Labs) (Morton, 1971, 145)



Furthermore, bonds and barrier can be thought of as the facilitating interaction of differential gearing or additive power/torque. Purposefully coupling different areas of the organization together artificially disengages the unconscious construct underlying understanding and reengages it in a more unified form—these bonds serve to direct the net impact of pacing and scale in the same direction. As Morton says, in "functions [that] are spatially intermixed, but

organizationally separate, it is easy for research and development problems, knowledge, and people to flow across the interface without fear that one function will dominate or inhibit the other" (Morton, 1971, p. 66). Here, the scale and pace issues are no longer at odds or in competition.

To combat mutually-divisive elements of in-group out-group development and isolated syntactic or semantic knowledge regimes, Morton suggests strategic coupling in order to reduce outperformance and growth of certain areas at the expense of (or at least well-exceeding that of) others; the phenomenon is expected given geographic or technical specialization, and one that Morton views as being able to impact or derail the broader pre-determined goals and the well-being of the organization. Empirical studies suggest that these communication patterns do have a direct and measurable response to bonds (in the form of coupling) and barriers (Allen, 2014).

7. CASE: Xerox PARC and Explosion of Novelty and Innovation

Xerox's Palo Alto Research Center (PARC) began as a desire to restart research at Xerox coinciding with changing CEOs, with outgoing Joe Wilson and incoming Peter McColough both agreeing on the need for new sources of growth. PARC experienced a particularly prolific period of transformative computing innovation in the 1970s, with the Computer Sciences Laboratory (CSL) at the center of much of the action. Collaborating with other groups along the way, CSL brought to reality much of the integrated computer interface concept of today (even if today's reality does not quite match the vision of PARC): mouse input, the computer desktop, laser printing, and Ethernet.

The environmental context surrounding Xerox PARC is one that is not easily reproducible in any fashion and four factors contributed to PARC's creative output: 1) lots of money, 2) a large pool of hirable talent, 3) an inflection point with launch of new computer

technology, and 4) a hands-off management philosophy (Hiltzik, 1999, pp. xxv–xxvi). At various points, some companies may share common traits of abundant free cash flow to fund research and development, talented people, and/or managerial willingness to give free reign, but the transformation in the technological paradigm caused by the work being done is rarely rivaled.

Many analyses have a common theme that mismanagement, or at least the failure of management to realize the potential of their breakthrough inventions, ceded any competitive or technological advantage to other firms—and by extension, commercial dominance and success. Years later, any and all judgments made in relation to what went right or wrong is informed by the benefit of knowing objective outcomes. The focus of this paper is that relational construction with respect to boundary objects can help frame an understanding of how and why organizational flows matter to innovation.

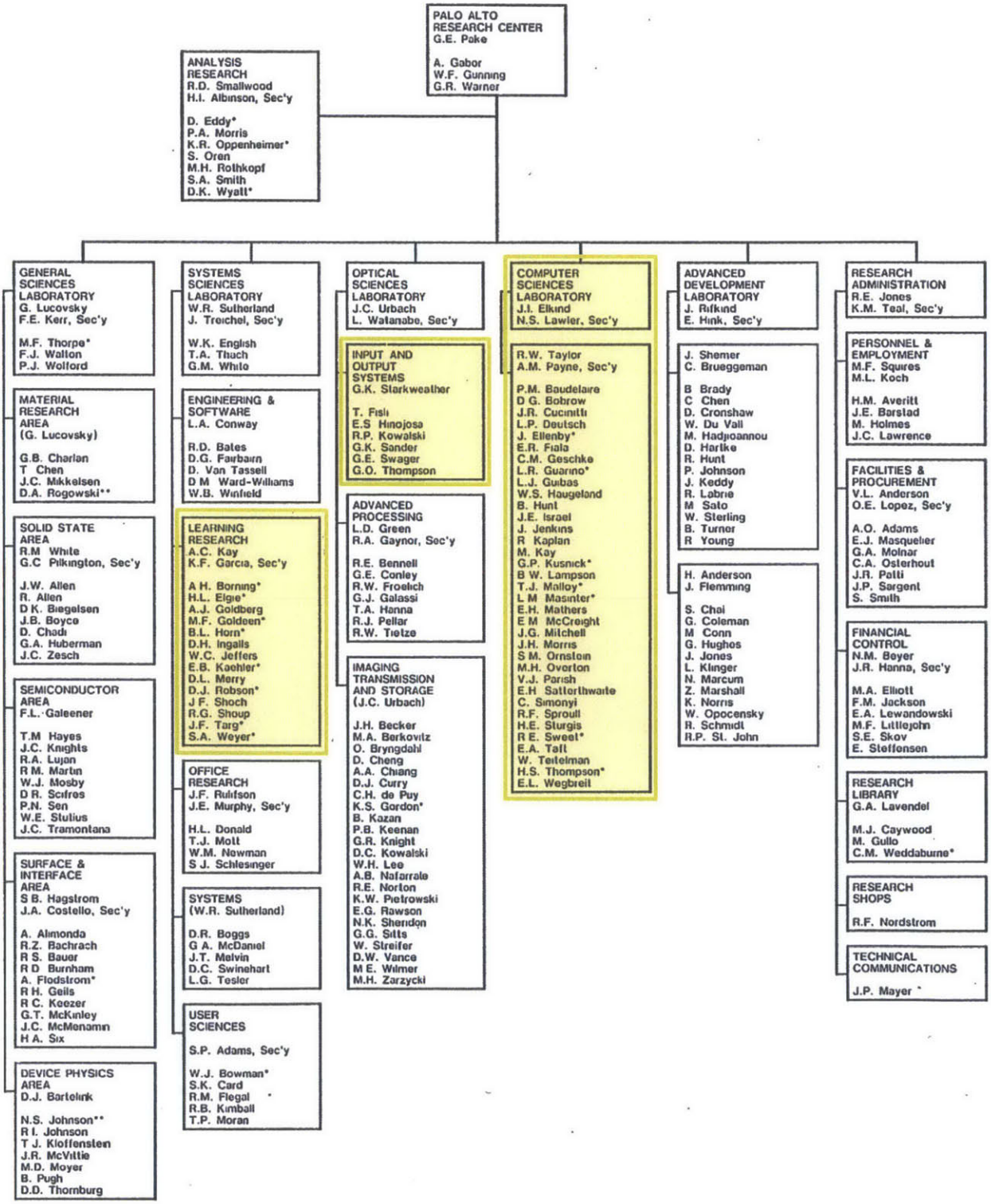
7.1 Organizational Influence

From the high level of chief scientist of Xerox, Jack Goldman directed the company to a people-focused culture of research and development: by building up a strong team and allowing them freedom to execute overall goals according to their intellectual achievement, the impetus to perform was on the engineers and scientists. Bob Taylor was brought to CSL his vision that PARC could help Xerox move beyond the copier business to a broader office information system. (Smith & Alexander, 1999, p. 63)

PARC was the embodiment of the intersection between management goals and methodology, business need, and multidisciplinary technological vision. Details of funding and resource allocation aside, any organization pursuing research and development functions experiences this confluence to varying degrees.

Figure 10 shows a delineation of functions within PARC (contents of paper in yellow).

Figure 7: Xerox PARC Organizational Chart (5/31/1976)



7.1.1 Physical Location as an Intentional Barrier

Perhaps an extreme case of geographic separation in corporate office locations (at the time, and less extreme today given global expansion or mergers and acquisitions), PARC, by design, was physically located near Stanford, separate from Xerox headquarters and the rest of the research and development team on the east coast. Peter McColough wanted PARC in a new office because it would allow a complete break from previous successes with xerography: it was a conscious choice to create an environment of isolation and independent thinking. (Hiltzik 36).

While ultimately successful for allowing PARC to concentrate on its own ideas and sources of innovative technologies, it also created an entrenchment of the lab's management modes and interface. From the sematic context, the rapid co-development of the working culture was not only highly technical in nature, but developed in relative isolation from external socialization, creating an intellectual ecosystem unable to be fully comprehended or appreciated by outsiders.

7.1.2 The Working Culture and Infrastructure at PARC

Indeed, the intellectual ecosystem was considerably different from almost anything the broader organization had ever seen. Taylor introduced a system of intense questioning by peers he called "Dealer" in effort to make sure the research had been well thought out (Hiltzik, 1999, p. 146). With a focus on scientific truth and objective judgment, this mandatory weekly meeting bred and reinforced strong group ties and an informally-direct team dynamic.

Additionally, Taylor not only shaped *how* people interacted, but also *who* would be interacting as well. In recruiting, he had potential new additions interview with every single person in the lab, and only with approval bordering on unanimous would a candidate be hired

(Hiltzik, 1999, p. 120). Certainly, the new hires would be technically proficient, but the subtler implication of this is that only those who got along well and could fit into the environment would be hired. While this fostered smoother informal conversations and technical interactions, it also served to reinforce and further entrench the existing culture of direct, objective achievement.

To outsiders, though, the cultivation of highly effective technical proficiency and keen analysis of key developments and research projects created a culture that was neither familiar nor entirely comfortable. Perhaps not by intention, but the survival and proliferation of engineers and ideas within this environment may have led to a degree of intellectual reinforcement and a sense of superiority. For the visiting Lynn Conway—an accomplished female engineer who had previously worked on an IBM supercomputer—the overall resulting culture resembled that of a cult (Hiltzik, 1999, p. 149).

The issue at stake here is how these cultural incompatibilities and the relative isolation contributed to the development of boundary objects and affected knowledge transfer.

7.2 Relational Construction: Boundary Objects in Action

Even without the influence of boundary objects, it would stand to reason that the hiring of highly-intelligent dreamers could result in some representations of knowledge being categorized as residual object by Xerox and its organizational norms. As an illustrative example, resident big picture expert Alan Kay was called into Jerry Elkind's office to discuss how Kay' pet project to build a computer usable by children would fit into the budget and the mandate to build the office of the future. Unable to discuss in concrete terms and metrics at the time, Kay was advised by others that he had "to develop written research plans, compile budgets, and keep notes—in short, to look and act like a serious researcher" (Hiltzik 166-167).

With this new understanding, Kay spent months putting together a plan and budget of *smaller* components of the computer for children—a text and graphics generating system—which successfully yielded funds for future study. Even as Kay was working on something useful for existing computing products, he was concurrently working on something that would be part of his grand vision as well. The framing of goals was very important and shows how seemingly conflicting corporate and personal initiatives may actually overlap.

With identification and explicit specification of those commonalities, the value of novelty can be made concrete and communicated reproducibly in another realm of corporate operations. A truly residual object finds little support without some degree of transformation, and the relational construction will not be the first to change, as process innovation is slower-paced. As such, boundary objects can and must change over time to be relevant and to fit existing infrastructure.

In 1971, within a year of its official start, two boundary objects helped define how PARC would fit into the rest of PARC: the MAXC and the Pendery Papers.

7.2.1 Prototyping as Strengthening Internal Communication

Pushed to make their own clone of the Digital Equipment Corporation's PDP-10 from scratch, the lab put the Multiple Access Xerox Computer (MAXC) together in about a year and less than $1 million. Whatever the primary motivation for building, the process of collectively working together on a boundary object made explicit the tacit knowledge that each held.

This process of prototyping can be seen as not just producing a boundary object, but an environment of collaboration and cross-pollination as well. In effect, the real-time juxtaposition of work and knowledge iteratively makes aspects of tacit knowledge into explicit knowledge,

and allows for sharing of perspectives and skills. The rapidity and ease with which challenges could be resolved bolstered the interactive process at the time and later as well (Hiltzik 108).

With a group that coalesces around the construction of a boundary object, the completion of that object incorporates within it a representation of collaborative effort and accomplishment. The build infrastructure in the lab could then incorporate a familiarity with others' relative strengths and weaknesses that not only generated mutual respect, but also could streamline prototyping or final production down the line.

7.2.1.1 External Alienation and Solidifying Perceptions

It is important to note how internal and external perceptions of a boundary object—the relational construction—can be simultaneously diametrically opposed. Within PARC, the boundary object of the MAXC represented what they had learned working together, how they were able to hit highly technical and complicated targets, and how the path could be open to them from there. The rest of the corporation—especially SDS (the makers of the spurned Sigma, Xerox's own PDP-10 competitor)—could see the MAXC as a representation of PARC's inability to work well with other groups within the corporation.

The long-term categorization of PARC achievements—or even PARC itself—as an "other" meant a perception of a separate entity, not integrated into and not truly a part of Xerox. With this understanding the out-group perception of PARC, any misstep would only serve to bolster that outsider view of PARC, not to mention the barrier of distance in assuaging any existing or potential concerns.

At which point there is a management inflection point in deciding whether or not to take action, the relation between that team and broader organization may be forcibly changed, which also changes team dynamics in turn. Goldman could have relocated a few or all PARC teams

back to the east coast, which would have brought two conflicting cultures in direct alignment, with the victor as the side with management support.

7.2.2 The Pendery Papers: Blueprints for the Future

Like the MAXC before it, the Pendery Papers were a byproduct of PARC response to organizational conditions: understanding the work being done at PARC and how it could possibly benefit Xerox for the purposes of budget justification. Initially so-called to make fun of the broader corporation and its demands from Don Pendery, whom referred Alan Kay referred to as the "head planner" (1993), the Pendery Papers nonetheless solidified the grand vision and goals of PARC. Once introduced as a physical boundary object, this catalog effectively translated the big-picture dreams PARC was known for into a concrete object that could be interacted with and understood on many fronts. It could be transported from west coast to east coast, and simultaneously reviewed by many.

In effect, despite the different mental frameworks and intent, the Pendery Papers changed tacit or implicit knowledge into explicit knowledge that could be shared with the broader organization. Even so, within the organization of PARC, the clarity of collective purpose and lofty goals worked to push the technological development forward.

7.3 Adoption and Knowledge Transfer

Even as the CSL group was becoming more isolated in its approach to external interactions—after all, the MAXC helped to bring people closer together—its culture of shoot-from-the-hip scientific inquiry and evaluation did not preclude internal projects from being alienated. In PARC's case, informal research and build teams sprouted up around new ideas as promising as potential improvements in machine microcode, or as curiosity-driven as an attempt

to produce a pair of speakers to Bose's at a fraction of the price. In either case, the basic process was the same: rounding up people who could then tackle the problem head on.

For the projects that showed promise, it would be worked on until completion, but if it failed to yield results, people gave up and worked on something else. This method of self-selection could leave promising technologies behind, because it is precisely at the moment of novelty solidification that a project could be abandoned. Moreover, novelty value confirmation at this stage could be strongly influenced by available knowledge and groupthink.

7.3.1 The Birth of Laser Printing: Embedded Opposition

The ubiquitous laser printing of today almost fell victim to such evaluation influences. In 1960, the laser was invented and soon after, Gary Starkweather began studying it at the University of Rochester, desiring to continue at Xerox on the east coast, given the brightness limitations of conventional lighting in xerographic processes. However, his colleagues would criticize the reliability, safety, cost, and other technical limitations of lasers—as Starkweather described it, "(i)n 1968 [those were] probably ... valid question(s). But [they weren't] valid question(s) if you looked at where the technology might go" (Hiltzik, 1999, p. 130).

In this situation, it appears that the other researchers in the laboratory were strongly influenced by their own perceptions of how they understood technology. At the most basic level, if some product or product promise does not fit into a broader range of technological framework, it is in the best interest of the researcher or the company to bring those issues forward—less waste and more time spent on productive projects. At the same time, however, it appears that the other researchers in the lab were not only objectively opposed to the use of lasers in xerography, but also subjectively pre-disposed to react with other social cues such as sneers. Going beyond

novelty-confirmation, such social rejection is based on norms of operation and the technical organizational memory.

Either by design or reality, barriers can close off promising research, or as in this case, doing so would have sheltered Starkweather from some of these active negative influences. Starkweather's only recourse was to look to PARC and ask George White, a research executive on Xerox head scientist Jack Goldman's staff, to help save his project (Hiltzik, 1999, p. 60, 131).

White was in a position higher up in management and could recognize the promise of Starkweather's research since White himself had studied lasers at one time. Starkweather had to break out of the immediate infrastructure of his team and lab in order to find receptivity to his ideas. Even though PARC would have been a better fit, the Rochester lab did not want to let Starkweather go, and it took Goldman himself to approve the transfer.

7.3.2 Prototypes as Effective Boundary Objects

It appears, therefore, not every boundary object in whatever complete or intermediate forms over time will effectively communicate ideas to everybody. Certain people are able to recognize the value of certain contributions earlier—particularly with respect to their own past or current work experience. The combination of work may result in a changed boundary object with farther-reaching potential, a wider-scope of comprehensibility, or increased compatibility with current infrastructure. Changing solutions is not the only option—the very problem or need being addressed can change, and in so doing, this new framework opens up new possibilities of value creation (Frischmuth & Allen, 1969). What can occur is a cycle of isolation, reorientation, and assimilation or exclusion within the group as results and boundary objects are more or less comprehensible.

Starkweather was still missing the software behind making images on paper, but once at PARC, he was able to combine his boundary object with that of Butler Lampson and another researcher named Ron Rider (Hiltzik, 1999, p. 138). Lampson and Rider had essentially created—for no immediate need or application—the ability to transfer digital images to the printer, and the three were able to create a laser printer together: these boundary objects were novel pieces of tacit information, curiosity, and vision, and only by introducing them in tangible forms could their value be recognized. One or the other by itself was a curiosity, but the combination of two innovations resulted in a boundary object whose value could more easily be assessed.

The concept is not to generate as many open-ended boundary objects as possible and then hope to combine them serendipitously. Different parties can share a similar vision, undertake serious development on viable solutions, and still fail without a supportive infrastructure. The prototypes spurred on effective exchange *in relation* to an object—that is, the object itself drew out and attracted other related tacit knowledge. That type of infrastructure creation—of object and action—is enabled by novelty solidification, novelty confirmation, and collaboration.

7.3.3 Physical and Technical Bonds and Barriers at PARC

Even while PARC offered Starkweather the lifeline he was looking for, PARC itself did not represent an escape to a utopia free from such infrastructural pressures and marginalization of unconventional ideas: indeed, visual application-focused Dick Shoup was facing opposition from Bob Taylor and Butler Lampson regarding his work on Superpaint, a color, digital painting, and computer graphics application. They did not see the point of color within the context of the office of the future, and essentially drove Shoup out of the group (though later Shoup and his work went on to influence the development of LucasFilm's use of computer effects and the

creation of Pixar). (Hiltzik, 1999, pp. 238–241) Interestingly, the issues facing Starkweather and the laser were similar: with a few more years, the cost of implementation would be greatly reduced, even if it was not "right" as an immediate product.

No organization is safe from individual or social biases, organizational memory, or prioritization based on apparent immediate need. When possible, bonds and barriers can be erected to encourage the incubation of great and promising ideas. That said, even after incubation, a promising idea and effective boundary object is still subject to the same valuation judgments—James O'Neill (a former Ford finance in charge of engineering and manufacturing at Xerox) almost cancelled the laser printer after seeing a complete form because he saw "no immediate prospect of high-volume production or marketing backup" (Hiltzik, 1999, p. 142). It was Goldman who saved the laser printer and put it into production. Conscious sheltering of ideas has to occur at all levels of the organization, and at any point in development or production.

7.3.4 Connecting the Mobile Office Object to all of Xerox

At the grand unveiling through Futures Day at the Xerox World Conference in 1977, the office of the future as PARC imagined it was put on display. Everything from moving the mice and the on-screen graphics, to color printing, was present and well-received by the wives of the executives, many of whom were secretaries (Smith & Alexander, 1999, p. 209). While their wives were very excited, Xerox personnel were more indifferent to the technology and to PARC—even surprised that things worked. Informed as it was by both its preconceptions of PARC and ill-informed as it was regarding the revolutionary and useful nature of the office PARC created, Xerox ultimately let Futures Day pass without further action.

Futures Day was a boundary object at the organizational scale, but there was a failure of connection between innovative new technologies and their intended market, even as their

intended market voiced their admiration for the technology and its implications. It was up to the business and finance people to recognize market need, but as seen from O'Neill's desired cancellation of the laser printer, this data gathering process can be flawed and misguided by subjective forecasts. That interaction of social preconceptions, technical understanding (or lack thereof), and managerial priorities laying elsewhere resulted in an environment of low adoption, despite Futures Day's intended purpose.

7.4 Implications of PARC

Chesbrough (2006) describes the performance of PARC in relation to one of its spin-offs, SynOptics, a company focused on making a faster Ethernet. He describes the success of SynOptics as not having just been a direct application of technologies invented within PARC, but the recombination of many parts thereof—similar to how the laser printer combined innovations. SynOptics success could have just as well been completed captured in-house, but the valuation of boundary objects—particularly based on relational constructions based on past and present conditions instead of on future possibilities—can result in value being lost to the originating parent.

It is not simply enough to shelter or execute on a boundary object; a company must analyze its success and failure—and the success and failure of the relational construction—in order to recognize the promising new process pathways for novelty incorporation.

While PARC may be viewed as some having experienced a string of failures in realizing the potential of its technology, the preponderance of missteps can also be interpreted as a systemic disconnect between intended goals and recognition of goal completion. If the mandate of PARC was to create the office of the future, they certainly did it. At the point of completion, though, novelty recognition or knowledge translation steps were not effective in connecting the

technology back to the commercialization aspects of business and finance—the social interactions were unable to generate wholesale adoption of game-changing PARC technology by Xerox.

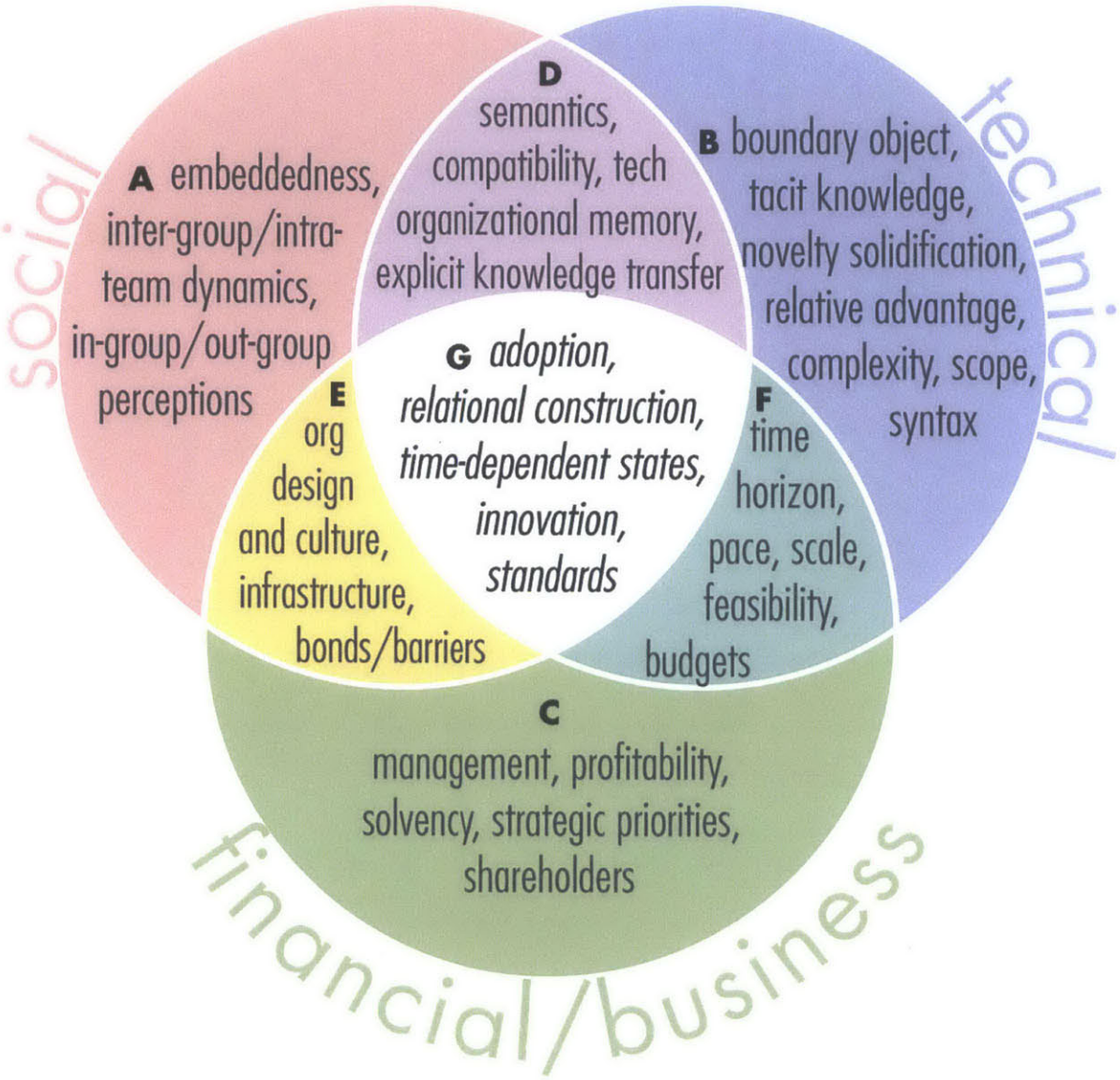
8. Discussion: Categorization of Failures

Broadly speaking, the situations surrounding boundary object conflicts are incredibly varied, so infrastructure and relational construction are hard to generalize. That said, given the importance of long-term growth and competitive advantage, it is possible and useful to consider sources of boundary friction, so as to identify infrastructure-dependent solutions for nurturing innovative ideas. The goal should be to consider possible sources of organizational conflict and to design or structure interactions in such ways as to avoid or confront those.

8.1 Dimensions of Boundary Object Failures

Figure 11 shows the intersection of three aspects of research and development: social, technical, and financial/business factors. The points of intersection represent boundaries to be overcome in order for ideas to be successfully communicated and adopted (they can also be considered conflict dimensions or interfaces), with particular emphasis on the integrated middle area, or the relational construction of understanding. This framework attempts to address the issues introduced by Jalonen and Lehtonen (2011) that factors of innovation uncertainty are interlinked and change over time.

Figure 8: Social-Technical-Financial/Business Interface Framework



8.1.A: Social Issues

This section of interactions is strongly influenced by human behavior and psychology. All the conscious and subconscious preconceptions form the framework by which people judge the world and others. In this sense, their knowledge and personal experiences are strongly embedded within their thought processes. Similarly, on a larger scale, distinct groups can coalesce with their own norms or collective past,

which creates embeddedness of knowledge, goals, or behavior as well. The reinforcement of this, particularly in relation to the reinforcement of group dynamics—such as separation from others—results in in-group out-group biases. That is, without regular interactions with other groups or members of other groups, "other-ness" in categorization may result, which constitutes a mental or behavioral barrier. Social interactions are not unchangeable, but they do tend to have persistence and inertial properties absent external intervention or influence to the contrary.

8.1.B: Technical Issues

The section is the most objective portion of the interaction, and at the same time, hardest to represent as such. Not only does this section include boundary objects being created, but also all the tacit knowledge and inspiration underlying the technology. The concept of novelty and the novel idea resides here, such that novelty solidification results in an artifact or other boundary object capable of interacting with the social or financial/business sections.

The nature of the innovation is also here—at least the extent to which it (or its future iteration) is an improvement over current technologies or methods—and therefore provides the background data allowing for novelty confirmation. At each stage of solidification, the novel idea and its representation can become more complex, more expansive in scope, or more specific or generalized in associated syntax. The transition away from this section is the subjective choice of the originating scientist or engineer to decide or try to influence when others see and how they interact with the boundary object.

8.1.C: Financial and Business Issues

As much as financial values are objective, their interpretation with respect to strategic and the associated valuation of relative importance is not. Organizational considerations of staffing and other personnel considerations are not considered, because those involve more of a person-company interface. In this section, "the company" is the impersonal actor whose main considerations are continued profitability, solvency, and business viability.

It is, in fact, more accurate to say that this section is more of an outward-facing interface involving the company and public or consumer demands. An understanding of shareholder concerns and market trends informs the decisions made regarding budget, existing processes, cost structures, execution, response time, and expected profit—all of which create a valuation metric and framework for evaluating feasibility of initiatives or the success of personnel.

8.1.D: Transfer and Sharing of Technical Knowledge

The "subjective" interpretation of boundary objects lies in how others perceive the technology, and therefore is a test of how successful that representation is—this is the stage of explicit knowledge transfer, or of such transfer being the goal. Given the individual variations of knowledge, not every boundary object will be equally well received, comprehensible, or determined valuable by every person at exactly the same time. Implicit or explicit standards make for an uncertain process, though mutual trust and respect may increase patience in trying to understand the boundary object or may improve the quality and quantity of feedback.

Ultimately, though, a fundamental source of breakdown lies in transparency. At the very least, the semantic interpretation of what has been completed may yield incompatible interpretations of the concept, or tacit misunderstanding. It may be difficult, impractical, or

counter-productive to convey the full thought processes regarding the development of a particular boundary object representation of new technology—and so the omission of certain such important facts may influence the reception of the novel idea.

It is also, therefore, at this stage that bonds and barriers can reinforce, shelter, or hinder the progression of novelty solidification. Because organizational memory—technical and otherwise—resides at both the group and overall company level, subjective or premature judgment of value is highly possible, with either positive or negative consequences for adoption. Organizational structure can increase the quality of interactions with a boundary object (e.g. physical manipulation and testing of a prototype, brainstorming about applications and implementation methods) with an open and shared office space; can remove novelty solidification from environments of widespread doubt or political jockeying; and relocate to areas with more appropriate resources to the investigative or development task.

8.1.E: Organizational Infrastructure

The consideration of what the organizational goals and purpose are can strongly influence the layout of physical and practical interactions. The open, concentrated layout of a trading floor allows for numerous simultaneous and rapid face-to-face interactions, as a function of the need to connect suppliers and buyers of financial instruments. Conversely, a corner office for upper level management typically discourages interaction both from a physical location and divider standpoint—indicative of a need to stay out of the normal flow of business in order to better conduct administrative or larger-value tasks. Even vertical separation by one or more floors can significantly influence communication patterns, with decreased interactions in aggregate (Allen, 2014). The physical corporate infrastructure is one key part of realizing innovative goals.

As the conscious communicative divide starts with organizational design and the shaping of corporate culture, as discussed in Chapter 2, those decisions trickle down across all levels of employees and codify an infrastructure, or normal course of action and interaction. Bonds and barriers serve to temper or accelerate the social forces surrounding interaction with new technology. For example, with a barrier in place, the *degree* to which social influences can impact the technical interpretations of a boundary object are lessened, both in the sense that solidifying novelty may be done so for protective isolation, and in the sense that barriers reduce the efficiency and effectiveness of explicit knowledge sharing.

This organizational infrastructure by itself is not a powerful force of change, as it only represents the normal rhythm and momentum of current business culture. It is strongly influenced by the past and present, with less focus on the future unless a change in leadership or policy changes the context of existing business operations.

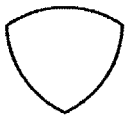
8.1.F: Functional Evaluation of the Value of Novel Ideas

Corporate infrastructure necessarily incorporates some component of the valuation of research pursuits, but it is in the finance/business-technical interface that the two objective units of money and boundary objects meet in subjective fashion. Here, the resource considerations flow beyond what is right for the organization, to what is right for the organization in the context of its current and intended place in the market. The time horizon, therefore, is both internally-important and externally-derived.

The pace of the business, as mentioned in Chapter 3, is not simply how quickly business operations cycles complete, but rather the investigation of how the forward progress of the company can meet market demands, and the resulting integration of expected profits over time. As a result, scale and feasibility of potentially profitable innovations are investigated along these

dimensions, as it is the cost and risk by which this temporal valuation is discounted. The budget or resources allocated reflect this relative valuation—relative to the market, and relative to how other internal projects are expected to perform relative to the market.

8.1.G: The Relational Construction of Knowledge Transfer



The intersection of social, technical, and financial/business forces and motivations in aggregate is at the heart of all innovation and its multicollinearity is more true to real-life interactions. What this relational construction describes, therefore, is actually the probability of adoption. Adoption in terms of commercialization of key technologies is the grand goal, but adoption can also mean an investment on the part of the organization to pay attention to the work being done, and to commit to concurrent and cooperative growth. Certain research and development projects may get more funding, which allows the corporation to pursue new future avenues for future growth.

Because of the interaction of organizational infrastructure as being one of momentum, there is a strong time-dependency relating to the understanding of boundary objects at play, such that the corporate memory and collective level of knowledge increases with each additional advance (competitive advantage necessitates changes in order to keep or improve a relative position). As the propensity to pay attention to novel technologies in whichever stage of completion increases or decreases, the forms of boundary objects considered comprehensible change over time, as do the language and frameworks used to describe them.

8.2 Framework Interactions over Time

The changes in boundary objects and the relational construction surrounding play out not independently, but in relation to each boundary of interaction and vary over time. Joy Mountford, one of the developers of Apple's QuickTime, recalls the transformation of the interaction over

time, introducing more controls, more features, and ultimately more complexity (though it could be argued that much of it was intended to streamline the user experience): "the sophistication of your products have to actually match the sophistication level at that time of the consumer base" (Moggridge, 2007). The same is true of boundary objects in development and in thinking about how the infrastructures and interfaces change.

Figure 9 shows a simplified form of the framework, encompassing the central essence of each section and interface. Knowledge transfer is the desired result of the relational construction, and it is the goal. These interfaces all signify the tensions at the boundaries, and how they relate to the different sections of motive influences. Transparency is an important component of knowledge transfer, as it is the moderating influence, the amount of facilitation or lubrication in terms of the pace and scale of interacting gears.

These interactions all have different interpretations and implications for the enterprise. The first interaction interface of knowledge sharing is represented by the intersection of technical and social sections, such that each interaction deepens the conversation with an imbued memory: that is, boundary objects change

Figure 10: Simplified Interface Framework

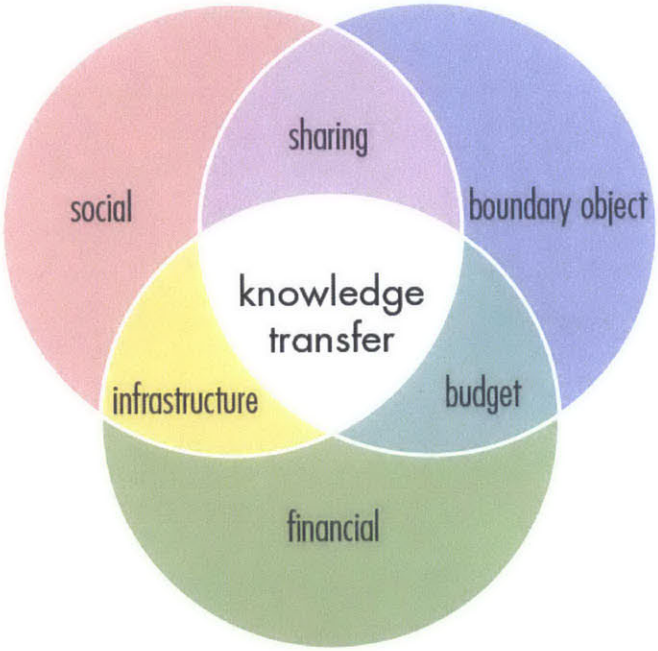
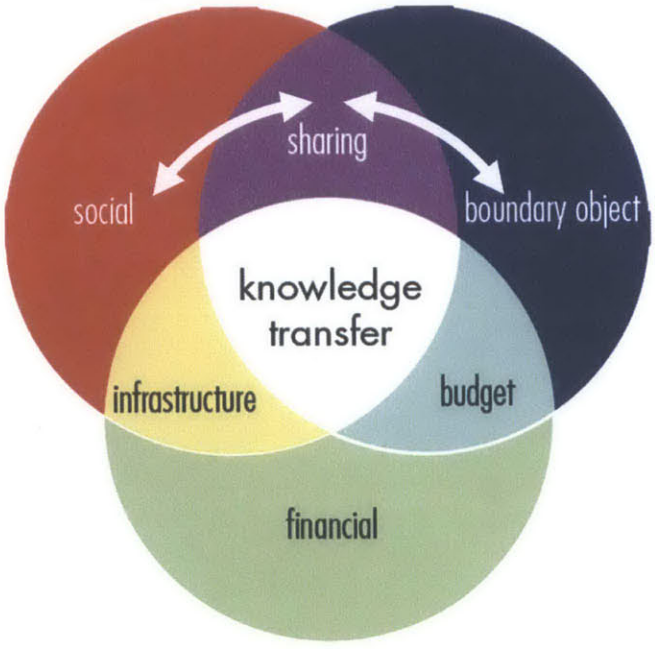


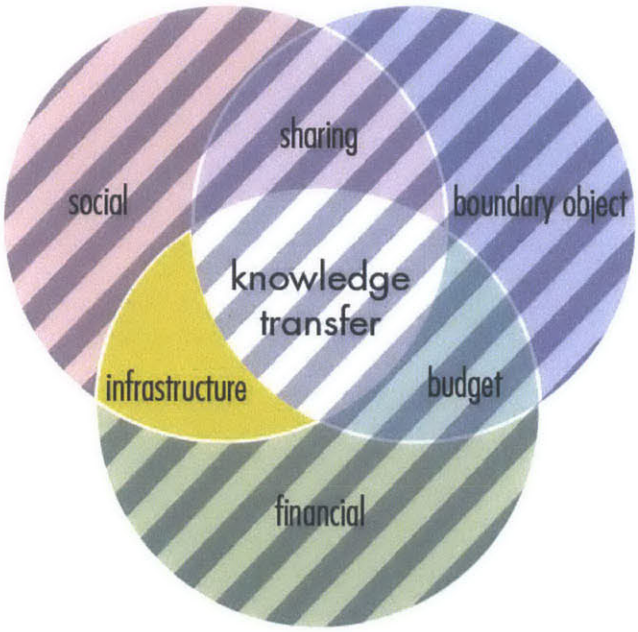
Figure 9: Social-Technical Interface



(for better or for worse) in accordance to social interactions, and the knowledge and interaction dynamics embedded within social realms change as well.

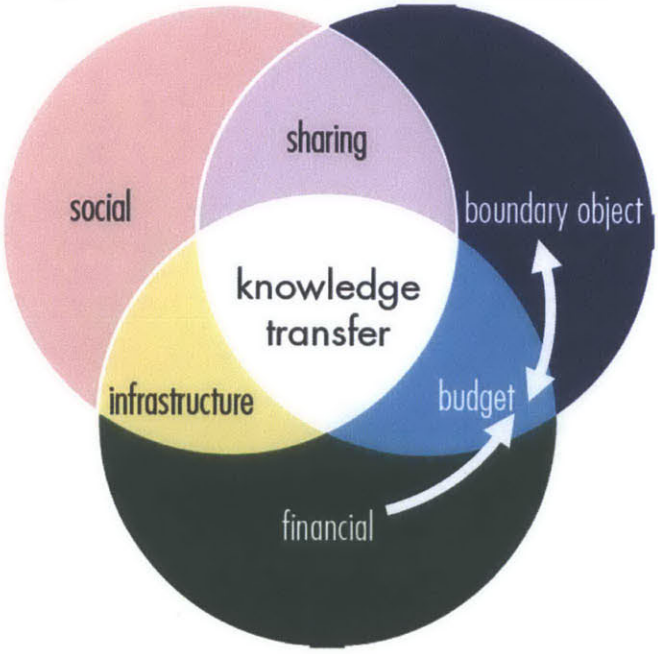
With the intersection of social and financial areas, the infrastructure is derived. Here, everything about organizational structure, office locations and layouts, and established corporate cultures is represented. And as each of these permeates the actions of all included within the organization, infrastructure can be thought of as affecting all other sections and interfaces, even though it in itself is a byproduct of two sections. This relationship implies, more than anything else, that exogenous or unexpected actions within this space have secondary impacts throughout the organization. Bonds or barriers erected in this area influence the efficacy of sharing, for example.

Figure 11: Social-Financial/Business Interface (Infrastructure)



The final two-area intersection represent the budget interactions, such that the corporation allocates money, and it is up to the particular boundary object project to negotiate its own value and associated funding. The dynamics of this vary from company to company, but the basic idea is that funding comes from outside of the research team and not

Figure 12: Financial/Business-Technical Interface



from the researchers themselves. Even if a product is immediately profitable, given that it is a product within a broader organization, it is not automatically entitled to all of its own profits.

In the center interface area, all the sections interact in more or less bi-directional pathways over time, with the exception of money flowing one way. Again, transparency facilitates all interactions, but the pacing is modularly dependent, as incremental sequential changes in state occur; a global transformative shock would essentially recreate an entire organization at once, so it is less likely within normal operating contexts.

Figure 13: Larger Relational Flows

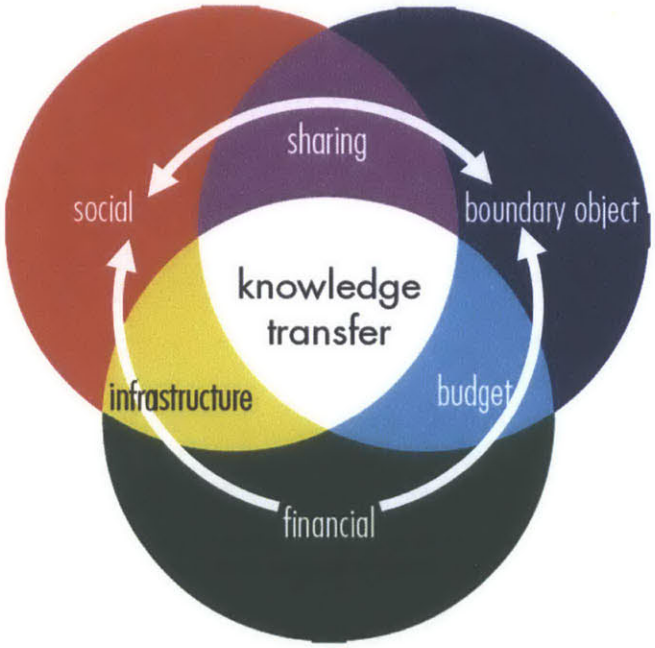
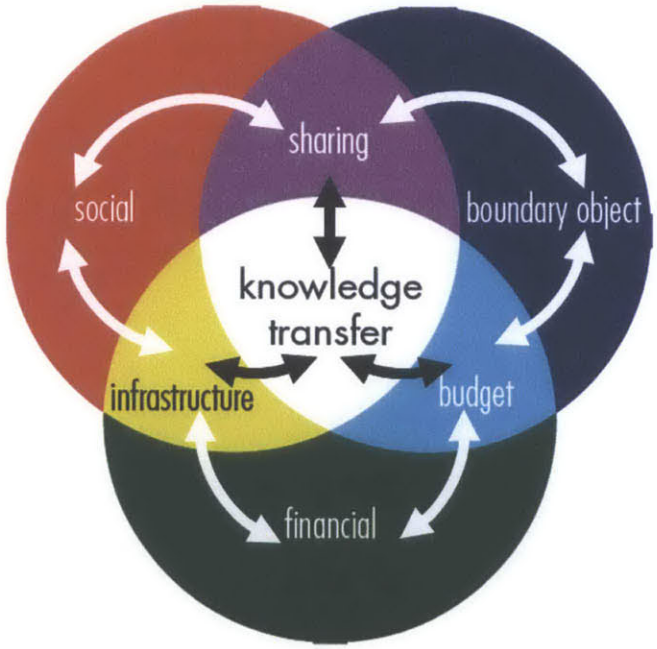


Figure 14: Smaller Relational Flows

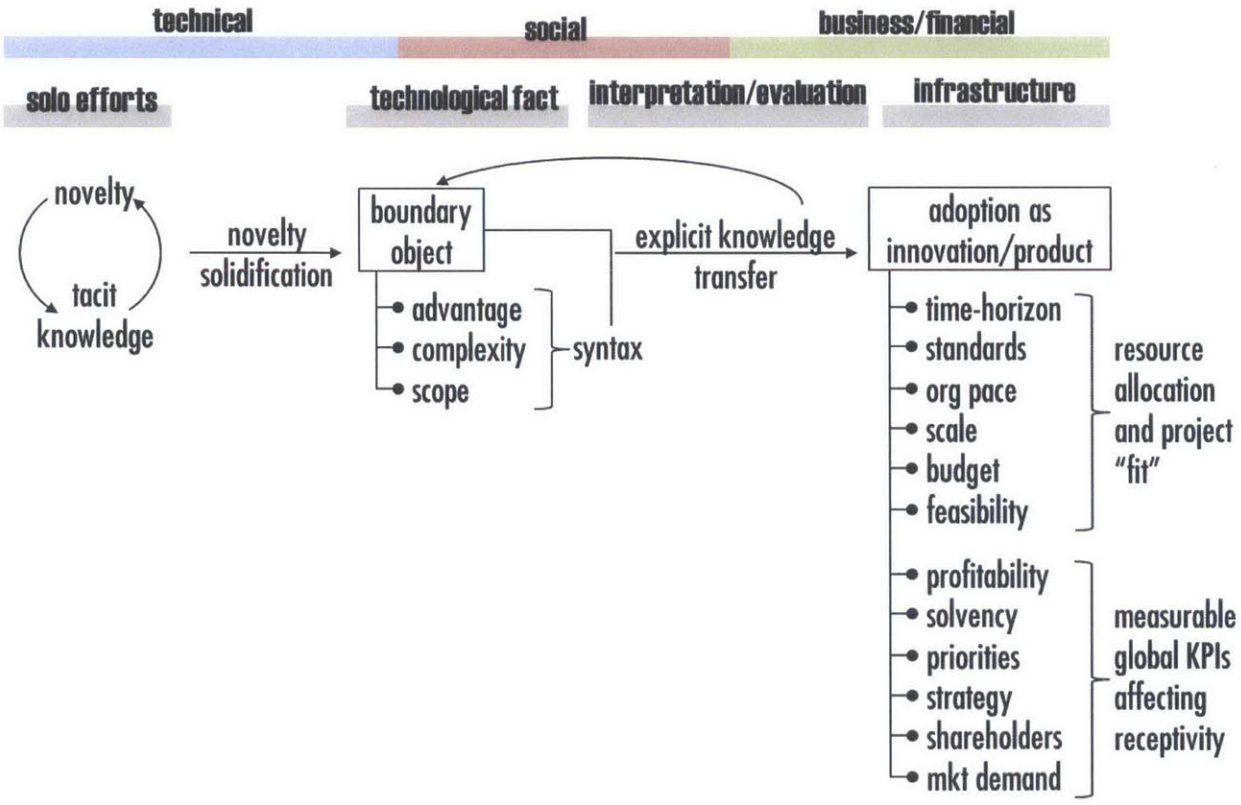


Behind the idea of interaction is the concept of losing control over larger flows—in fact, it would more be accurate to describe the long-term flows in smaller segments. The influence that any section has on another is of a dispersive nature, and it is only with realization of this that boundary object acceptance can be either understood or implemented better. For example, because of the fact that the boundary object may change over time, the questions are how, when, and into what form to change. Influencing something already in development a dynamic

communications issue, as effective knowledge sharing requires a move from higher-level to more detail-oriented details over time (Von Krogh et al., 2000, p. 23). Simultaneously, the movement between fine and generalized knowledge either over-informs to the detriment of interest, or under-informs to the detriment of engagement. There needs to be a dynamic shift between thinking, understanding, adapting, and doing.

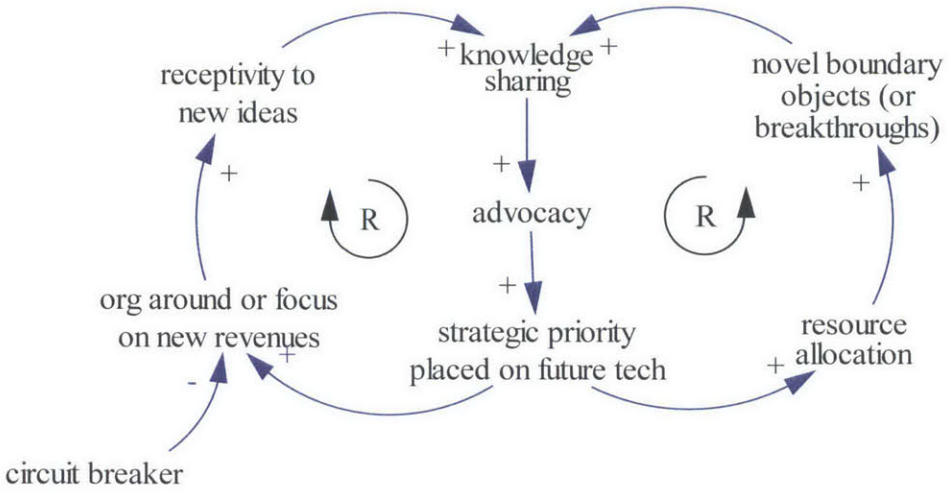
Because of the dynamic changes required in context, a linear corporate workflow as shown in Figure 18 limits the interpretation:

Figure 15: Relational Construction as Linear Corporate Workflows



Tracking organizational movements over time begins to take on a system interpretation of these interactions, such that the process of novelty solidification allows for manipulation and collaborative transformation:

Figure 16: Relational Construction as a System



In this particular case, an organization can be thought of as strongly reinforcing a positive or negative outlook on and environment for such transformations. However, given the strong linchpin of infrastructure in this model, a circuit breaker of new policies, organization, or physical space (the erection of bonds and barriers, for example) can reverse the system momentum and pace. Put more broadly, there must be "discipline to resist the natural tendency to focus on specific projects and instead target interventions at maintaining the integrity of the development process" (Repenning, 2001, p. 298).

9. Conclusions

The story of PARC is not just a historical case—it is representative of the same boundary challenges facing any technical organization, even an archetype, as it just so happens that almost everything they were working on was new and revolutionary. The rate at which they confronted true novelty and had to interact with multiple interfaces was staggering. At the same time, one could just as easily go into any lab today and begin defining the boundaries and interactions thereof. To the extent that knowledge sharing, team building, and intercompany coordination

methodologies may be employed, it is still the fundamental actualization of novelty that persists: there will always be people, there will always be money, and there will always be new technological frontiers to be explored.

This is particularly true with the rapid advances in what is possible (the implications of Moore's law are perhaps even more radical and important today than they were at the time of the Pendery Papers), and broader technical goals of what was once considered science fiction are now foreseeably feasible. Many of the tools, components, or paradigms extant today can form a connective path of getting there, though that path is fraught with potential abandonment of promising technologies. The identification and value judgment constituting the cross from novelty to innovation to *useful and valuable* innovation is quite context-dependent and subjective in itself. And that is precisely the point.

This paper serves to point out the underlying issues facing potential boundary object failures in order to ensure as much successful communication and nurturing of developing novelty as possible. It is always easier to retroactively evaluate the decisions of management and strategies of companies by looking at market success. It is easy to second-guess the decisions of Xerox management in commercializing the office of the future (or really, the office of today) with the benefit of the end state, but there were changing relational constructions and boundary objects over time in order to arrive at the conception of what PARC was.

Again, this paper only serves to look at the successful conversion of novelty into higher levels of realized innovation when infrastructural understanding of a novel idea is limited—the motivations and decisions being made can fit into the broader context of interfaces among and between social, technical, and financial/business sections. The uniqueness of PARC in defining an entire field even as they were chased by competitors is not truly a case of unique competitive

advantage; today's emerging online, mobile, and wearable contexts show an ecosystem that refuses to simply grow within the confines of an existing footprint, and that expands to encompass previously impossible opportunities. As one pioneer goes forward, competitors are following faster than ever and at lower cost (perhaps with lower performance as well) given less research and development expenditures necessary. Therefore, the understanding of interfaces is important for effective recognition and nurturing of the next big thing.

9.1 Implications for Real-World Applications

Even without an internal corporate relational construction, boundary objects exist in relation to other boundary objects, such that better graphics and creative gaming controls (PS3, Xbox 360, iOS, Nokia) is insufficient, as user base, content, and social interaction are almost more important as defining features. This second-order boundary object interactivity can occur from within a company's suite of products (MacBook ←→ iPhone → iOS→ iPhoto←→ iCloud), or it can have a symbiotic interaction with market players (iPad → iOS → App Store → Candy Crush ←→ other revenue-generating games) and from without given concurrent evolution with key strategic partners or with third-party peripherals, accessories, and lines of business.

Product designers can think about the connection between novelty and the use case, and how the user base or monetization justifies the managerial economics of strategic expansion into that space. It should be noted, though, that by replacing the "technological" with the "creative" to describe design studios or similar results in the framework losing its power. Because relational construction depends heavily on an understanding of the valuation of novelty and the market demand as part of the business/finance-creative interface, internal and consumer subjective taste will always partially reject and partially accept novel ideas. As personal taste eliminates a clear

direction, the power to influence lessens and therefore, the model begins to lose meaningful interpretation, and a more pronounced propensity toward high-level decision-making may result.

The more relevant product-centric takeaway is that by framing these types of issues clearly and as soon into the process as possible, quirky new products that previously could not have been feasible can now be right-sized, survive, and capture value in today's changing technology and content environment. Thinking more broadly about innovative capacity also leads to a question of not just when to introduce new products, but when to pull old ones as well (de Figueiredo & Kyle, 2006). Novelty valuation is necessarily linked to organizational forces, and the explicit recognition thereof allows the organization itself to become a meta-boundary object improvable by all parties involved.

Happily, the stock of open-mindedness is not finite, and can be increased or its use facilitated by management choices. Public understanding of corporate motivations also changes the financial and business strategy choices, such that the financial/business-technical interface can become more intricate over time, as the global level of sophistication increases. As semantic explanation becomes easier with long-term internal relationships, the company needs to balance the comfort of established communication with the influx of new talent and new ideas. In other words, the boundary of novelty will always be changing in unexpected ways, and for better or for worse, these framework issues are reliable and ongoing sources of potential conflict.

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