ROTATING LEADERSHIP AND COLLABORATIVE INNOVATION: RECOMBINATION PROCESSES IN SYMBIOTIC RELATIONSHIPS

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Rotating Leadership and Collaborative Innovation: Recombination Processes in Symbiotic Relationships

ABSTRACT

Relationships between organizations are at the heart of how industries are organized, and are central to industry innovation. Using a multiple case, inductive study of eight technology collaborations between ten organizations in the computing and communications industries, this paper examines why some interorganizational relationships engender innovations while others do not. Comparisons of more and less innovative collaborations show that collaborative innovation involves not only possessing the appropriate structural antecedents (e.g., R&D capabilities, social embeddedness) suggested by prior research, but by employing dynamic organizational processes that solve critical innovation problems related to recombination across boundaries. While domineering and consensus leadership processes are associated with less innovation, more innovative collaborations employ a rotating leadership process that involves *alternating decision control* to use complementary capabilities in both partner organizations, *zig-zagging trajectories* that engender broad technological search, and *fluctuating network cascades* to promote the mobilization of highly varied participants. A broader contribution is to describe how recombination processes like rotating leadership underlie the capacity of organizations to develop symbiotic relationships that are prominent in dynamic and interdependent environments like the computing and communications industry.

Relationships between organizations are at the heart of how industries are organized. While much research focuses on the benefits of endorsement and efficient exchange that derive from these relationships (Dyer, 1997; Stuart, Hoang, & Hybels, 1999; Uzzi, 1996) or how they are formed (Eisenhardt & Schoonhoven, 1996; Gulati, 1995b; Stuart, 1998), less research has focused on their capacity to generate innovations (Ahuja, 2000; Stuart, 2000). Product development and acquisition are critical sources of innovation (Ahuja & Katila, 2001; Brown & Eisenhardt, 1997). Yet in interdependent and unpredictable environments it is unlikely that single organizations can consistently develop or acquire the best innovations. Instead, many organizations use technology collaborations as an essential element of innovation strategy (Mowery, Oxley, & Silverman, 1998; Teece, 1986).

Technology collaborations are interorganizational relationships focused on the collaborative development of technological innovations (Ahuja, 2000; Powell, Koput, & Smith-Doerr, 1996; Stuart, 2000). Sometimes called innovation partnerships or R&D alliances, these relationships use a collaborative approach to innovation involving the development of new technologies across organizational boundaries. When successful, collaborative innovation allows partners to reap the benefits of both an open innovation approach that utilizes new external knowledge (Chesbrough, 2003; Teece, 1996), and a closed innovation approach that ensures some proprietary protection of innovations through the use of contracts (Mayer & Argyres, 2004; Teece, 1986). Examples in the computer industry are prominent, ranging from Intel and Microsoft's many collaborations (Bresnahan & Greenstein, 1999; Casadesus-Masanell & Yoffie, 2007) to Apple and Google's recent collaborations (Rosmarin, 2007). Indeed, many high-performing products such as Motorola's RAZR, Microsoft's Xbox, and Apple's iPod use collaboratively developed technologies to establish product platforms (Kahney, 2004; Schoenborn, 2006; Takahashi, 2006), suggesting that collaborative innovation is significant in dynamic, interdependent industries.

Despite their importance, technology collaborations can be fraught with difficulties and many fail to achieve their innovation objectives (Ahuja, 2000; Doz, 1996; Stuart, 2000). Collaborative innovation is challenging because it involves searching for existing knowledge in both partner organizations, and then constructing new and useful knowledge combinations that address both partners' strategic objectives (Doz, 1996; Rosenkopf & Nerkar, 2001). Some organizations repeatedly overcome these challenges to develop long-lived "symbiotic relationships" based on multiple innovative technology collaborations, although innovation is not always guaranteed. For example, Intel and Microsoft's seemingly straightforward relationship involved repeated confusion and conflict about technological development, placing future innovations in doubt (Casadesus-Masanell & Yoffie, 2007). Yet somehow these two organizations overcame these problems to develop multiple technologies underlying the Wintel platform (Bresnahan & Greenstein, 1999). As Intel CEO Andy Grove once described, Intel and Microsoft became "joined at the hip" with highly intertwined strategic trajectories due to these collaborations (Burgelman, 2002: 341). The mystery is how some pairs of organizations meet the challenges of collaborative innovation while others fail to do so. Why do some technology collaborations generate innovations while others do not?

Insofar as strategy and organization scholars have considered this question, they have focused primarily on structural antecedents of innovative technology collaborations. A striking feature of this research, though, is that it rarely examines the collaborative innovation process. First, prior research on collaborative innovation relies on archival data and finds that strong R&D capabilities and related, complementary technologies are likely to improve collaborative innovation performance (Ahuja, 2000; Hagedoorn, 1993; Stuart, 2000). Second, the broader literature on alliances finds that collaborative experience, alliance functions, efficient governance form, and prior relationships are likely to improve collaborative performance (Anand & Khanna, 2000; Gulati, 1995a; Kale, Dyer, & Singh, 2002; Uzzi, 1996). While no doubt useful, these structures do not explain the processes by which partners actually organize and execute collaborative innovation.

The purpose of this paper is to understand why some technology collaborations generate innovations while others do not, and thereby improve our understanding of collaborative innovation more broadly. Given the lack of prior research on the organization of collaborative innovation, we use grounded, inductive methods to examine eight technology collaborations among ten firms in the computing and communications industries. By selecting cases that share the structural conditions recommended by the literature (e.g., strong R&D capabilities, dedicated alliance functions, socially embedded relationships), we control for rival structural explanations in order to focus on less well-explored collaborative processes. Despite sharing the prior literature's recommended structural conditions, we find that these cases, nonetheless, have widely varying innovation performance.

In the inductive study that follows, we find that less innovative collaborations use different processes to manage collaborative technological development than more innovative collaborations. Less innovative collaborations use two processes that may appear useful – *consensus leadership* and *domineering leadership* – but ultimately generate less innovations than collaborations using a third process – *rotating leadership*. Although structural antecedents like strong R&D capabilities and social embeddedness allow all three processes to proceed, each process involves a distinct approach to collaborative decision control, technological search, and mobilizing participation that shapes how partners recombine technologies over time. A broader theoretical contribution is to identify major recombination problems that organizations must overcome to innovative collaboratively.

BACKGROUND

Technology Collaborations and Alliance Performance. Three streams of research are relevant background for this study of innovation in technology collaborations. The first stream focuses on determinants of alliance performance including a few studies about innovation in technology collaborations. This literature focuses mostly on structural antecedents of performance. For instance, prior research suggests that possessing strong R&D capabilities (Ahuja, 2000; Stuart, 2000), related and complementary technologies (Ahuja, 2000; Hagedoorn, 1993), and absorptive capacity (Lane & Lubatkin, 1998) is conducive to generating innovations in technology collaborations. Most of these studies infer that innovations were generated collaboratively from changes in firm-level measures of innovation performance following collaborations. For instance, in a study of 150 semiconductor firms, Stuart (2000) found that a firm's innovativeness, as measured by its patenting rate, increased following alliances to innovative partners with well cited patents. Firms with alliances to innovative partners also possess greater subsequent sales growth, an effect that is amplified for smaller firms (Stuart, 2000).

Although not directly focused on technology collaborations, the larger literature on alliance performance surfaces a number of important antecedents that are likely relevant for technology collaborations. For instance, prior research links alliance success to collaborative experience and dedicated alliance functions (Kale et al., 2002; Zollo, Reuer, & Singh, 2002), effective contracts and appropriate governance form (Dyer, 1997; Park & Ungson, 2001; Parkhe, 1993), and socially embedded relationships (Gulati, 1995a; Uzzi, 1996). Alliance performance in these studies is either inferred from repeat alliance formation patterns or with measures of firm performance that follow alliances. For instance, Kale and colleagues (2002) link the presence of dedicated alliance functions to abnormal stock returns following alliances, arguing that these functions house expertise related to alliance capabilities. Collectively, this literature suggests important antecedents of cooperative relationships and a few broad antecedents that appear to underlie the development of innovations in technology collaborations, although it does not focus directly on the collaborative innovation process.

By contrast, some prior research focuses on alliance processes, focusing on underlying evolutionary mechanisms leading to variable outcomes. Learning and cooperation are the broad focus of this work (Arino & de la Torre, 1998; Doz, 1996; Hamel, 1991; Larson, 1992; Uzzi, 1997). An exemplar is Doz's (1996) comparison of three technology collaborations focused on minicomputers, jet engines, and drug delivery systems. This research focuses on inter-partner learning and its effect on the continuation or dissolution of the collaboration. Successful collaborations in Doz's (1996) study have reinforcing cycles of learning, reevaluation, and readjustment that effectively maintain the collaboration. By contrast, failing collaborations may engender some inter-partner learning, but because partners don't learn how to work together they ultimately dissolve the relationship (Doz, 1996). Other studies reinforce the importance of learning from each other and together. Arino de la Torre's (1998) study of a single joint marketing venture finds that partners can jointly learn from mid-term failures to improve collaborative processes and outcomes. And in a study of garment manufacturer networks, Uzzi (1997) finds that embedded relationships where trust is based on multiple prior interactions enjoy the benefits of complex problem solving and learning with fine-grained information transfer. By contrast, some studies emphasize the competitive aspects of inter-partner learning in alliances (Casciaro & Piskorski, 2005; Hamel, 1991; Katila, Rosenberger, & Eisenhardt, 2008; Khanna, Gulati, & Nohria, 1998). Hamel's (1991) intensive study of two partnerships between European and Japanese firms shows how learning can become destructive if partners race to learn their partner's skills and technologies before dissolving the partnerships. Taken together, this literature tends to focus on how collaborations last, often with a focus on learning and cooperation, but not whether and how they generate innovative outcomes.

Innovative Recombination. A second important stream of literature focuses on technological innovation in organizations. A central theme of this literature is that innovation can be modeled as a process of evolutionary search for new "recombinations" of existing knowledge, technologies, and other resources (Helfat, 1994; Katila & Ahuja, 2002; Martin & Eisenhardt, 2009; Nelson & Winter, 1982; Podolny & Stuart, 1995; Rosenkopf & Nerkar, 2001). As Schumpeter (1934) argued, "To produce means to combine materials and forces within our reach … To produce other things ... means to combine these materials and forces differently (p. 65)." Drawing on this theory, the empirical literature links innovation performance to recombinations of old and new knowledge and knowledge from different areas, using patents, again, as the measure of innovation. An exemplar is Fleming's (2001) study of technological familiarity in a sample of 17,264 patents. He finds that patents which cite familiar patent subclasses tend to be more well cited in the future, suggesting that reusing familiar elements creates a productive trajectory for innovative search. However, he finds that the cumulative use of this same citation subclass tends to decrease future citation because, over time, the utility of a familiar search trajectory is exhausted (Fleming, 2001).

Other work contrasts different trajectories for innovation search – for instance, in a study of patenting by US chemical firms, Ahuja and Katila (2004) find that firms tend to respond to search exhaustion by broadening search paths with patents that cite science-sources. Rosenkopf and Nerkar (2001) argue that recombination which expands search beyond local knowledge tends to span technological and organizational boundaries – their finding that search which spans organizational boundaries generates the most innovative optical disk technologies is broadly consistent with the broader rationale for undertaking technology collaborations. In a rare study using a non-patent-based measure of innovation – new product introduction – Katila and Ahuja (2002) examine the effect of patent search depth on the innovativeness of 124 robotics firms, finding that firms with moderate search depth generate more new product introductions than firms with low and high search depth. Taken together, this research highlights the importance of deep and broad search for developing innovative combinations of technologies, but does not detail how individuals and teams work together to produce new combinations in organizations, or how this is done across boundaries.

Collaborative Projects. A third related stream focuses on collaborative project teams where creative action and innovative outcomes are possible. Of particular importance are the micro-dynamics of how different individuals become project participants (Bechky, 2006; Edmondson & Bohmer, 2001; Klein, Ziegert, Knight, & Xiao, 2006; Obstfeld, 2005, 2010). An exemplar study is Edmondson and colleagues (2001) research on 16 hospitals implementing new minimally invasive cardiac survey (MICS) technologies. They found that successful implementation of new routines for using MICS involved a concerted enrollment process whereby new team members are motivated to join, and subsequent participatory practice sessions to encourage new behaviors by these members. Related research that further emphasizes the leadership dynamics of participation is Klein and colleague’s (2006) study of a hospital’s trama unit, a context which demands fast, improvised action that is reliable and appropriate. They observed how trama teams treated 175 patients, finding a pattern of dynamic delegation wherein senior leaders delegated leadership to and from junior leaders to generate reliable performance, but also skill building for novice members of the team (Klein et al., 2006).[i] And Maurer and Ebers's (2006) study of six new biotechnology firms further emphasizes the need to change social capital, finding that the highest performing firms made ties to new and different partners as new resource needs emerged.

Other research is consistent with dynamic participation to generate novel behaviors, but focuses on stable structures around which dynamic participation processes can unfold (Bechky, 2006; Davis, Eisenhardt, & Bingham, 2009; Human & Provan, 2000). For instance, in their study of two networks in the wood-products industry, Human and Provan (2000) found that while many variations on participation are possible, participants tend to maintain the same strategic orientations towards building legitimacy over time. And in a study of four film projects, Bechky (2006) emphasizes the importance of well-established roles to maintain stability in temporary collaborative work. One important role is that of the broker who facilitates interactions between other participants – brokers who span boundaries are known to be useful coordinators and gatekeepers in strategic alliances (Hargadon & Sutton, 1997; Rosenkopf, Metiu, & George, 2001; Tushman, 1977). For instance, in his study of automotive engineering, Obstfeld (2005) found that brokers with a *tertius iungens* orientation focusing on facilitating other's interactions have a higher likelihood of participating in the 73 innovations that emerged. Overall, this literature suggests that mobilizing participants requires active facilitation by managers, although it unclear how to effectively mobilize participants to innovate with technology collaborations.

In summary, research on the antecedents of alliance performance present important pre-conditions that are relevant for technology collaborations, and process research highlights the importance of learning and cooperation feedback loops. Yet with a few exceptions, these studies tend to focus on dissolution as a key measure of low alliance performance. Unfortunately, dissolution is a poor measure of failure in technology collaborations since partners may dissolve these collaborations after the innovation objectives have been achieved (i.e., success). The innovation literature suggests that recombination and search are broadly relevant, but this research has little to say about how recombination actually unfolds in organizations, or between organizations. Finally, research on collaborative projects highlights the importance of dynamic participation, although the participation processes that are most conducive to collaborative innovation, the goal of technology collaborations, are unclear. Taken together, this literature suggests that the variance in innovation performance could be productively explored in a process-focused study of technology collaborations – hence, our research question is why do some technology collaborations generate innovations while others do not?

METHODS

The research design is a multiple-case, inductive study of interorganizational technology collaborations. Given the importance of understanding collaborative processes, this research involves inducing insights from data collected in the field. Multiple cases permit a replication logic in which the cases are treated as a series of experiments that confirm or disconfirm emerging conceptual insights (Eisenhardt, 1989; Yin, 1994). The results of multiple-case research are typically more generalizable and better grounded than those of single-case studies, making them more amenable to extension and validation with other methods (Davis, Eisenhardt, & Bingham, 2007). We chose technology collaborations between large, established organizations for several reasons. From a research standpoint, these organizations typically share antecedent characteristics associated with collaboration performance (e.g., extensive prior experience), enabling a focus on collaborative process without the complication of varied antecedent factors. From a pragmatic standpoint, these organizations have enough resources to engage in significant joint R&D. Finally, their size is likely to preclude their acquisition of each other, putting M&A in the background, and making collaboration necessary and important.

The research setting is the computing and communication industries, which we define broadly as the set of organizations who produce computer and communications related products such as processors, laptops, mobile phones, and internet software. This organizational field is a particularly appropriate setting because the convergence of communications, computing, and internet services created multiple opportunities that required collaboration between organizations across semiconductor, hardware, and software sector boundaries (Bresnahan & Greenstein, 1999; Mowery & Rosenberg, 1998).

Dyadic Sample

Table 1 describes the eight cases of collaboration between the ten organizations in this study. The collaborations lasted from 1-3 years, all occurring within the period from 2001 to 2006. While the cases are named for the broad technological area of the collaboration projects (e.g., Security), the organizations are disguised with pseudonyms drawn from Shakespeare (e.g., Macbeth). These technologies span many relevant technology categories from security circuits and firmware (Security) to mobile email applications and operating systems (Mobile Email) to voice-over-internet-protocol hardware (VOIP Phone). The organizations participating in these collaborations do business in the relevant sectors of the computing and communication industries, ranging from semiconductors (Macbeth) to operating systems (Lear, Rosalind) to mobile devices (Rosalind, Portia). Most pairs of collaborating organizations had extensive prior relationships with each other as complementors, buyer/suppliers, joint sales and marketers, and even direct competitors. Finally, the sample includes six organizations headquartered in the US and four headquartered internationally, reflecting the global nature of these high-technology industries.

We took pains to mitigate bias and enhance the reliability of the sample of collaboration cases. For instance, we focused on cases that shared important antecedents of superior collaboration performance suggested by the academic literature. As Table 1 illustrates, all the relationships in this study share the literature's recommended antecedents including extensive experience collaborating and dedicated alliance functions (Gulati, 1995a; Kale et al., 2002), and strategically interdependent partners in complementary sectors (e.g., hardware/software, circuits/systems) (Gulati, 1995b). In addition, these relationships are characterized by multiple prior inter-firm interactions which led to common organizational structures and boundary-spanning ties between individuals and workgroups (Gulati, 1995a; Uzzi, 1997). Both partners dedicate significant resources to joint development and govern these collaborations with loose "memorandums of understanding" (MoUs) which are incomplete relational contracts specifying "broad areas of technology exploration" (Baker, Gibbons, & Murphy, 2002;

Grossman & Hart, 1986). Finally, these organizations were all technical and market leaders (i.e., either 1st or 2nd in market share) in their respective domains which are highly related technical areas (e.g., circuits, chipsets, systems, applications) that facilitated discourse in the common language of the computing and communications industry (Ahuja, 2000; Dougherty, 1992; Lane & Lubatkin, 1998). Despite sharing these relevant antecedents, these collaborations have a wide variance of innovation performance which this study seeks to explore.

Data Collection and Sources

This study uses several data sources: qualitative and quantitative data from semi-structured interviews, and publicly available and private data from websites, corporate intranets, business publications, and materials provided by informants. We conducted 72 case interviews over 24 months. We interviewed informants from multiple levels of both organizations including the executive leads who oversaw the collaboration; multiple strategic alliance directors, product-line general managers, or laboratory heads; and technical leads, scientists, and engineers. Multiple informants at multiple levels lead to a richer and more reliable model (Eisenhardt, 1989; Miller, Cardinal, & Glick, 1997).

Throughout data collection, an important goal was to mitigate sources of bias. The semi-structured interviews were 60-90 minutes, following an interview guide directing the informant to tell the known facts of the case. To minimize informant biases (Golden, 1992; Miller et al., 1997), we gathered thousands of pages of secondary data both on-site and from the media about these collaborations. Most interviews were tape-recorded and transcribed, with a total source material of 1643 pages from interviews. In most cases, we collected data as the collaboration progressed, returning multiple times to conduct site-visits, generating both real-time and retrospective data that improved the understanding of how events unfolded (Leonard-Barton, 1990). Care was taken to motivate informants to provide accurate data by promising confidentiality (Eisenhardt, 1989).

Data Analysis

As is typical in comparative case research, we analyzed the data by first writing individual case histories synthesizing interviews and archival data (Eisenhardt, 1989). Triangulation with different types of data promotes a richer, more reliable account (Jick, 1979). Case histories focusing on a chronology of the collaboration ranged from 40 to 90 single-spaced pages and took six months to write. Such chronologies support insights related to processes (Van de Ven & Poole, 1995). This data was analyzed using both within-case and cross-case techniques suggested by Miles and Huberman (1994) and Eisenhardt (1989) to develop conceptual insights. This analysis is displayed in Figure 1 which contains data about important collaboration events and outcomes for each case including details about major decisions, changes in objectives, participation patterns, and technologies generated.

Phases

The most basic unit of analysis in these collaborations is the phase.[ii] We define a phase as an interval of time when qualitatively similar work activities occur that differ from activities that came before or after. For example, Technology Design is distinct from Product Marketing because design involves various activities such as sketching various blueprints and diagrams and developing computational models whereas marketing involves courting reference customers, organizing events, and developing communications for different customer segments. Other phases focus on typical new product development activities such as Prototyping or Testing (Clark & Fujimoto, 1991). Yet they also include specialized collaborative activities such as developing written Agreements and Dividing Intellectual Property. We measured the beginning of a phase when one or more informants from each organization indicated that participants began to actively work on new tasks. We measured the end of a phase when one or more informants from each organization indicated that these activities stopped. *"We began negotiating in February." "We really didn't finish until April."* Moreover, we often used a combination of archival information and interviews to triangulate the beginning and end of phases. Our data allow us to measure the beginning and end of activities to the month – so while some overlap between the end of old activities and beginning of new activities can occur, we observe clear demarcations between phases at this level of precision.

The number of phases for each collaboration range between five and eight, with the exact number depending upon the content of the collaboration. For example, the Wireless Networks collaboration had six phases, while the Middleware collaboration had seven phases. A key difference was that the Wireless Networks developed new products for an existing platform, while the Middleware collaboration involved developing a new product platform and, thus, involved an extra of phase focused on Platform Development (phase #4). In addition, the duration of phases can vary even when the general nature of the work is roughly the same. For instance, sometimes joint marketing efforts rely on existing channels while in other cases new channels must be developed. For example, new technologies in the Security collaboration were sold to existing microprocessor customers so that marketing took a relatively short three months. In contrast, selling the products in the Web Services collaboration involved developing a new channel of software developers over five months. The duration of phases ranges from 1 to 12 months. While managers have some discretion over the content and order of phases, characteristics of the work itself are relevant. For example, reaching an agreement precedes product development, and product development precedes marketing in all collaborations. These coding methods yield a clear demarcation between phases for each collaboration case.

Innovation Performance

During the cross-case analysis of the data, a broad view of innovation performance emerged. Consistent with both the informants in this study and the prior literature, we define *innovation performance* as the degree to which collaborations generated new technologies and intellectual property that had a positive impact on product lines and company performance. This definition integrates various aspects of innovation in the literature including new technologies and codified intellectual property (IP) such as patents created in the process (Ahuja, 2000; Grant, 1996a; Griliches, 1990), the impact these technologies have on the organizations' product lines including new product releases and improved product platforms (Comanor & Scherer, 1969; Henderson & Clark, 1990; Katila & Ahuja, 2002), and the consequences of innovation such as product performance (Cohen & Levinthal, 1989; Grant, 1996b; Kogut & Zander, 1992). In analyzing the cases, we assessed all these factors. The result is a particularly robust multi-factor measure of innovation performance.

Collaborative innovation performance is operationalized with five measures: (1) the number of new technologies generated by the collaboration; (2) codified intellectual property; (3) immediate product line impact (e.g., changes to an existing product platform or new product releases); (4) market acceptance of the new technologies including qualitative evaluations by analysts, and immediate financial performance of the products; and (5) participant's perceptions of the overall innovation performance. These measures are detailed Table 2.

We used United States patent applications as our measure of intellectual property (IP). The established organizations in the sample use experienced IP lawyers and tend to have high patent acceptance rates, making patent applications a useful proxy measure of innovation (Comanor & Scherer, 1969; Trajtenberg, 1990). Moreover, for each case, we assessed the collaboration's impact on each partner for at least one year post-collaboration including data on technology exploitation and evaluated product line impact, defined as product or platform enhancements and new products released as a result of these new technologies (Comanor & Scherer, 1969; Katila & Ahuja, 2002). We conservatively recorded only a few clear instances of performance changes that were a direct result of the new technologies generated by the collaborations (Levin, Klevorick, Nelson, & Winter, 1987; Narin, Norma, & Perry, 1988). Finally, we supplemented this data with subjective assessments in which informants were asked to rate the overall innovation performance of the collaboration on a 10-point rating scale. These ratings were averaged across all informants and rounded to the nearest integer; these ratings are highly similar across levels of hierarchy – i.e., executives, managers, and engineers – and between partners. Krippendorff's Alpha = .7905, suggesting that this measure has high inter-rater reliability.

For example, Ariel and Cleopatra's Middleware collaboration had high innovation performance, producing a variety of new internet-based technological features and interfaces, 18 patent applications, and an average subjective innovation performance given by participants of 9 out of 10. The collaboration enhanced Ariel's software development toolset for large enterprise customers, and allowed Cleopatra to develop new software interfaces (APIs) for use by the many small organizations in their software ecosystem. By contrast, Falstaff and Macbeth's VOIP Phone collaboration produced no significant new technological assets, although Falstaff filed four "conceptual" patent applications, and had an average subjective innovation performance of 2 out of 10. Falstaff's VOIP Phone product would lag behind competitors, while Macbeth would suffer the harsh judgments of technical analysts for another failed RF project, and ultimately be forced to exit the wireless communications market and sell their business unit.

ROTATING LEADERSHIP AND COLLABORATIVE INNOVATION

The collaborations in this study begin similarly: two partners come together to develop new technologies, products, and platforms that combine the complementary skills and technologies of each organization (see Table 1). *"This better help us build a new platform!" "New products are the only worthy objective."* Moreover, these collaborations tend to begin with similar activities – an Agreement phase to craft written contracts, a Roadmapping phase to do detailed planning, etc. Each organization possesses dedicated alliance functions, extensive collaboration experience, and strong prior relationships with their partner. Despite these similar beginnings, the innovation outcomes diverge substantially.

The data indicate a link between outcomes and processes used to lead these collaborations. Some collaborations used what we term here a *domineering leadership* process wherein a single partner mobilizes participants, determines innovation objectives, and controls decision making. Other collaborations used what we call a *consensus leadership* process wherein organizations mobilize participants together, agree to common objectives, and pursue shared decision making. Yet, both of these processes are associated with lower innovation outcomes than a third process which emerged from this research, *rotating leadership,* wherein organizations take turns leading the technology collaboration in discrete phases over time. Rotating Leadership involves three distinct components: (1) alternating decision control between partners, (2) zig-zagging trajectories with frequent changes to innovation search objectives, and (3) fluctuating network cascades to mobilize different participants across phases. We describe these three components below, noting their basic structure in early phases (1-3), how they unfold in later phases (4-7), and their ultimate impact on technological innovation (see also Figure 1).

Alternating Decision Control

The processes by which partners make specific decisions about technological development can shape innovation activities. We found three basic patterns related to decision making. In some cases decision making was controlled by a single partner who led most phases of the collaboration. This domineering approach ensures that leading partners can make quick unilateral decisions without consulting their partner. In other cases partners shared control of decision making by ensuring that consensus was reached in most phases of the collaboration. Yet collaborations that used these processes had less innovative outcomes. By contrast, the most innovative collaborations alternated decision control between partners to rotate leadership, enabling unilateral control of rapid decision making by leading partners over time.

To understand collaborative decision making, we examined the major decisions made in each collaboration case, noting when partners made decisions unilaterally or shared decision making in every phase. A major decision is defined as any explicit choice that materially affects the collaboration. These focus mainly on specific technical and operational decisions, but also some strategic decisions that shape innovation outcomes – they include which technologies to develop and how to do so, how to include technologies in products and platforms, and how to target customers with these products. To analyze decisions, each decision is classified as either *unilateral* or *mutual* based on who was involved in the choice – representatives from one organization or both organizations, respectively. Informants gave highly consistent accounts of the major decisions and decision makers in each phase, explaining, for example: *"We let Mercutio control the marketing deadlines."* or *"Cleopatra's team made that decision."* The number of decisions per phase ranges from one to six.

To further examine how decision control changes across phases, we define an alternation in decision control as a transition between phases that occurs when the organization making most unilateral decisions in one phase is different than the organization making most unilateral decisions in the prior phase.[iii] Not all transitions between phases involve decision control alternations (e.g., sometimes one partner maintains control). Figure 1 displays this analysis including the count of unilateral and mutual decisions in each phase, and the total number of decision control alternations. In this analysis, we discovered that more innovative collaborations alternated decision control more than less innovative collaborations. Multiple alternations are characteristic of the rotating leadership process.

Decision Control in Early Phases (1-3). An example is the VPN System collaboration between Rosalind and Prospero in which the two partners alternated decision control three times. The objective of the collaboration was to build a new virtual private network (VPN) system that allows users to access corporate intranets from offsite locations. This required both application expertise from Prospero, a leading software vendor, and operating system (OS) expertise from Rosalind, a prominent hardware and systems vendor. From the beginning, both partners agreed that Prospero's managers should lead the Design phase (see phase #2 in Figure 1) because their expertise in software applications would have a direct impact on customer adoption. At first, Prospero's managers assumed they would also lead subsequent phases – Platform Development (phase #3) and Application Porting and Design (phase #4) – because of the importance of software in these activities.

But after discussions between Rosalind's and Prospero's managers, it became clear that the application's features depended critically on the structure of the operating system, which Rosalind controlled. As one Rosalind manager explained: *"The way it works is they don't have our source code, and <we don't have theirs>. That's the way it is."* Prospero could design software that worked around the current operating system if necessary, but if they could convince Rosalind's managers to rewrite the operating system using a Linux software kernal it would significantly enhance the applications they could develop. This represented a real dilemma for Propsero's managers. While ceding control of the next Platform Development phase (#3) to Rosalind meant they would gain a valuable new Linux-based operating system, it would be difficult for Prospero to control other critical development decisions that occurred in real-time. A Prospero manager explained why they ultimately decided to cede control to Rosalind:

> *"We've been trying to pitch Linux to them for years and years but their messaging in the marketplace was that their legacy OS was special. We don't believe that. From the Prospero perspective, we really need them to switch to Linux before we start the <software application> innovation per se, and only they could do that. Usually Prospero just makes all the decisions, and pushes Rosalind to take it or leave it, but we really needed them to do this first."*

During the Platform Development phase, Prospero and Rosalind conducted a joint progress review to assess the new security platform. Managers from both organizations agreed that Rosalind's engineers had developed a robust, new platform. The same Prospero manager admitted:

> *"The platform works. <Moving to Linux> should help us reduce costs and enhance the distinctiveness of the Rosalind/Prospero product. This way, Rosalind can take pieces of Prospero's software and find areas to fit it in. That should produce new features."*

In contrast, other collaborations (E-Commerce; Wireless Networks; Web Services; VOIP Phone) used either domineering leadership or consensus leadership processes that did not involve alternating decision control. Consider Lear's Web Services collaboration with Ophelia, another case focused on software systems. Managers at Lear, a leading developer of software applications, planned to maintain control in every phase of their collaboration with Ophelia, a major internet company. For example, during the Roadmapping phase (#2) Lear's managers made a *"take it or leave it"* offer in which Lear would fund and unilaterally develop the tool that accessed Ophelia's customer database. Under this plan Ophelia's sole contributions would be to grant Lear access to their database and provide minor input into the design of the internet infrastructure. Asked to describe the basis of complementarity, Lear's technical lead focused on the improvement's to Lear's applications, *"This marries the two together: rich <internet> document creation and the ability to pull that content into the application. We had products looking for a solution … it was a natural win."* Despite some reluctance, Ophelia's executives agreed to Lear's proposal, hoping they would be able to informally influence Lear's design process. One Ophelia manager was optimistic:

> *"Some say 'we don't want that 800 pound gorilla in our space.' …but a lot of what happens at Lear is through personal relationships. If you can use personal relationships then you don't have to go in with official approval to get things done. Things can happen very quickly."*

Yet, as the collaboration evolved, Lear's managers made all decisions without Ophelia's involvement.

By contrast, Falstaff and Macbeth used a consensus leadership process in their Wireless Networks collaboration that involved joint decision making, consensus-building, and agreements sealed "on a handshake". The goal of the collaboration was to use technologies from Falstaff's wireless business unit and Macbeth's communication labs to build better wireless communications equipment that worked on existing "Wireless LAN" infrastructure. *"We haven't deluded ourselves into thinking we have an agreement yet…but <the main idea> is to use Macbeth's fast <silicon> and Falstaff's Ethernet IP on these new <wireless standards>."* The collaboration's managers explicitly committed to consensus leadership, which they had previously used in a successful marketing collaboration where decision-making was simple and fluid. *"We really leveraged the smooth processes in the marketing collaboration."* Consensus leadership involved seeking agreement in every phase of Wireless Networks development, requiring extensive communication that created occasions for misunderstanding about how and which choices were made. Each phase involved seeking consensus on nearly every decision, with single partners never having complete control of any phase.

Decision Control in Later Phases (4-7). Innovative collaborations continued to use alternating decision control during later phases. For example, after the Platform Development phase (#3) ended in the VPN System collaboration, Rosalind returned control of the collaboration to the Prospero team, who went on to make critical decisions affecting the customer-experience such as the design of the graphical user interface (GUI) during the Application Porting and Design phase (#4). One Rosalind manager reflected on the process used to lead the collaboration so far, *"This relationship has been successful for a long time. … We found that somebody really had to take the lead."* Informants in the VPN System case repeatedly emphasized that the pattern of alternating decision control seemed to accelerate and clarify the decision-making process because one organization was clearly in control of each phase.

After the basic security applications had been ported to the new OS platform, the collaboration moved to the Application Development phase (#5) when many innovative application features would emerge. Managers from both organizations intended for Prospero to retain control in this software-intensive phase. In parallel, Prospero's senior managers were pursuing an important acquisition to strengthen their security technology portfolio. One executive explained,

> *"We are a bit late in this <other nascent market>… With this acquisition, we get the product offering and brand. They are perfectly aligned with our vision and are an ideal complement to our products."*

After two months, though, a crisis emerged that threatened Prospero's ability to participate in the collaboration. In brief, Prospero failed to make the acquisition, and their reputation suffered in the marketplace. As a result, senior executives from Prospero who were intimately involved in the collaboration were forced to turn their attention away from the VPN System collaboration (and innovation efforts, more generally) to craft new marketing messages for their company.

After weeks of unanswered questions and requests, Rosalind's managers directed the joint engineering team to begin application development without the benefit of Prospero's executives. One Rosalind manager explained, *"We took over."* Consequently, Rosalind's executives made unilateral decisions about the technical scope of the product that benefited their own firm. For instance, they directed the team to prioritize mobile VPN functionality over other features since Rosalind had deeper expertise and more product tie-in opportunities related to mobile security technologies. Thus, collaborative leadership rotated to Rosalind, unbeknownst to Prospero's executives.

Sometime later, Prospero's marketing crisis was resolved and their senior management returned to find an on-schedule collaboration that was already nearing key product milestones. The modified product fit Prospero's requirements, although with Rosalind's stronger emphasis on mobile VPN features. On reflection, Prospero's managers considered this new emphasis a small price to pay for a finished product,

> *"I think frankly – my honest impression of this is we've under-performed as a partner. I think we've done ourselves a disservice because we didn't dedicate ourselves to it. … But, you know, they really saved us."*

Alternating decision control enabled quick decision making when this partner was occupied.

Alternations can be planned or unplanned. In some cases, control alternates because partners agree that one firm's capabilities seem better matched to upcoming activities than the other firm's capabilities. In other cases, decision control can be seized (or given), often triggered by external events. Prospero's failed acquisition generated an unplanned alternation to Rosalind in the VPN System collaboration. All of the more innovative collaborations (Security, Middleware, VPN System, Mobile Email) involved both planned and unplanned alternations. The data indicates that innovative development of technologies can follow from either type of transition.

A common pattern in the most innovative collaborations using rotating leadership is to follow planned alternations in the first few phases with unplanned alternations in later phases (e.g., Security, Middleware, VPN System, Mobile Email). Partners seemed to push for planned alternations first in order to ensure that known capabilities from both partners are utilized to generate innovative combinations of technologies. A Security manager noted, *"We don't just want an enabling program. We want them as a co-creator of <technologies> and that means making them heavily involved. … We tried to stay out of their hair. If we give them time, they'll devour it."* Unplanned alternations emerge later when single partners recognize that their capabilities are well suited to new problems emerging in real time, or when external events trigger them. The prior planned alternations seem to prepare them to react favorably to eventual unplanned alternations.[iv] Yet whether planned or unplanned, alternations enable partners to make unobstructed decisions that have a higher likelihood of achieving some of their own strategic objectives, the focus of the next finding. Another manager summarized his attitude towards planned and unplanned alternations, *"Does it really matter how we get there…as long as we get our shot?"*

Less innovative collaborations using domineering leadership in early phases tend to do so in later phases. For example, in later phases of Web Services collaboration, Lear continued to make all decisions. Ophelia's managers abandoned their early optimism, and openly worried about how they would apply their capabilities to the collaboration. One Ophelia manager noted, *"Lear's <application>*

group really didn't make it very easy to build integrated solutions with them, or even use<their technologies>…" The same Ophelia manager noticed that his colleagues were becoming *"afraid of working with Lear"* and thought that *"bad things might happen."* Ophelia's participants worried that with little influence over decision making, the combination of Lear's applications and their search technologies would fail.

With shared decision control in consensus collaborations, decision roles become increasingly unclear in later phases. In the Wireless Networks collaboration, an important misunderstanding emerged about the complex issue of whether and how Macbeth would use Falstaff's technical certification process. Whereas Falstaff understood that Macbeth was fully committed to Falstaff's certification requirements, Macbeth understood that they would only *"follow the spirit"* of Falstaff's certification process. Certification was a *"deal breaker"* for Falstaff because they needed to ensure that all of their partners' products used the same networking standards. A Falstaff executive described, *"For <our relationship> with Macbeth, we start by engaging through our certification program. This must be our narrow focus for now…and later on we can expand beyond that."* By contrast, Macbeth's managers thought that certification didn't apply to technology collaborations*: "Their certification program is just for extensions to wireless standards. <It is mainly> for client vendors to support <and> help Falstaff differentiate against their competitors."* Despite extensive discussion, Macbeth and Falstaff had widely differing views of the importance of certification.

Decision Control and Innovation Outcomes. One important impact of alternating decision control is that it enables partners to use complementary capabilities at different times during collaborative innovation. Alternating control of VPN System collaboration three times allowed Rosalind and Prospero to apply their different capabilities to technical work. For example, the alternation which gave Rosalind control of the operating system platform in phase #3 allowed them to use their unique capabilities in infrastructure design to improve the system's robustness. This in turn gave Prospero the Linux system which allowed them to develop various application innovations. For instance, Prospero's technical director described how designing a new GUI (graphical user interface) on Rosalind's new Linux-based system forced them to improve their GUI prototyping methods in real-time. *"A lot of the value* *resides in this software."* More unexpectedly, it was Rosalind decision to develop mobile VPN features that became what industry analysts would call the product's "most distinctive" features:

> *"These features allow mobile users to access information … when a VPN is created in accordance with security policies. All data is secured…the users benefit from an experience that is intuitive and easy to use. (Industry Analyst)"*

These mobile VPN features built directly upon Prospero's basic VPN applications and Rosalind's hardware systems, illustrating the valuable technology combinations that are generated when each organization applies its unique capabilities over time. Understanding their partner's prior contributions allowed leading organizations to determine how to use their own capabilities in a complementary way. Ultimately, this collaboration generated a VPN appliance with improved speed, memory, and unexpectedly robust mobile integration that would become a market leader.

By contrast, collaborations which dominating decision control were unable to access unique capabilities and technologies from the non-leading partner. For example, in the Web Services collaboration, Ophelia's delivered specific technologies (e.g., APIs, database scripts) requested by Lear, yet took little initiative to look broadly across their divisions for the "best" technologies. For example, Ophelia's managers knew that an elegant technical solution to a database problem existed in their search-engine division, but it was not used in the collaboration because they didn't seek it out. Ophelia's technology manager feared that without decision control, they would be unable to effectively integrate these new technologies. *"I didn't really know if they needed it,"* and *"I didn't want to stick my neck out [for the project]."* In retrospect, using Ophelia's search technology could have substantially improved the applicability of Lear's product. Lear's technical leaders regretted not finding the "missing link" that might have improved their products. According to one Lear manager, *"We wanted to…demonstrate <the product> as a smart client application. One of the things was that … it needed to be able to consume web services."* Had it been shared, Ophelia's search technologies may well have led to many novel combinations with Lear's leading productivity applications. Ultimately, the Web Services collaboration produced a working prototype with narrow utility for users. *"So, Lear created a solution that looked pretty basic and rudimentary* *compared to what some of their developer communities [could] come up with."* Development yielded incremental innovations that many participants believed were not worth the efforts.

During consensus leadership, both partners have difficulty using their unique capabilities because of unclear decision making roles. For example, the confusion about whether to use Falstaff's certification process in the Wireless Networks case led to circuits that did not fulfill these requirements and needed to be redesigned. Without certified circuits, Falstaff was unable to apply its detailed knowledge of wireless interfaces in the next phase. Waiting for redesigned circuits led to substantial deceleration of the collaboration and postponed innovation activities. *"It pains me to no end… Now Falstaff is saying, 'we can't do this in time…'"* Ultimately, Falstaff's executives pushed to scale back the collaboration in order to complete certification, and made significant changes to their management team involved in the relationship. As one Falstaff manager reflected, "*With the wireless collaboration… <now we are> …asking what we are really trying to do, and what would we cut…these are the real problems to solve [now].*"

One potential explanation for the idea that alternations enable partners to enlist complementary capabilities that are conducive to collaborative innovation is that different types of technologies (software vs. hardware) are more or less conducive to innovation. While generally reasonable, the data does not support this explanations since more and less innovative collaborations focus on circuits (Security vs. Wireless Networks), hardware (VPN System & Mobile Email vs. Wireless Networks & VOIP Phone), and software (Security, Middleware, and VPN System vs. E-Commerce, Web Services) or different combinations of these technology types (see Table 1 for details). Furthermore, each of these cases brings together partners with combinations of technological expertise that are a standard basis of complementarity in horizontal collaborations in this industry (e.g., circuits/systems, devices/software described in Table 1). Detailed examination of the cases never indicated that partners lacked basic technological capabilities in their focal technological area – each firm is a reputable market leader and technically competent in their respective domains.

Rather, alternating control seems to enables partners to enlist complementary capabilities during innovation. By controlling decision making unilaterally, organizations access their own capabilities and ensure that partners do so as well when alternations occur. Partners are better able to enlist complementary capabilities by examining their partner's outputs when they gain control. Alternating decision control overcomes a general tendency that organizations may have in relying too much on their own resources during collaboration. During technology collaborations, such a tendency harms innovation by over-utilizing familiar knowledge and generating incremental innovations (Ahuja & Katila, 2001; Fleming, 2001). Dominating decision control makes it difficult to marshal capabilities from the non-leading partner, whereas shared decision control leads to misunderstandings about accessing capabilities from either organization. Overall, this finding highlights a general problem in collaboration innovation of utilizing the unique capabilities and resources of both organizations.

Zig-Zagging Trajectories

Partners make important decisions to achieve the innovation objectives of the collaboration. Prior research about alliances emphasizes that partner's objectives can change as they learn during alliances (Arino & de la Torre, 1998; Doz, 1996; Hamel, 1991), while innovation research emphasizes searching broadly for effective combinations of technologies (Fleming, 2001; Katila & Ahuja, 2002), but the relationship between technological objectives and the breadth of innovative search in collaborations remains unclear. In this study, we found that more innovative collaborations frequently change objectives to broadly search for innovations. During each phase, leading partners search the space of innovations along a given technological trajectory, defined as a set of sequential improvements along various technical performance dimensions (Dosi, 1982; Henderson, 1995). Alternations enable new leaders to change objectives and follow different trajectories that better align with their own strategies and capabilities. We describe this overall pattern as a *zig-zagging trajectory* because of the many shifts in direction of that changing objectives facilitate. In contrast, collaborations led by one dominant organization tend to incorporate little of their partner's perspectives and so rarely change objectives.

Progress may be made on these objectives, but the resulting narrow trajectories explore little of the innovation space and tend to generate incremental innovations. Collaborations using consensus leadership changed objectives somewhat more often than those using domineering leadership, but made slower progress towards objectives because of the need to gain agreement about innovation activities. The resulting trajectories therefore seem to lack search depth. By contrast, the zig-zagging trajectories of rotating leadership involve search depth, because partners possess unilateral control during phases, and also search breadth, because of the frequent changes to collaborative objectives, our second major measure of the rotating leadership process.

A collaborative objective is here defined as any high-level strategic goal of the collaboration related to the joint development of technologies, products, and platforms. Typically, partners agree to the initial objectives in the collaboration's first phase. However, initial objectives may only outline the basic opportunity (e.g., Mobile Email, VOIP phone), and leave important considerations unclear (e.g., the target market). We observed that objectives can change in three basic ways: partners can eliminate, elaborate, or add objectives (see Figure 1). Examples include when partners switch from a proprietary to open-source strategy, use new instead of old technologies, or target existing instead of nascent markets. Objectives change either when managers make explicit decisions that alter objectives or when events force changes – i.e., sometimes the results of R&D experiments automatically select some technological options over others. And running out of time in a phase can effectively eliminate objectives.

Search Trajectories in Early Phases (1-3). Partners with innovative collaborations frequently change objectives, often in conjunction with alternations in decision control. Changed objectives shift the technological problems to be solved and the activities that emerge. To illustrate, consider Portia and Rosalind's Mobile Email collaboration. The initial objectives focused on building smart phones with email functionalities. As leadership rotated over time, these objectives changed nine times. For instance, when Portia led the Roadmapping phase (#2), they focused on making their mobile email software work on Rosalind's mobile devices. Soon, Portia's managers realized that Rosalind's phone platform would need to be redesigned to allow Portia's email application software to install seamlessly and to work with a wide variety of wireless service providers. A Portia manager explained these changes:

> *"This is about propagating software such that those devices could work with us… GSM, CDMA, GPS…we need to regularly support all these standards with all the carriers including the Cingulars, T-Mobiles, and Verizons of the world. We are connected to so many different things in the system... We need to <learn how to> license our technology to other handset manufacturers."*

That is, Portia added a new objective to develop a more modular phone platform that leveraged new wireless standards that Rosalind handsets normally did not support.

Often zig-zagging trajectories emerge because partners adjust their objectives in response to decisions and outcomes resulting from their partner's control in a prior phase. For instance, leadership rotated to Rosalind in order to integrate Portia's email software with a new user interface during the Product Porting (#3) phase. When they took over, Rosalind's managers realized that the new modular platform required important changes to Portia's software in order to improve the end-user's emailing experience. Rosalind's managers argued that a better back-end interface was *"necessary to ensure high-quality service"* from the major US telecommunication carriers. Portia's mangers were reluctant to accept this new objective because of the extra time that pursuing this new trajectory would take:

> *"We want to learn … but at the beginning, it took a really long time <to make> the first basic and limited client. Some friction came from that. It was lots of development work, but not a lot of ... results or revenues."*

Yet despite these differences in opinions, Portia's executives ultimately yielded to Rosalind's request to redesign the back-end interface.

By contrast, domineering leadership generates narrow search trajectories by pursuing unchanging objectives. For example, Lear's domineering leadership of the Web Services collaboration led to Lear's choice of objectives with little input from their partner Ophelia. During the Agreement phase (#1), the collaboration seemed to create value for both partners. The initial objectives were to include Ophelia's web services technologies into Lear's software application suite in order to enable them to access various internet websites. Ophelia's managers pushed the Lear team to consider the larger possibilities of

Web2.0 technologies outside of traditional "client-side" software applications, but were ultimately unsuccessful. An Ophelia manager recalled:

> *"We tried to convince them of the potential of these technologies… We even looked at NASDAQ, which is the best example. They basically used a financial version of XML… We invested a lot of money in showing Lear that <Lear's product> was like a productivity version that consumed a lot of data. ...but this evangelization is hard."*

In spite of Ophelia's efforts, Lear's managers refused to explore other product-applications of web services technologies. As one Lear manager explained, *"We at Lear wanted to demonstrate [our products] as a smart client application. We defined this as the ability to consume web services."* The resulting trajectory moved steadily towards Lear's lesser aspiration of integrating Ophelia's database with their application, thereby missing critical opportunities to innovate in the fast-growing Web2.0 space.

Falstaff and Macbeth's consensus leadership in their Wireless Networks collaboration did allow for a few changes to objectives, although progress along these trajectories was ultimately limited, leading to shallow search. The initial objectives focused on developing new wireless network technologies to be used in Falstaff's router products that built on Macbeth's communications circuits. Early changes in the Agreement phase (#2) expanded the scope to include building wireless chips for the military and large enterprises. Advocates for the military and enterprises products were present in both organizations, so they agreed to pursue both objectives. Yet after six months of planning along both trajectories, the group consensus moved from prioritizing development of military prototypes to prioritizing the enterprise chips because of the greater opportunity large enterprises represented if the new products could enter the market quickly.

Search Trajectories in Later Phases (4-7). Partners in innovative collaborations often built upon earlier changes in objectives to develop other changes to objectives in later phases. The Mobile Email case illustrates again. Dating back to their initial conversations, Portia and Rosalind's managers had an ongoing but unresolved debate over whether they should design more or less robust mobile systems. Achieving robustness involved developing incremental improvements to voice call quality and stability. Portia's managers argued that robustness was critical and could be done quickly. Robust performance was a critical element of Portia's reputation and a distinctive competence of their engineering group, so Rosaland's team relinquished control over product integration and testing during the Application Integration (#5) phase. Consequently, Portia changed the objectives to focus on developing robust handset technologies for new voicemail features. And instead of developing a new software platform, Portia's managers chose to utilize an older software platform with the new voicemail features in order to save integration time. Subsequent marketing in the last phase (#6) focused on these new features and bug-free platform as an ideal combination for email-intensive enterprise users.

By contrast, the domineering pattern involving few objective changes repeated itself in the later phases of the Web Services collaboration. During Product Development (phase #4), Ophelia's managers tried to convince Lear's managers to expand the target market from traditional software segments focusing on consumers and enterprises to independent software vendors (ISVs) as well. Ophelia's technology managers argued that targeting ISVs with deep experience integrating internet and application software would lead them down a beneficial trajectory that would broaden the applicability of the product. *"We want to roll this out and offer it to our affiliated community and … see if we get them to build and extend it,"* one Ophelia manager explained. Instead, the collaboration followed standard product development processes used by Lear with its products developed in-house. When integration became too difficult, they modified objectives to scaling back the number of software applications using web services when software. After scaling back the product applications, Lear's managers were then forced to refocus the product on a much narrower market segment of "power users" who would use web services in only one application. The same Ophelia manager complained, *"[Lear's] bar is too low for us. For Ophelia, we really want to reach more people and ultimately have mass-market appeal."* Lear ultimately achieved their main objective – linking web services to their applications – but in a routine way that failed to capitalize on Ophelia's capabilities or fulfill their objectives.

Consensus leadership involved no changes to objectives or a few changes that diminished initial aspirations. Consider the Wireless Networks case, where some participants wished to add new objectives during the Technology Development phase (#4), but changes required sign-off from managers in multiple business units, and they never received final approval. *“This seems slow… We’re just waiting <for Falstaff> to find the right manager. They need to bless the meetings.”* These multiple stakeholders questioned the value of the collaboration and tried to impose multiple competing requirements. Slow planning led to even slower engineering that missed multiple internal milestones. Eventually, disappointing progress reviews led to new executive leadership at Falstaff who imposed a new vision for the future using resources from other business units, all in the hope of salvaging the collaborative relationship. That is, they significantly lowered their aspirations with a modified objective:

> *“Now we just want to have one successful in-depth relationship in the wireless space… We want to make sure there are three features that get adopted into Falstaff’s wireless product line, and then into Macbeth’s product line.”*

Search Trajectories and Innovation Outcomes. Zig-zagging trajectories enable partners to search broadly in the space of potential innovations with deep search within phases and changes in direction across phases. For example, early changes to objectives allowed Portia and Rosalind to ensure that a new set of carrier requirements were incorporated into handset design during the Mobile Email case. Later changes in objectives led to an unexpected combination of “new” user interface with an “old” software platform that was more robust than competitor’s products:

> *“We provided features <that worked on the old> protocols. It sounds easy, but … this is a robust solution. The competition is already in the application layer, but now we stretch down into the deepest ISO layer to a really low level where you handle the radio signal on the network. This is the reason it works so well.”*

Such deep integration made it difficult for competitors to copy their solution. One Rosalind manager summarized the valuable combination: *“It’s been a hard road to hoe, but … now that we’re on the other side … < we see that the impact > is including their footprint in the market and our attractive brand …it is very positive.”* After eight changes to objectives, the innovative Mobile Email collaboration generated a new phone platform and multiple handset products with push email and various smartphone applications.

By contrast, few objective changes with domineering leadership generates narrow search because partners don’t incorporate partner’s perspectives.[v] Changes that did emerge tended to focus on responding to failure. For example, after scaling back the product applications in the Web Services collaboration, Lear's managers refocused product development to target a much narrower market segment who would use web services in only one application. An Ophelia manager complained, *"[Lear's] bar is too low for us. For Ophelia, we really want to reach more people and ultimately have mass-market appeal."* Lear ultimately achieved their main objective – combining web services software and their applications – but in a routine way that few saw as innovative. A Lear manager admitted, "*Now, the application itself, was it the most compelling broad reach? No, no it wasn't."*

With consensus leadership, more changes to objectives may be initiated, but slow progress was made in developing possible technologies that meet these objectives. Prior literature suggests that failing to meet objectives can lead to early dissolution (Doz, 1996). Consistent with this view, one of our consensus cases – the VOIP Phone collaboration – abandoned development after a relatively short 21 months and 6 phases because of slow progress towards objectives. Yet limited progress along trajectories need not dissolve collaborations. For example, after wireless chips became too difficult to develop during Technology Development (#4) phase of the Wireless Networks collaboration, the group consensus moved to reduce the number of chip features under development but continued the collaboration. This case lasted 34 months and 6 phases, approximately average for our sample. Overall, five changes in objectives led to workable products based on moderately improvements in technological performance. *"Those changes really saved us."* The result, however, was viewed as an incremental innovation at best. *"We ultimately did make a product. …but seemed we missed that strategic focus."*

One alternative explanation for the notion that search breadth is achieved by frequently changing objectives with zig-zagging trajectories is that less innovative collaborations are inherently less ambitious from the start. Less ambitious projects have difficulties accessing critical resources. Yet this does not seem to be the case since the initial objectives of the collaborations in Figure 1 indicate comparable aspiration levels. *"We bet the company on this…"* Each collaboration received large commitments of financial resources to fund day-to-day activities and extensive time and scrutiny from top managers, occupying multiple participants for many months (described below). Moreover, all of the less innovative collaborations pursued opportunities that ultimately became important markets (led by competitors). Taken together, there is little evidence that failed collaborations were inherently less ambitious.

Rather, the data indicates that frequently changing objectives enables partners to search broadly for innovations. When leadership rotates, managers change objectives in order to match their own preferences and capabilities. These changes involve defining new technical problems and seeing new ways to solve them. As partners solve these problems, they search for innovations along different technological trajectories than before. In contrast, collaborations with domineering leadership generate narrow trajectories always defined by the leading partner, whereas collaborations with consensus leadership become mired in discussion and disagreement about which trajectory to pursue, generating shallow search trajectories. Overall, this finding highlights a general problem in collaborative innovation of developing a collaborative search trajectory that broadly explores the space of innovations.

Fluctuating Network Cascades

Achieving innovation objectives involves combining different resources in new and useful ways. Because the key resource is often technical knowledge possessed by different individuals in the collaborative network, accessing resources involves mobilizing some of these individuals to participate during innovative activities (Ibarra, 1993; Obstfeld, 2005). We observed a common participation pattern: in every phase of these collaborations, a cascading mobilization of participants emerges that begins with one or several people contacting and including other people who in turn may involve others. In all cases, the two organizations are connected through a preexisting boundary-spanning network composed of different executives, managers, and engineers with a wide range of expertise.[vi] A *cascade* is here defined as the path in which a subset of network members come to participate during a phase of collaborative work. But while all collaborations exhibit cascades, the most innovative collaborations enlist a more diverse set of participants because their cascades fluctuate across phases. As collaborations pursue changing objectives with partners alternating control across phases, managers call upon diverse participants to address different innovation activities.

A cascade path includes the order by which different participants start actively working during a particular phase, and who specifically mobilizes others. For example, in the cascade Jane → Bob → Dave & Jill it is Jane who begins work in this phase and then enlists Bob to work; later Bob enlists Dave and Jill to work (at the same time). We measure an individual's active participation in a cascade as occurring whenever two or more informants told us that this person began working as a result of another's efforts to enlist his or her participation.[vii] Fluctuation occurs when the cascade in one phase is followed by a different cascade in the next phase. For example, the cascade above may be followed by the cascade Bob → Dave → Andrew in a later phase – the phases have different participants, with the exception of Bob and Dave who provide continuity across phases. Typically, fluctuations occur because current participants activate new participants to work on qualitatively different tasks in a new phase where their expertise seems valuable – e.g., Dave brings Andrew into marketing activities because of Andrew's detailed customer knowledge.

The *degree of fluctuation* is here defined as the change in participants across phases, and is measured in two ways. The first measure of fluctuation is <u>the difference in participants between phases</u>. For example, if ten people participate in the current phase and only two of them did not appear in the prior phase, then the percentage of different participants in the current phase is 20%. Yet while participation between two phases may differ by alternating between two relatively stable groups, a difference measure does not capture the degree to which participants come from outside these two groups and are wholly new to the collaboration. This leads to the second measure of fluctuation which is the <u>new participants in each phase</u>. This second measure captures new entrants to the collaboration. For example, if one of the ten people in the example above begins work in the collaboration for the first time, then the percentage of participants in the current phase who are new is 10%. Both measures – (1) different participants and (2) new participants – are measured for each phase, and are then averaged across phases to generate two overall measures of fluctuation for each case of collaboration.

We found that the degree of fluctuation is highest in the most innovative collaborations. As partners alternate control and pursue changing objectives, they enlist a diverse set of participants with cascades that fluctuated across phases. We examined other measures of diversity such as length of the cascade chain, number of different roles, or different levels in the hierarchy, but found no distinct patterns across more and less innovative cases with these measures. Instead, it appears that activation of different and new participants is linked with innovation. Like a waterfall whose path shifts over time, fluctuating cascades vary participation and which recombination problems these participants address.

Network Cascades in Early Phases (1-3). For example, the cascades fluctuated extensively across phases of the Security collaboration which focused on developing new circuits to enable better network security. As Falstaff and Macbeth alternated control and changed objectives, managers activated a large number of different and new participants in most phases. For example, cascades fluctuated extensively in the Design phase (#3). The design phase began in earnest when Macbeth's CTO directed an engineering Vice President to prepare a design proposal for Falstaff's executives to review. This led to the first activation in this cascade. Macbeth's CTO trusted that his VP would know and activate others with critical expertise. As participants explained, executives from Falstaff and Macbeth had strong ties, having collaborated in the past:

> *"Our <executives> already know each other. They meet periodically…. Macbeth always had this internal plan about how to use <Security circuit> technologies, and we started talking a lot about how we could use it on communications equipment. We were looking at each of our places in the ecosystem and thought, 'Gosh, wouldn't it be great if our products could … have some kind of trustworthy association to improve security? … Adam [Macbeth's VP] was put in charge of making this happen."*

In the second activation, Macbeth's VP then turned to his trusted subordinates, including two technical project managers, to help formulate the technical details of this "advanced Security" proposal for Falstaff. The team of three worked on the proposal for months until they found the "right language" for joint development:

> *"Then we had this breakthrough meeting where we finally figured out how to pitch this to Falstaff. It became very clear…we would focus on getting a collaboration agreement figured out and, if we're going to get embarrassed, we'll just get embarrassed together."*

As a result, these meetings activated Falstaff's executives in the collaboration who, unbeknownst to Macbeth's participants, called upon their security product managers to assess Macbeth's proposals. As one Macbeth manager explained, *"We had Peter and Maria in the room as Falstaff's executive sponsors,"* and it wasn't until *"the next series of meetings <that> they brought in their lower level people to go into the bits and bytes."* Overall, the Design phase (#3) enlisted 78% different and 78% new participants. These cascades flowed down the hierarchy from one organization into the other in a way that would not have been predicted by the source of the cascade, Macbeth's CTO.

In contrast to the fluctuating cascades which emerge as partners rotate leadership, domineering and consensus leadership processes involve less fluctuation that involves a less diverse set of participants over time. For instance, domineering leadership involves a cascade of activation down the chain-of-command of the controlling firm that resembles the cascades that occur during rotating leadership in a single phase. Yet because this partner never relinquishes control, the resulting participation pattern is similar across phases of development. Consensus leadership involves a pattern of "maximum involvement" that managers hope will construct a single large team that will work together in every phase. Yet because of the high time-commitments involved, fewer participants come to participate in this team than managers hope. In short, both domineering and consensus activation cascades produce stagnant participation from the same over-involved employees.

For example, Lear generated similar cascades as they dominated leadership of the first phases of their Web Services collaboration with Ophelia. After the Agreement phase (#1), participation always began with Lear's executives calling upon two project managers who controlled the cascades. For example, the Roadmapping (#2) phase enlisted 29% different and 29% new participants, and then the next Platform Development phase (#3) repeated this pattern with 0% different and 0% new participants. Yet despite Lear's domineering leadership, a few Ophelia participants were involved: typically, Lear's co-leads would call upon an Ophelia's manager who would direct the lower level Lear employees to conduct the work. A Lear manager described, *"It took very little effort to <develop> the idea for this one. We just* *talked to <Ophelia's project manager>."* After much of the work was completed in each phase, a final step involved Ophelia's manager calling upon his boss – Ophelia's VP in charge of technology platforms – to quickly approve important decisions. Ophelia's project manager explained: "*Getting signoff from my boss wasn't hard... He just looked at it and said, 'That looks pretty good. I guess it will further our goals. Let's do it.'"*

By contrast, the VOIP Phone and Wireless Networks collaborations used a consensus leadership process involving cascades with little fluctuation that emanated from middle managers. For example, this led to 33% different and 33% new participants in the Project Scoping (#2) phase, and 0% different and 0% new participants in the subsequent Technology Development (#3) phase in the VOIP Phone collaboration. The typical pattern was that a pair of managers from both companies always called upon the same executives and, then, a cross-functional team of functional experts and engineers during every phase. *"We aim for maximal involvement."* Managers asked participants to stay involved in all phases of the collaboration, and waited until this lengthy activation pattern was completed until holding meetings to gain consensus on each phase's work goals. As becomes clear in later phases, the domineering and consensus patterns fail to involve key participants who may have contributed valuable expertise.

Network Cascades in Later Phases (4-7). In later phases, collaborations with fluctuating cascades reinforce their effects with continued use. For instance, partners who have designed basic technologies in early phases often seek to enlist new participants to improve these technologies in later phases. Again, the Security collaboration illustrates. After the Design phase (#3), participation changed again as Falstaff's mangers assumed leadership in another technology-focused phase, Prototyping (#4). A new cascade began when Falstaff's VP called upon a trusted alliance manager who, in turn, enlisted an experienced engineering director to prepare Falstaff's security engineering team to build prototypes based on the new designs. During the Prototyping phase seven different participants (88% of the total eight) were activated, six of whom were new entrants to the collaboration (75% of the total eight). A director and security team who worked in prior phases also participated in Phase 4 – these common participants were a typical way to provide continuity during transitions.

Activating Falstaff's engineering director was a critical step, since he had deep connections into Falstaff's product groups and also knew some of the security experts at Macbeth. Before this engineering director became involved, Falstaff's alliance manager admitted to *"just sort of making it up, assuming this is what we're going to need."* Even Macbeth's managers recognized a noticeable difference when the director was activated. Using a waterfall metaphor to compare how they accessed knowledge with and without this director's help, one manager explained: *"The beginning of Falstaff's waterfall seems slow. It seems slow for the water to fall into their product groups." "He helped us reach their [security and hardware product] groups."* Their perspective changed dramatically with access to the product groups: *"People told us Falstaff was really product oriented. Now we're having that mindshift – they want to expand on the basic themes and show how they fit into a broader picture."* Macbeth and Falstaff's product groups worked quickly to develop chipset prototypes that would be the basis for product development.

By contrast, the later phases of less innovative collaborations continue to be characterized by low fluctuation, or even declining fluctuation, over time. For example, recall how Lear limited involvement of Ophelia's executives to quick "sign-off" duties in early phases of the Web Services collaboration. The late involvement of Ophelia's executives in early phases created difficulties in accessing technical experts within Ophelia's platform group in later phases. This pattern can be traced back to the Roadmapping phase (#2) in which few new participants were enlisted to plan high-level technology standards and related milestones – only 29% new participants emerged (i.e., 2 new people) compared to 70% new participants (i.e., 7 new people) during Roadmapping phase (#2) in the innovative Security collaboration. Specifically, Ophelia's technical experts waited until the executives became heavily involved before becoming involved themselves. For example, only 14% different and 14% new participants emerged in the Product Development phase (#4), a trend that persisted in later phases.

Consensus-based participation also ossified over time. For example, the Wireless Networks collaboration had different and new fluctuation in phases 4-6 that were below 30%, despite having very different R&D, product development, and marketing activities to perform. As described above, consensus decision making often led to confusion, which generated more and longer team meetings. *"This is just taking so long. We're just waiting…"* To compound this issue, all participants were obliged to attend most meetings in each phase. Across phases, however, consensus-based collaborations seemed to involve a smaller number of employees than executives wanted. There is some evidence that potential new participants avoided this project because of the seemingly high time commitment of attending every phase. For example, two employees in the Wireless Networks collaboration stated that they did not participate because they did not have time for all the meetings. And in the VOIP Phone case, prominent technology experts didn't participate because they couldn't understand why they should attend every marketing meeting. Some managers believed that involving these experts may have rescued the collaboration from technical failure.

Network Cascades and Innovation Outcomes. Fluctuating cascades seem to increase the diversity of the knowledge pool that is available for innovation by mobilizing different participants across phases. The Security collaboration illustrates. As described above, the fluctuating cascades in this case involved participants from various labs, divisions, and functional groups across phases. Overall, managers in Security case mobilized an average of 67% different and 44% new participants across phases – CTOs from both Falstaff and Macbeth provided continuity throughout the collaboration as these different teams applied themselves to different problems in different phases. Consistent with prior research on the importance of diverse team composition (e.g., Beckman, 2006), the collaboration benefitted from widely varying technical expertise in semiconductor design, chipsets, firmware, interfaces, and systems software. This expertise was used to produce new circuits, hardware, and software that solved complex security problems for enterprises and consumers.

For example, we described above how accessing a technical director with security expertise was critical in later phases, but lower-level engineering teams with technical expertise in computer networking, operating systems, and servers were also important. Engineering teams were deeply involved in solving problems but, consistent with other research (Klein et al., 2006), executives reasserted control over cascades in later phases when the task demanded it. As one Falstaff manager noted, *"We were making advances in network security with linkages to the server but … we really needed control on the client. [Collaborating with Macbeth's team] on their chipset was an obvious candidate. … Now we [have control] and are able to deliver value to customers in new ways."* Managers attributed these and other improvements to their partner's expertise which they accessed through these cascades. As a Macbeth manager noted, *"[We used] a smaller team, or even one person, to be an architect and begin to flush out the technical concepts, and then [they gained access to] the networking division, the enterprise group, and the communications group. Eventually we got through those barriers and once we did things were on autopilot."* These teams benefitted from diverse perspectives in these activities. New security circuits and hardware produced by this highly innovative collaboration became widely used in major corporate data centers.

By contrast, limited involvement of diverse participants with domineering leadership seemed to reduce the diversity of technical knowledge available for innovative recombination. For example, the Web Services collaboration involved only 24% different and 18% new participants on average. The effect of limited fluctuation on knowledge diversity was recognized only later during the Product Development (#4) phase of the Web Services collaboration when the team was forced to admit that they lacked enough knowledge of Ophelia's technologies to reach milestones in time. When it became clear that the collaboration would generate only rudimentary web services integration, Ophelia's main objective, Ophelia's VP proclaimed the collaboration *"dead on arrival."*

Consensus cascades, similarly, reduced the diversity of knowledge available for innovation. While ensuring that that all participants had a voice in development, these cascades generated extensive communication and complex coordination that seemed to tire those who did participate, and cause other employees to avoid participation. The need to gain consensus with all participants led to confusions that delayed development in both the VOIP Phone and Wireless Networks collaborations. For example, managers of the Wireless Networks collaboration explicitly aimed for "maximum involvement" in every phase. Involving everyone in every meeting generated ambiguity about who was in charge, which further decelerated workflow in later phases. One manager lamented, *"This <joint> wireless team has been working for awhile, so they had the experience… But somehow the execution isn't working."* Multiple delays led the Wireless Networks team to reduce the number of features they would include on their wireless chips.

One alternative explanation for the idea that fluctuating cascades facilitate collaborative innovation because they vary participants is the notion that participants vary automatically across phases either because different skills are needed to address different activities and objectives in phases, or a new firm in control of decisions automatically enlist different participants. Yet an examination of evidence reveals that this need not be the case. For instance, activities in similar phases can have dramatically different fluctuation patterns across cases (e.g., compare new participants in the Product Development phases of more and less innovative cases like Security and Web Services). And while alternations and changed objectives do have a weak association with fluctuating cascades, there are multiple cascades that do not follow these events (e.g., phases #6, #7 in Security, #4, #5 in Middleware, etc.), suggesting a looser coupling between components that is discussed below. In short, different activities in different phases may seemingly "require" new participants for innovation, but it is not a given that new participants will be mobilized automatically.

Instead, mobilizing new participants in innovative collaborations seems to depend on an active cascading process that fluctuates across phases. New participants bring new expertise and fresh perspectives to achieve the changing objectives that emerge when partners alternate control. These new participants are necessary because technical knowledge is typically tacit and difficult to transfer (Hansen, 1999; Rodan & Galunic, 2004). Thus, asking local members to take on the roles of members who are distant is not viable. Activating diverse participants with fluctuating cascades may also be necessary because the leaders responsible for innovation – e.g., engineering VPs or project managers – typically have limited knowledge of the network structure and content beyond their own contacts (Casciaro, 1998; Krackhardt, 1990), placing any one manager's ability to assemble an appropriate team in doubt. Thus, longer cascades appear to be necessary to achieve diversity. Overall, fluctuating cascades appear to address a general problem in collaborative innovation of assembling a diverse set of knowledge and other resources for eventual recombination.

DISCUSSION

We began by noting that despite the important role that interorganizational relationships sometimes play in generating technological innovations, less research has focused on why some of these collaborative relationships generate innovations while others do not. Our core contribution is a better understanding of the collaborative processes that unfold in technology collaborations and contribute to innovation. Our major finding is that a rotating leadership process was more conducive to collaborative innovation than domineering and consensus processes. Our second contribution is an emergent framework that details how the three components of rotating leadership improve the collaborative recombination of technologies across boundaries (depicted in Figure 2). Rotating leadership involves *alternating decision control* which enables partners to make unilateral decisions without consultation, *zig-zagging trajectories* to frequently, and change objectives, and *fluctuating network cascades* to mobilize different and new participants across phases. Taken together, the process ensures that partners make important decisions and marshal complementary capabilities, broadly explore the innovation space, and mobilize diverse participants during collaborative innovation.

Recombination Problems in Collaborative Innovation

A broader theoretical contribution is to outline some general mechanisms underlying the organization of collaborative innovation. Technology collaborations are but one instance of a broader family of collaborative innovation phenomena, defined as innovative recombination that occurs across any meaningful group boundaries, whether these collaborations are between teams, divisions, or entire organizations. Distinct from open and closed innovation, collaboration innovation phenomena are united by a common set of problems related to boundary-spanning recombination including (1) accessing complementary capabilities of both partners, (2) ensuring a broad search for innovations, and (3) bringing different participants with diverse resources together to generate innovative recombinations.

Rotating leadership is one such process that may allow broader insight about collaborative innovation to be developed since each component of this process addresses itself to these recombination problems. For instance, the first major problem focuses on marshalling complementary capabilities and resources from both organizations. Prior research emphasizes how the tacitness and complexity of technical knowledge make it difficult transfer, integrate, and recombine in social networks (Centola & Macy, 2007; Hansen, 1999; Rodan & Galunic, 2004). We contribute to this literature by outline more and less effective processes for accessing complementary resources in networks. Although managers in dominating organizations believed they could access complementary resources from their partner without relinquishing control to them, they had troubles doing so, either because non-leading partners were less motivated to assist them, or non-leading partners were unable to discern the basis of complementarity without possessing a broader view of collaborative strategy that is associated with possessing decision control. Marshalling complementary capabilities and other resources from both groups during collaborative innovation seems to involve a seemingly unachievable paradox: it seems to require unilateral control of decision making for *both* organizations to bring their own capabilities into play. This paradox is resolved by separating intervals of control across time, as occurs during alternating decision control. In contrast to consensus leadership, with rotating leadership partners developed clear roles and uniformity of purpose which allowed leading organizations to discover an emergent basis of complementarity by examining the outputs of their partners' preceding phase of control. This temporal separation of control may be an essential aspect of marshalling complementary resources from multiple groups during collaborative innovation.

A second problem is that broad search is by no means an inevitable outcome of simply accessing complementarity capabilities. Prior research found that innovation involves a difficult combination of recombinant uncertainty and long timeframes for technological development (Ahuja & Katila, 2004; Fleming, 2001; Henderson, 1995) with a wide variety of possible technological trajectories that are difficult to evaluate *ex ante* or even *ex post* (Dosi, 1982; Dougherty, 1990). We add to this literature by noting how trajectories change collaboratively, and when they fail to do so. Domineering trajectories fail to change not because dominating partners necessarily pre-plan all innovative activities (actually these partners clearly improve and react to conditions on the ground, often improving existing technologies in an incremental fashion) – instead, domineering leaders have difficulty using their partner's perspectives to enable changes to collaborative objectives. Consensus paths fail not because of a lack of planning (actually many conflicting plans emerge) – instead, these partners struggle to execute one of these plans and follow a singular path which might improve technical performance. By contrast, when partners rotate leadership they change objectives in ways that extend current trajectories, but in new directions – these zig-zagging trajectories mitigate long time frames and recombinant uncertainty by relying on their partners to engender change and advance new directions.

The final major problem involves accessing diverse knowledge in a boundary spanning network. Prior research suggests that brokers and boundary spanning ties are important for innovation because they are more likely to contain diverse information (Beckman & Haunschild, 2002; Burt, 2004; Obstfeld, 2005; Tushman, 1977). We add this literature on social networks and innovation by pointing out how fluctuating network cascades mobilize these networks over time by assembling different teams that can contribute diverse resources to innovation during each phase. Each of the networks we studied possessed brokers and boundary spanners, yet this alone did not guarantee diverse knowledge would actually be accessed. When compared to domineering and consensus activation processes – which share a common emphasis on similar participants across phases – the fluctuation pattern in rotating leadership generates more diverse inputs, thereby increasing the recombinant potential of available knowledge. A overall insight is that solving this problem is difficult not only because diverse knowledge may not be present in a given network structure, but also because it is difficult to ensure that the team who is actually working possesses diverse knowledge and changes over time.

An understanding of these processes and related mechanisms adds a complementary perspective to existing research emphasizing structural antecedents of collaborative innovation. A great challenge that managers face is that structural antecedents like strong R&D capabilities, embedded relationships, and effective contracts do not greatly constrain what processes can be utilized. For example, while strong R&D capabilities can lead partners to prefer domineering leadership, and embedded relationships may lead partners to assume that consensus leadership is preferable, strong capabilities and embedded relationships do not forestall consensus and domineering processes, respectively. And both structural conditions are clearly conducive to rotating leadership, suggesting that a deeper understanding of processes in conjunction with structures is necessary to complete these explanations.

This suggests an important question: to what extent do some components of the rotating leadership process cause other components? The question has consequential strategic implications because it shapes the allocation of managerial resources between collaborative mechanisms. It seems natural that the three components are interrelated because alternating control engenders changes to objectives, and changes to objectives imply that new participants may be necessary. Consider a possible link between alternation and fluctuation: alternating decision control appears to trigger the onset of fluctuating cascades when the source of each activation cascade emerges from whichever organization currently possesses unilateral decision control. Yet a more detailed analysis in Figure 1 indicates a looser coupling: activation sources can change without alternations of decision control (e.g., from phase 3 to 4 in Middleware) and extensive alternation can trigger only moderate fluctuation (e.g., Mobile Email). While the two components do seem synergistic (alternation and fluctuation co-occur in the most innovative cases), it is not difficult to imagine fluctuation without alternation. Overall, we conclude that while the rotating leadership process productively combines these component processes, they are logically and operationally separable.

Boundary Conditions in Dynamic, Interdependent Environments

Considering these mechanisms collectively and separately may offer the most potential for explaining a broader range of collaborative innovation phenomena. Consider R&D alliances in the pharmaceutical industry, where asymmetric collaborations between large drug and small biotech companies are the norm (Doz, 1988; Owen-Smith & Powell, 2003). While large drug companies may desire innovative collaborations with small biotech firms, a problem arises if their well established routines for controlling decision making in these asymmetric relationships make it difficult for them alternate control. In this context, we might expect to observe a mixture dampened alternation but enhanced fluctuation that leads to partial innovation benefits. Examining the E-Commerce case is also instructive since this mid-range case mixed domineering and rotating leadership: Lear's intention to control the entire collaboration was thwarted for one phase when control rotated unexpectedly to Mercutio and then unexpectedly back to Lear. In fact, this case provides the best test available for the idea that unplanned rotations can be effective without support from other planned rotations. Its net effect was to momentarily break Lear's inward focus and central planning, radically change the objectives, and rescue this collaboration from total failure.

Of great importance for our ability to generalize this emergent theory is to identify key boundary conditions for the applicability of rotating leadership.[viii] One the one hand, it should be noted that rotating leadership is a process that is seemingly only relevant when two entities are seeking to innovative collaboratively. Indeed, there is some evidence that partners chose consensus and domineering processes because they seemed to work in prior non-innovation-focused collaborations (e.g., a successful marketing collaboration where consensus leadership seemed to work preceded the Wireless Networks collaboration). We identify two conditions that appear to limit the generalizability of the findings.

First, we expect rotating leadership to be most applicable in highly interdependent environments like the computer industry where value chains are highly disaggregated, and products include components from multiple different firms. For example, it is no accident that innovative collaborations repeatedly emerge between circuits & hardware companies, hardware & software companies, and software & internet companies since innovations often involve changing architectures that span sector boundaries (Henderson & Clark, 1990; Jacobides, 2006). Typically, organizations specialize in one or a few horizontal layers in highly interdependent industries (Adner & Kapoor, 2009; Bresnahan & Greenstein, 1999) such that complementary partners can be found in other layers. By contrast, non-interdependent industries possess many competing firms without clear complemenatarities where a collaborative process like rotating leadership may not be productive (Hamel, Doz, & Prahalad, 1989; Ozcan & Eisenhardt, 2008). Second, we expect rotating leadership to be most applicable in dynamic markets characterized by an unpredictable flow of technological opportunities. Interdependence without dynamism involves disaggregated industries where technological leadership is undisputed and the returns to innovation are low (Adner & Kapoor, 2009; Bresnahan & Greenstein, 1999). Rotating leadership is well suited to dynamic, interdependent industries because opportunities for the innovative combination of complementary resources are present. Overall, we expect our theory to reach a boundary condition in non-interdependent and non-dynamic industries where organizations tend to lack complementarity or the capacity to develop useful innovations.

Rotating Leadership and Symbiotic Relationships

Another theoretical contribution is to resolve a puzzle in the literature on interorganizational relationships. What is at stake for many of the organizations conducting technology collaborations is not only the immediate generation of innovative products and platforms, but also the maintenance of their long-run *symbiotic relationships*, defined as relationships which enable mutually reinforcing changes to partner's strategies and structures. Symbiotic relationships are especially prevalent in dynamic and interdependent industries where such arrangements enable organizations to mutually adapt to their environments (Adner & Kapoor, 2009; Dobbin, 1994). An important example is the long-term relationship between Intel and Microsoft, which features prominently in Burgelman's (2002: 341) study of Intel's strategic evolution:

> *"[Intel's CEO] Andy Grove described the relationship…as 'two companies joined at the hip.' While constantly vying for perceived leadership of the PC industry and jealously guarding their own spheres of influence (software for Microsoft and hardware for Intel) most of the time the two companies were able to maintain their symbiotic relationship…"*

The puzzle is how such relationships avoid the inertial tendencies which we should expect from long-lived interorganizational relationships (Davis, 2010; Uzzi, 1996). Like other organization structures, such relationships have a tendency to create rigid routines and other organizational structures that engender reliability, accountability, and efficiency but come to constrain flexible responses to environmental dynamism (Davis et al., 2009). Indeed, these relationships may share some aspects of temporary organizations (e.g., film projects) like stable role structures but negotiated role enactment (Bechky, 2006). The central difference is that participants may expect symbiotic relationships to continue indefinitely if a virtual cycle of success and readjustment can be established with a series of repeated alliances (Gulati, 1995b; Uzzi, 1997). The problem arises, however, because these long-lived relationships often fail to adapt to new environmental demands, generating vicious cycles that lead to relationship dissolution (Azoulay, Repenning, & Zuckerman, 2010; Doz, 1996). How do organizations overcome the inertial tendencies of symbiotic relationships?

Rotating leadership may be part of the solution because of its capacity to facilitate innovative development. Prior research has shown that innovations are often the precursor of productive changes to strategies and organizational structure (Greve & Taylor, 2000). For instance, in this study partners with innovative collaborations used new technologies, products, and platforms to enter new markets (Security; Middleware; Mobile Email), shift to more open IP regimes (Middleware; VPN System), and create new business units (Security, Middleware, VPN System), while less innovative collaborations led organizations to exit existing businesses (Wireless Networks), cede new markets to competitors (E-Commerce; VOIP Phone), and dissolve or sell business units (Wireless Networks; Web Services). These productive (and unproductive) changes to strategy and structure have a direct impact on the longevity of these relationships. We tentatively conclude that by facilitating organizational adaptation, rotating leadership creates a context in which new collaboration projects can emerge, thus extending relationship duration. Of course, not all managers in complex organizations employ the same processes in all collaborations. Yet while not all collaborations between symbiotic partners need always use rotating leadership – e.g., only 1 of 3 of Macbeth and Falstaff's collaborations in this study used rotating leadership and innovated extensively – it is reasonable to expect that even the occasional use of rotating leadership underlies the longevity of relationships in dynamic and interdependent environments where innovation is important. Future research could productively explore duration and innovation processes.

Conclusion

The theoretical contributions of this study focus on recombination processes like rotating leadership which marshal capabilities, change search objectives, and vary participation in ways that solve critical collaborative innovation problems and sustain broader symbiotic relationships. These ideas differ from perspectives emphasizing the presence or absence of various structural antecedents like R&D capabilities and dedicated alliance functions which represent basic preconditions for development but do not address critical problems plaguing many collaborative innovation efforts. An important lesson of this research is that without distinct methods for exploring such processes, structural constructs that are found in publically available databases can easily mask dynamics that are at the heart of many organizational phenomena. Seemingly critical in this regard is an important methods contribution of this study: selecting cases that share structural antecedents scholars can not only increase the degree of quasi-experimental control, but also the ability to focus on less well explored processual phenomena that may better explain outcomes of interest. Heightened inductive focus in this study led to the discovery of general collaborative mechanisms and three related constructs – control alternations, changing objectives, and fluctuating participants – that can be used in future deductive research. If these ideas survive empirical test, they could provide a richer account of collaborative innovation phenomena that are increasingly relevant in dynamic and interdependent industries.

Table 1: Description of Collaboration Cases

	Case Name	Case #1	Case #2	Case #3	Case #4	Case #5	Case #6	Case #7	Case #8
		Security	**Middleware**	**VPN System**	**Mobile Email**	**E-Commerce Tools**	**Wireless Networks**	**Web Services**	**VOIP Phone**
Organizations	**Partner A Sector**	**Macbeth** Semiconductors	**Ariel** Systems	**Rosalind** Mobile Devices / OS	**Rosalind** Mobile Devices / OS	**Lear** OS / Software Apps	**Macbeth** Semiconductors	**Lear** OS / Software Apps	**Macbeth** Semiconductors
	Partner B Sector	**Falstaff** Network Equipment	**Cleopatra** Software Apps	**Prospero** Software	**Portia** Mobile Devices / Software	**Mercutio** Online Marketplaces	**Falstaff** Network Equipment	**Ophelia** E-Commerce	**Falstaff** Network Equipment
	Firms' Prior Collaboration Experience	Extensive; Dedicated Alliance Functions	Extensive; Dedicated Alliance Functions	Extensive; Dedicated Alliance Functions	Extensive; Dedicated Alliance Functions	Extensive; Dedicated Alliance Functions	Extensive; Dedicated Alliance Functions	Extensive; Dedicated Alliance Functions	Extensive; Dedicated Alliance Functions
Relationship	**Prior Relationship between Partners**	Embedded & Interdependent	Embedded & Interdependent	Embedded & Interdependent	Embedded & Interdependent	Embedded & Interdependent	Embedded & Interdependent	Embedded & Interdependent	Embedded & Interdependent
	Prior Interactions between Partners	Tech and Product Development, Joint Sales & Marketing, Buyer/Supplier, Standards, R&D consortia, Direct Competition	Joint Sales & Marketing, Buyer/Supplier, Technology Standards	Product Development, Joint Sales & Marketing, Standards, R&D consortia	Technology Standards, R&D consortia, Direct Competition	R&D consortia, Buyer/Supplier	Tech and Product Development, Joint Sales & Marketing, Buyer/Supplier, Standards, R&D consortia, Direct Competition	Joint Marketing, Buyer/Supplier, Standards, R&D consortia	Tech and Product Development, Joint Sales & Marketing, Buyer/Supplier, Standards, R&D consortia, Direct Competition
Technology Collaboration	**Innovation Objective**	Security Circuits and Software	Internet-enabled Enterprise Middleware	Secure Networking Appliances	Mobile Email Devices and Software	E-Commerce Software Tools	Network Circuits and Software	Software to Access Websites	VOIP Phone and Circuits
	Collaboration Duration	30 Months	45 Months	25 Months	42 Months	18 Months	34 Months	18 Months	21 Months
	Complementary Expertise by Partners A / B	Circuits / Systems	Systems / Software	Devices / Software	Devices / Software	Applications / Internet	Circuits / Systems	Applications / Internet	Circuits / Systems
	Related Technologies Possessed by Both Partners	Security Firmware	Communications Protocols	Security Systems	Mobile Data Infrastructure	Database Software	RF Algorithms	Software-design Tools	TCP/IP Components
	Governance Form	Memorandum of Understanding	Memorandum of Understanding	MoU + Existing Joint-Sales Contract	Memorandum of Understanding	Memorandum of Understanding	Memorandum of Understanding	Memorandum of Understanding	Memorandum of Understanding
Data	**Internal / External Archival Data (pages)**	1300 / 1600	1100 / 1500	1500 / 1200	1400 / 1100	700 / 1100	1200 / 1700	1100 / 1200	1000 / 1500
	Case Interviews	15	7	7	7	7	13	6	10

Table 2: Innovation Performance

Case: Partners (Number)	New Technologies and Intellectual Property	New and Improved Products and Platforms	Market Acceptance and Product Performance	Average Subjective Evaluation of Innovation Performance	Selected Quotations Regarding Innovation Performance
Security: Macbeth – Falstaff (1)	Security improvements to circuits, software, and chipsets. Circuit linkages to network equipment. 19 patent applications, 10 white papers	Macbeth's processor includes new security and manageability technologies that are featured prominently in their high-end products. Falstaff bases a new line of software around these new technologies.	A prominent OEM becomes a reference customer for the Macbeth-Falstaff combined solution. Analysts foresee industry structure changes based on these high growth products. Technologies diffuse to data centers first and the server market.	**Overall Average = 9** **Macbeth Average = 9** **Falstaff Average = 8**	"[Falstaff] really had no strong position in the security area, and we wanted a lever against Lear. Now we [have that], and are able to deliver value to customers in new ways." "Macbeth's numbers are so big that if I moved the cycles by one percent, you know, we get an additional billion dollars... So, the bar is high, but this collaboration…had that sort of impact: if we can get the major OEMs signed up to support these technologies next year then they'll want to buy [an additional] ten percent year-over-year contribution while the market grows. So, I really do feel strongly that this was a success"
Middleware: Ariel – Cleopatra (2)	New robust programming environment for enterprises. New internet-based middleware that supports virtualization, portals, and authentication. Directory and application server technologies. 18 patent applications, multiple white papers.	Ariel's robust middleware engine used in large scale enterprise applications. Cleopatra's shifts to new programming language and internet-based middleware that is more robust and easier to support.	Ariel's tool sets become dominant in internet development market. Cleopatra's new internet-based middleware and applications are rated as excellent by industry analysts and gain market leadership in every important segment in the next 3 years.	**Overall Average = 9** **Ariel Average = 8** **Cleopatra Average = 9**	"It was absolutely successful. Actually, it drove a completely new product architecture. I mean, [our middleware] wouldn't exist without [their technology], and that drove their whole new value proposition for their customers and their future destiny. I think that probably no one at Ariel could imagine anymore doing this [technological] evolution without Cleopatra." "[The collaboration] has really changed many of our internal activities. It has sure has had an impact. We had huge competitors like Caliban, Hamlet, and look where they are now! Cleopatra is number one in every segment, in every country…"
VPN System: Rosalind – Prospero (3)	Improved appliance robustness. Linux-based OS with increased speed, memory, and multi-threading improvements. New secure mobile- VPN and firewall integration components. New intrusion detection and mesh architecture. 8 patent applications, multiple white papers.	Rosalind and Prospero base new integrated firewall / VPN appliance around new Linux OS, and emphasize new integration with mobility features as distinctive product advantage.	Customers like robustness and supportability, although the analyst communities focus mostly on new mobile security enhancements.	**Overall Average = 7** **Rosalind Average = 8** **Prospero Average = 6**	"Well, this new project has been reasonably successful." "I think frankly--My honest impression of this is we've under-performed as a partner. I think we've done ourselves a disservice because we didn't dedicate ourselves to it. We found that somebody really has to take the lead. Now we're working a little on catch-up." "Basically, certain places we compete, other places we cooperate. The irony is that this is a very successful partnership in terms of revenue, market visibility and market penetration. Luckily, there is a lot of value coming: the market is looking for a specialized [product like our] offering, and I think we definitely bring value to the table."
Mobile Email: Rosalind – Portia (4)	Push email software ported to Rosalind's OS. Technologies for 3rd party smartphone vendors including client-email integration, conference calling, speakerphone inter-operability, and security locking. 13 patent applications, multiple white papers.	Portia's basic push-email product available on Rosalind's current generation handsets. Push email and mobile data services available on Rosalind's next generation smartphones.	Develops small 'beta test' user base for current generation phone market before larger subscriber growth of next generation smartphones. Portia improves their voice quality of service, and Rosalind improves their Rosalind-branded email program offerings.	**Overall Average = 7** **Rosalind Average = 7** **Portia Average = 7**	"There's nothing wrong with the collaboration at the moment, although it's a little bit slow on new technological development compared to what is available if you go to the nearest email vendors ... But I think that Portia's footprint in the market, combined with our attractive brand and devices then--I think the performance is positive." "It was a hard row to hoe, but now that we're at the other side of it, we have what we wanted to get out of it. I think we've ironed out a lot of kinks." "In the second phase it's more [about] generating revenue... We are working with them, but it's not a totally smooth road..."

E-Commerce Tools: Lear – Mercutio (5)	New software tools that link internet content to client software applications like spreadsheets, email, and web design tools. 7 patent applications, a few white papers.	XML based add-ons available by download from Lear.com, but not as stand-alone client applications. Mercutio sees steady growth of automated transactions through Lear's applications, yet these offer little value for both customer bases.	Prominent joint-marketing and demo events impress industry analysts. Mercutio's power user community adopts some features, demonstrating their desire for transaction-automation tools.	**Overall Average = 7** **Lear Average = 8** **Mercutio Average = 6**	"On releasing [Lear's new software suite], people were saying Lear, you know, is not as hip as some of those web companies. But, now with Mercutio, we showed integration, and I think that resonated with a lot of people." "With Mercutio it seems like there were a lot of…cooks in the kitchen…and everybody was adding their own ingredient to the recipe…so coordination was pretty difficult. We were kind of struggling with…how many features we put into this solution." "We would have been successful without Lear."
Wireless Networks: Macbeth – Falstaff (6)	Mobile router and transceiver technologies with increased bandwidth, range, and memory. 9 Patent applications, 5 white papers.	Mobile Router device delivered to the military, but with no impact on Macbeth or Falstaff's main product lines. Next generation transceiver technology do appear in the new wireless router product line.	Mobile router product is not launched. Transceiver viewed as incremental 'next step' building block technology and doesn't result in significant revenue growth. Bundled features get good ratings from analysts, but generate little excitement with customers.	**Overall Average = 5** **Macbeth Average = 4** **Falstaff Average = 5**	"Now, we are actually engaged with them and they are building stuff on our technology. But I honestly don't think that the value for [us] is really adequately defined. And, you know, I think that's ok because we are trying to build a relationship and are willing to sacrifice a little bit to get there." "Right now it seems [we] sort of we missed that real strategic focus -- like what are we trying to do, and what feature would we cut because of the lead-time involved. When we are starting to engage at a real problem solving level, then that'll be a marked change."
Web Services: Lear – Ophelia (7)	Web Services linkages between application linkages to e-commerce database. 5 patent applications, one white paper.	Lear's document processing application has limited access to Ophelia's e-commerce data.	Technologies not marketed broadly; download hidden on a Lear.com website with thousands of other downloads. Feature gains no acceptance with developers and analysts do no reviews.	**Overall Average = 5** **Lear Average = 5** **Ophelia Average = 5**	"Now, the application itself, was it the most compelling broad reach? No, no it wasn't." "For [our other collaborations], we designed a [large] PR campaign. This level of [intense PR planning] didn't happen for Ophelia." "We walked away friends. Most collaborations you may walk away bad. We thought we made something good happen and got attention. Now, I'm not really as metrics driven as I should be, so we didn't think about it from that perspective."
VOIP Phone: Macbeth – Falstaff (8)	None 4 patent applications, but no white papers.	Falstaff's VOIP phone product line will not have the option to use Macbeth's communications architecture in the near future.	Falstaff's VOIP phone generates little revenue or excitement from analysts.	**Overall Average = 2** **Macbeth Average = 2** **Falstaff Average = 4**	"I think I would say both sides did very poorly, right? I think there were miscommunications about expectations." "We ultimately failed to get to an agreement. If we had figured that out earlier, we could have saved a lot of wasted time." "The process wasn't working because when we got to the second phase it all fell apart."

Table 3: Summary of Evidence Linking Rotating Leadership and Collaborative Innovation

Case Name (Partners)	Collaborative Process				Innovation Performance	
	Overall Pattern	**Fluctuating Network Cascades**	**Zig-Zagging Trajectories**	**Alternating Decision Control**	**New Technologies and Intellectual Property**	**Average Subjective Rating of Innovation Performance**
Security (Macbeth - Falstaff)	Rotating Leadership	Extensive 69% Different and 52% New Participants	Extensive 7 Objectives Changed	Extensive 3 Alternations in Decision Control	High 19 Patents	High 9
Middleware (Ariel - Cleopatra)	Rotating Leadership	Extensive 68% Different and 50% New Participants	Extensive 6 Objectives Changed	Extensive 4 Alternations in Decision Control	High 18 Patents	High 9
VPN System (Rosalind-Prospero)	Rotating Leadership	Moderate 50% Different and 29% New Participants	Extensive 8 Objectives Changed	Extensive 3 Alternations in Decision Control	High 18 Patents	Medium 7
Mobile Email (Rosalind – Portia)	Rotating Leadership	Moderate 62% Different and 31% New Participants	Extensive 8 Objectives Changed	Extensive 3 Alternations in Decision Control	High 13 Patents	Medium 7
E-Commerce Tools (Lear – Mercutio)	Domineering Leadership / Rotating Leadership	Moderate 50% Different and 25% New Participants	Moderate 3 Objectives Changed	Moderate 2 Alternations in Decision Control	High 7 Patents	Medium 7
Wireless Networks (Macbeth – Falstaff)	Consensus Leadership	Limited 38% Different and 20% New Participants	Moderate 5 Objectives Changed	None 0 Alternations in Decision Control	Medium 9 Patents	Low 5
Web Services (Lear – Ophelia)	Domineering Leadership	Limited 24% Different and 18% New Participants	Limited 2 Objectives Changed	None 0 Alternations in Decision Control	Low 5 Patents	Low 5
VOIP Phone (Macbeth – Falstaff)	Consensus Leadership	Limited 13% Different and 8% New Participants	Limited 1 Objectives Changed	None 0 Alternations in Decision Control	Low 4 Patents	Low 2

Figure 1: Detailed Analysis of Eight Cases of Technology Collaboration

Legend
- (U) Unplanned Alternation
- (P) Planned Alternation
- → Participant Activation

Case #1: Security – (M)acbeth & (F)alstaff (Rotating Leadership)

	#1 (1 mo)	#2 (10 mo)	#3 (5 mo)	#4 (4 mo)	#5 (5 mo)	#6 (2 mo)	#7 (3 mo)	Totals (Summaries)
Phase (Length)	#1 (1 mo)	#2 (10 mo)	#3 (5 mo)	#4 (4 mo)	#5 (5 mo)	#6 (2 mo)	#7 (3 mo)	7 Phases (30 Months)
Focus	Agreement - craft written agreement about basic structure of collaboration	Roadmapping - high-level alignment of technology standards and milestones	Design - crafting detailed plans for new technologies, platforms, and products	Prototyping - creating physical models of technologies or products that can be refined	Product Development - using new technologies to improve or create new products that can be sold to customers	Dividing IP - agreeing to divide technologies and codified intellectual property between partners	Marketing - creating interest in new technologies, platforms, and products that were developed jointly	
Alternations			(P)	(P)	(U)			
Decisions – (M)acbeth unilateral			M,M,M		M,M,M,M	M	M,M	(Extensive Alternation) 3 Alternations
Decisions – mutual	F&M							
Decisions – (F)alstaff unilateral		F,F,F,F		F, F				
Changes in Objectives	Initial Objectives: Develop new integrated circuits and system software that improves enterprise network security using M's circuit F's system expertise	1. Jointly develop three new security and manageability technologies 2. Decouple circuit and system software marketing.	3. Use new technologies in one new M product and one new F product	4. Also include new technologies in an old F product	5. Eliminate planned modifications to security technology standards. 6. Facilitate outside companies to develop complementary products	7. Time-limited joint sales agreement		(Extensive Zig-Zagging) 7 Objectives Changed
Participation Activation Cascades	M Director → F Sales manager → F CTO → F SVP and Technical Leads	F CTO → F CDO, F SVPs and Various F Directors → Various M Directors, Two M Project Managers → M Marketing Manager; F SVP and M Director → M & F Legal Reps	M CTO → M engineering VP → Two M Project Managers → M Lab Director → M Security/ Managability Development Teams; M CTO & M VP → F CTO & CDO → F Security Team	F VP → F Lab Head & F alliance manager → M Alliance Manager & F Engineering Director → F Security Team, M Security experts, M Director → M General Manager	M CTO → M engineering VP → F Lab Head, M Alliance Manager, M Director & M Circuit Teams	M CTO → M engineering VP → F Lab Head, F Alliance Manager, & M Director → M Legal Team → F Legal Rep	M CTO → M engineering VP & M marketing VP → M marketing team → F Alliance Manager & F VP Marketing → F Marketing Group → F CDO & F CTO	(Extensive Fluctuation)
Different from Prior Phase		70%	78%	88%	60%	43%	67%	69% Different Participants (Weighted Average)
New to Collaboration		70%	78%	75%	20%	0%	44%	52% New Participants (Weighted Average)
Technological Outcomes		Roadmaps with common industrial objectives	Design documents for two technologies	Chipset technologies	Security and Managibility firmware. New interfaces for complementors	Systems software to access firmware	Joint security tech marketing program	**Innovation Performance:** 19 Patent Apps, 9 Subjective Evaluation. Circuits and firmware with new security and manageability linkages to network equipment.

Case #2: Middleware – (A)riel & (C)leopatra (Rotating Leadership)

	#1 (2 mo)	#2 (11 mo)	#3 (6 mo)	#4 (6 mo)	#5 (12 mo)	#6 (6 mo)	#7 (2 mo)	Totals (Summaries)
Phase (Length)	#1 (2 mo)	#2 (11 mo)	#3 (6 mo)	#4 (6 mo)	#5 (12 mo)	#6 (6 mo)	#7 (2 mo)	7 Phases (45 Months)
Focus	Agreement - craft written agreement about basic structure of collaboration	Roadmapping - high-level alignment of technology standards and milestones	Problem Identification - finding opportunities to improve existing technologies, products, or platforms	Platform Development - creating set of technologies that can be reused across multiple products	Middleware Development - developing technologies that connect software components and applications	Ecosystem Application Development - coordinating with small complementor firms to develop applications that utilize a new platform	Marketing - creating interest in new technologies, platforms, and products that were developed jointly	
Alternations		(P)	(P)			(U)	(U)	
Decisions – (A)riel unilateral		A,A				A,A		(Extensive Alternation) 4 Alternations
Decisions – mutual	A&C							
Decisions – (C)leopatra unilateral	C,C		C,C	C,C,C,C	C		C	
Changes in Objectives	Initial Objectives: Develop robust new middleware underlying C's enterprise applications using A's infrastructure expertise	1. Expand joint R&D and support arrangement to focus on Middleware underlying new internet-enabled applications	2. Add interfaces to facilitate development of complementary software. 3. Develop new C platform based on A software	4. Integrate applications and platform using new middleware		5. Extend migration path of old C platform	6. Enable reference customer to resolve bugs	(Extensive Zig-Zagging) 6 Objectives Changed
Participation Activation Cascades	C CTO → C SVP → A CEO → A VP	A VP → A Two Senior Software Directors → A Two Project Managers	C CTO → C SVP → C Project Managers → C Software Architects	A Project Manager & C Project Manager → C CTO, C & A VP → A and C Software Development Teams	A Project Manager & C Project Manager → C CTO, C & A VP → C Software Development Teams	A VP → A Senior Software Director → A and C Project Teams → A Marketing Group	C Marketing VP → C CTO, C Software Director & C Marketing Team	(Extensive Fluctuation)
Different from Prior Phase		67%	100%	67%	17%	80%	100%	68% Different Participants (Weighted Average)
New to Collaboration		67%	50%	67%	0%	60%	75%	50% New Participants (Weighted Average)
Technological Outcomes			Prototype of robust enterprise software platform	Fully tested enterprise software platform	Finish robust middleware software. Release 1st version	New enterprise application software	Bug-free version of application and platform	**Innovation Performance:** 18 Patent Apps, 9 Subjective Evaluation. Robust enterprise-ready middleware and programming platform supporting virtualization, portals, authentication.

Case #3: VPN System – (R)osalind & (P)rospero (Rotating Leadership)

	#1 (6 mo)	#2 (5 mo)	#3 (3 mo)	#4 (3 mo)	#5 (3 mo)	#6 (5 mo)	Totals (Summaries)
Phase (Length)	#1 (6 mo)	#2 (5 mo)	#3 (3 mo)	#4 (3 mo)	#5 (3 mo)	#6 (5 mo)	6 Phases (25 Months)
Focus	Roadmapping - high-level alignment of technology standards and milestones	Design - crafting detailed plans for new technologies, platforms, and products	Platform Development - creating set of technologies that can be reused across multiple products	Application Porting and Design - making existing applications work on new platform and creating plans for new features	Application Development - product development for software applications working on a common platform	Marketing - creating interest in new technologies, platforms, and products that were developed jointly	
			(P)	(P)	(U)		
Decisions – **(R)osalind** unilateral	R		R,E		R,R,R	R	(Extensive Alternation) 3 Alternations
Decisions – mutual		R&P		R&P		R&P	
Decisions – **(P)rospero** unilateral	P,P,P,P,P	P,P		P,P			
Changes in Objectives	Initial Objectives: Develop high-performance virtual private networking appliance using R's hardware and P's security software	1. Port existing software elements to Linux. 2. Add new security functions. 3. Add mobile security functions	4. Simply VPN system kernal	5. Develop appliance on upgraded hardware. 6. Validate system with key customers	7. Add new mobile VPN functions	8. Add certification requirements for external vendors	(Extensive Zig-Zagging) 8 Objectives Changed
Participation – **Activation Cascades**	R EVP → R VP & R Director → P VP → P CEO & P Director	P VP → P Director & R VP → R Director → R Platform Team	R Director → R VP, R Alliance Director & P Director → R & P Platform Teams	P Director → P Security Engineering Team & R Alliance Director → R Director	R Alliance Director → R VP, R Platform Team & R Application Team	R VP → R EVP → R Marketing Group, P VP & P CEO → P Marketing Group	(Moderate Fluctuation)
Different from Prior Phase		40%	33%	25%	75%	80%	50% Different Participants (Weighted Average)
New to Collaboration		40%	33%	25%	25%	20%	29% New Participants (Weighted Average)
Technological Outcomes			New Linux Platform	Improved VPN product on New Platform	Customer Validation. New Mobile VPN applications	Joint Marketing Plan. Certification Requirements. R downsizes	**Innovation Performance:** 18 Patent Apps, 7 Subjective Evaluation VPN appliance with speed, memory, multi-threading, and firewall improvements and linkages to mobile devices.

Case #4: Mobile Email – (R)osalind & (P)ortia (Rotating Leadership)

	#1 (11 mo)	#2 (5 mo)	#3 (6 mo)	#4 (7 mo)	#5 (7 mo)	#6 (6 mo)	Totals (Summaries)
Phase (Length)	#1 (11 mo)	#2 (5 mo)	#3 (6 mo)	#4 (7 mo)	#5 (7 mo)	#6 (6 mo)	6 Phases (42 Months)
Focus	Agreement - craft written agreement about basic structure of collaboration	Roadmapping - high-level alignment of technology standards and milestones	Product Porting - making an existing product work on new platform, architecture, or set of technologies	Product Development - using new technologies to improve or create new products that can be sold to customers	Application Integration - bringing together different applications in the same system or platform	Marketing - creating interest in new technologies, platforms, and products that were developed jointly	
			(P)		(U)	(P)	
Decisions – **(R)osalind** unilateral			R,R	R,R		R,R	(Extensive Alternation) 3 Alternations
Decisions – mutual	R&P	R&P		R&P			
Decisions – **(P)ortia** unilateral	P	P,P	P		P,P		
Changes in Objectives	Initial Objectives: Develop mobile devices with push email capability using R's phone platform and P's email software	1. Modularize R's phone platform so apps install seamlessly. 2. Test new platform on multiple environments	3. Develop email standards to work with multiple carriers. 4. Improve voice robustness of new phone platform	5. Add speakerphone function. 6. Add E-faxing function	7. Build first product using old hardware 8. Prioritize system integration apps over productivity apps		(Extensive Zig-Zagging) 8 Objectives Changed
Participation – **Activation Cascades**	P CEO → R EVP & P VP → R VP, R Director, P Technical Lead, P Director	P VP → P Director & R Director → P Technical Lead → P Software Team	R Director → R Hardware Integration Team & P Technical Lead → P Software Team	R EVP & R VP → P VP & R Director → R Hardware Integration Team	P Technical Lead → P Software Team, P Testing Team & P Director → R Director → R Testing Team & R Hardware Integration Team	R EVP → R VP Marketing → R Handset Marketing Group & P VP → P Marketing Team	(Moderate Fluctuation)
Different from Prior Phase		20%	50%	60%	71%	100%	62% Different Participants (Weighted Average)
New to Collaboration		20%	50%	0%	29%	60%	31% New Participants (Weighted Average)
Technological Outcomes		Robust and Modular Platform	Mobile Data Phone with Voice Robustness. Basic Email and Instant Message Applications	New Conference Calling. Security Locking and System Integration Applications	Two Additional Phones with New Functionalities	Launch with all major carriers worldwide	**Innovation Performance:** 13 Patent Apps, 7 Subjective Evaluation New phone platform and new handset products with push email and smartphone applications.

Case #5: E-Commerce Tools – (L)ear & (M)ercutio (Domineering Leadership / Rotating Leadership)

Phase (Length)	#1 (3 mo)	#2 (3 mo)	#3 (1 mo)	#4 (5 mo)	#5 (3 mo)	#6 (3 mo)	Totals (Summaries)
Focus	Agreement - craft written agreement about basic structure of collaboration	Roadmapping - high-level alignment of technology standards and milestones	Platform Development - creating set of technologies that can be reused across multiple products	Product Development - using new technologies to improve or create new products that can be sold to customers	Testing - ensuring the new technologies, products, and platform work effectively	Marketing - creating interest in new technologies, platforms, and products that were developed jointly	6 Phases (18 Months)
				(U)	(U)		
Decisions – (L)ear unilateral	L,L		L		L,L	L,L	(Moderate Alternation) 2 Alternations
Decisions – mutual		L&M,L&M,L&M		L&M			
Decisions – (M)ercutio unilateral				M,M,M			
Changes in Objectives	Initial Objectives: Develop e-commerce tools that access M's website and are integrated into L's applications	1. Use XML technologies to develop light-footprint linkages to L's applications		2. Build general-purpose web-development tools that work with Lear's system. 3. Add an email interface to these tools.			(Moderate Zig-Zagging) 3 Objectives Changed
Participation Activation Cascades	L Salesperson → M Director & L Program Manager → L Director & L Alliance Manager → L Technical Lead	L Alliance Manger & M Director → L Technical Lead & M Technical Lead → L Program Manager	L Technical Lead → L Director, L Product Group & L Alliance Manager → M Technical Lead	M Technical Lead → M Web-Finance Director → M Web-Finance Team → L Technical Lead	L Technical Lead → L Director, L Product Group & L Alliance Manager → M Technical Lead	L Director → L CEO, L Marketing Group, M Director, M Web-Finance Director	(Moderate Fluctuation)
Different from Prior Phase		20%	40%	50%	60%	80%	50% Different Participants (Weighted Average)
New to Collaboration		20%	20%	50%	0%	40%	25% New Participants (Weighted Average)
Technological Outcomes			GUI Platform Demo Using XML	E-commerce product with tools and email interfaces	Full Client Application using XML	L CEO Launch, Limited Roll-Out	**Innovation Performance:** 7 Patent Apps, 7 Subjective Evaluation New software tools that link client applications to some internet content.

Case #6: Wireless Networks – (M)acbeth & (F)alstaff (Consensus Leadership)

Phase (Length)	#1 (12 mo)	#2 (6 mo)	#3 (4 mo)	#4 (5 mo)	#5 (4 mo)	#6 (3 mo)	Totals (Summaries)
Focus	Roadmapping - high-level alignment of technology standards and milestones	Agreement - craft written agreement about basic structure of collaboration	Assessment - evaluating technologies, platform, products, and collaborative process to date	Technology Development - research and development activities aimed at developing new solutions to existing technical problems	Product Development - using new technologies to improve or create new products that can be sold to customers	Marketing - creating interest in new technologies, platforms, and products that were developed jointly	6 Phases (34 Months)
Decisions – (M)acbeth unilateral		M					(No Alternation) 0 Alternations
Decisions – mutual	M&F	M&F,M&F,M&F	M&F,M&F	M&F,M&F,M&F	M&F	M&F	
Decisions – (F)alstaff unilateral				F	F		
Changes in Objectives	Initial Objectives: Develop wireless local area network technologies that are embedded in F's routers and use M's communications technologies	1. Pursue multiple projects focused on wireless chips for enterprise customers and prototypes for military customers. 2. Prioritize military prototype over wireless chips	3. Change priorities to focus on wireless chips	4. Reduce wireless chip feature set. 5. Conduct multi-platform hardware compatibility testing			(Moderate Zig-Zagging) 5 Objectives Changed
Participation Activation Cascades	M Lab Manager → F Alliance Manager & F Alliance Director → M VP Platforms Unit & F VP Wireless Unit → F Tech-Partners Manager & M VP Wireless Management Group → M Lab Senior Manager & M Lab Bus. Dev. Manager → Various M Technical Leads; F VP Wireless Unit→ F CEO; M Lab Manager → M CTO	M Lab Bus. Dev. Manager, M Lab Senior Manager & F Alliance Manager → F Tech-Partners Manager & M Technical Lead → M Wireless Unit & F Technical Lead; M Lab Senior Manager, F Alliance Manager & F Alliance Director → M & F Legal Teams	M Lab Bus. Dev. Manager, M Lab Senior Manager & F Alliance Manager → M VP Wireless Management Group & F VP Wireless Unit → F CTO & M CTO, F Technical Lead, Various M Technical Leads	F CTO → F Alliance Director, F Alliance Manager & M Lab Bus. Dev. Manager → M Wireless Unit, F Technical Lead, Various M Technical Leads	F CTO → F Alliance Director, F Alliance Manager & M Lab Bus. Dev. Manager → M Wireless Unit, M VP Wireless Management Group → M Wireless Testing Group	F CTO → F Alliance Director, F Alliance Manager & M Lab Bus. Dev. Manager → M VP Wireless Management Group → M Technology Marketing Group & Wireless Testing Group → F Marketing Group	(Moderate Fluctuation)
Different from Prior Phase		44%	56%	29%	29%	25%	38% Different Participants (Weighted Average)
New to Collaboration		44%	11%	0%	14%	25%	20% New Participants (Weighted Average)
Technological Outcomes		Agreement Signed		Wireless Chips Completed and Tested	Wireless Chips Integrated into Circuit System	Limited Joint Marketing	**Innovation Performance:** 9 Patent Apps, 5 Subjective Evaluation New router and transceiver technologies with some bandwidth improvements.

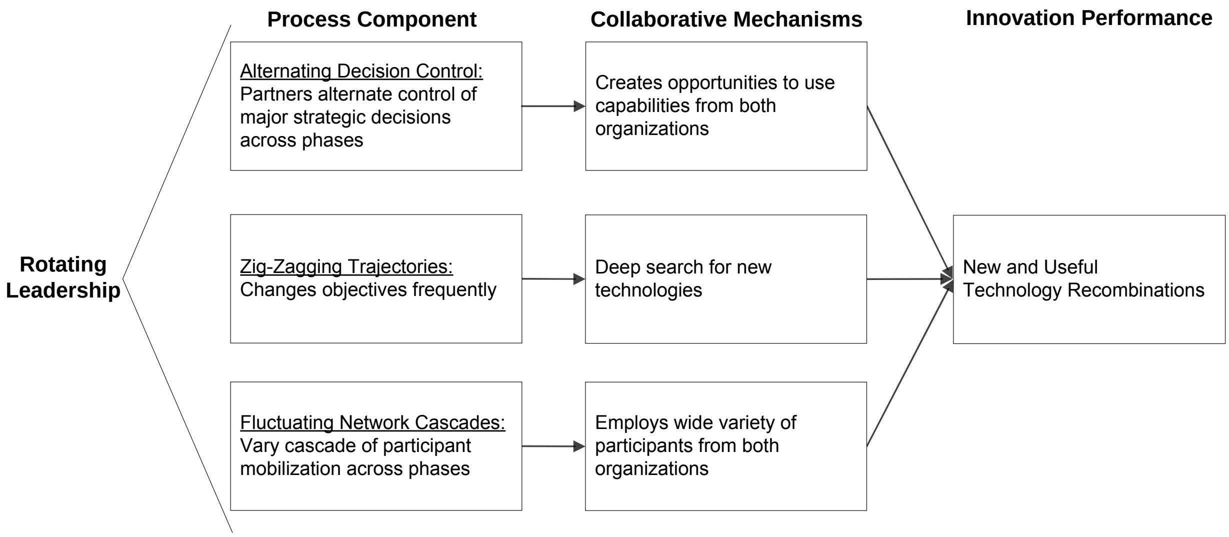
Case #7: Web Services - (L)ear & (O)phelia (Domineering Leadership)

		#1	#2	#3	#4	#5	#6	**Totals (Summaries)**
Phase (Length)		#1 (3 mo)	#2 (3 mo)	#3 (2 mo)	#4 (3 mo)	#5 (2 mo)	#6 (5 mo)	6 Phases (18 Months)
Focus		Agreement - craft written agreement about basic structure of collaboration	Roadmapping - high-level alignment of technology standards and milestones	Platform Development - creating set of technologies that can be reused across multiple products	Product Development - using new technologies to improve or create new products that can be sold to customers	Assessment - evaluating technologies, platform, products, and collaborative process to date	Marketing - creating interest in new technologies, platforms, and products that were developed jointly	
Decisions	**(L)ear** unilateral	L,L	L,L	L	L,L	L	L,L,L,L	(No Alternation) 0 Alternations
	mutual	L&O			L&O			
	(O)phelia unilateral						O	
Changes in Objectives		Initial Objectives: Use O's web services technologies to enable L's application suite to access complex websites seamlessly			1. Limit web services product offering to one application in L's product suite	2. Change the primary customer segment of new application functionalities		(Limited Zig-Zagging) 2 Objectives Changed
Participation								
Activation Cascades		L Product Director & L Product Head → L Program Manager & L Alliance Manager → O Technology Manager → O VP Web Products & O Technology Lead	L Program Manager & L Alliance Manager → L Product Team & O Technology Manager → O Technology Lead → O Web Technology Team; O Technology Manager → O VP Web Products	L Program Manager & L Alliance Manager → L Product Team & O Technology Manager → O Technology Lead → O Web Technology Team; O Technology Manager → O VP Web Products	L Program Manager & L Alliance Manager → L Product Team & O Technology Manager → O Technology Lead → O Web Technology Team; L Program Manager & L Alliances Manager → Other L Product Teams	L Program Manager & L Alliance Manager → L Product Director & O Technology Manager → O VP Web Products & O VP Marketing	O VP Web Products & O VP Marketing → O Technology Manager → L Program Manager & L Alliance Manager → L VP Marketing → L Marketing Teams	(Moderate Fluctuation)
Different from Prior Phase			29%	0%	14%	50%	29%	24% Different Participants (Weighted Average) 18% New Participants (Weighted Average)
New to Collaboration			29%	0%	14%	17%	29%	
Technological Outcomes					Limited Web Services Client Interfaces	Web Services Client Application	L markets it alone	**Innovation Performance:** 5 Patent Apps, 5 Subjective Evaluation Document application linkages to e-commerce database.

Case #8: VOIP Phone – (M)acbeth & (F)alstaff (Consensus Leadership)

		#1	#2	#3	#4	#5	**Totals (Summaries)**
Phase (Length)		#1 (10 mo)	#2 (2 mo)	#3 (2 mo)	#4 (3 mo)	#5 (4 mo)	6 Phases (21 Months)
Focus		Roadmapping - high-level alignment of technology standards and milestones	Project Scoping - deciding what tasks and activities are occurring in the project and which are not	Technology Development - research and development activities aimed at developing new solutions to existing technical problems	Agreement - craft written agreement about basic structure of collaboration	Assessment - evaluating technologies, platform, products, and collaborative process to date	
Decisions	**(M)acbeth** unilateral			M			(No Alternation) 0 Alternations
	mutual	M&F,M&F	M&F,M&F	M&F	M&F		
	(F)alstaff unilateral					F,F	
Changes in Objectives		Initial Objectives: Develop a digital phone with VOIP capabilities for enterprises using M's communications technologies and F's hardware systems expertise	1. Develop phone that operates on multiple networks				(Limited Zig-Zagging) 1 Objective Changed
Participation							
Activation Cascades		M Manager & F Manager → M CTO & F SVP Wireless Unit; M Manager & F Manager → M & F Alliance Managers, M & F Wireless Internet Development Teams	M Manager & F Manager → M Techincal Manager, M & F Alliance Managers, M & F Marketing and Legal Reps, M & F Wireless Internet Development Teams	M Manager & F Manager → M Techincal Manager, M & F Alliance Managers, M & F Marketing and Legal Reps, M & F Wireless Internet Development Teams	M Manager & F Manager → M Technical Manager, M & F Alliance Managers, M & F Marketing and Legal Reps, M & F Wireless Internet Development Teams	M Manager & F Manager → M Technical Manager, M & F Alliance Managers, M & F Marketing and Legal Reps, M & F Wireless Internet Development Teams; M Manager & F Manager → M CTO & F SVP Wireless Unit	(Moderate Fluctuation)
Different from Prior Phase			33%	0%	0%	18%	13% Different Participants (Weighted Average) 8% New Participants (Weighted Average)
New to Collaboration			33%	0%	0%	0%	
Technological Outcomes				Improved M Communication Architecture			**Innovation Performance:** 4 Patent Apps, 2 Subjective Evaluation No new technologies or products.

Figure 2: Theoretical Logic Linking Rotating Leadership and Collaborative Innovation



References

Adner, R., & Kapoor, R. 2009. Value Creation in Innovation Ecosystems: how the structure of technological interdependence affects firm performance in new technology generations. ***Strategic Management Journal***, 31(3): 306-333.

Ahuja, G. 2000. Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study. ***Administrative Science Quarterly***, 45: 425-455.

Ahuja, G., & Katila, R. 2001. Technological Acquisitions and the Innovation Performance of Acquiring Firms: A Longitudinal Study. ***Strategic Management Journal***, 22: 197-220.

Ahuja, G., & Katila, R. 2004. Where do resources come from? The role of idiosyncratic situations. ***Strategic Management Journal***, in press.

Anand, B. N., & Khanna, T. 2000. Do Firms Learn to Create Value? The Case of Alliances. ***Strategic Management Journal***, 21: 295-315.

Arino, A., & de la Torre, J. 1998. Learning from Failure: Towards an Evolutionary Model of Collaborative Ventures. ***Organization Science***, 9(3): 306-325.

Azoulay, P., Repenning, N. P., & Zuckerman, E. W. 2010. Nasty, Brutish, and Long: Embeddedness Failure in the Pharmaceutical Industry. ***Administrative Science Quarterly, Forthcoming***.

Baker, G., Gibbons, R., & Murphy, K. 2002. Relational Contracts and the Theory of the Firm. ***Quarterly Journal of Economics***, 117: 39-83.

Bechky, B. A. 2006. Gaffers, Gofers, and Grips: Role-Based Coordination in Tempoary Organizations. ***Organization Science***, 17(1): 3-21.

Beckman, C. M. 2006. The Influence of Founding Team Company Affiliations on Firm Behavior. ***Academy of Management Journal***, 49(4): 741-758.

Beckman, C. M., & Haunschild, P. R. 2002. Network Learning: The Effects of Partners' Heterogeneity of Experience on Corporate Acquisitions. ***Administrative Science Quarterly***, 47: 92-124.

Bresnahan, T., & Greenstein, S. 1999. Technological Competition and the Structure of the Computer Industry. ***Journal of Industrial Economics***, 47(1): 1-40.

Brown, S. L., & Eisenhardt, K. M. 1997. The Art of Continuous Change: Linking Complexity Theory and Time-paced Evolution in Relentlessly Shifting Organizations. ***Administrative Science Quarterly***, 42: 1-34.

Burgelman, R. A. 2002. Strategy as vector and the inertia of coevolutionary lock-in. ***Administrative Science Quarterly***.

Burt, R. 2004. Structural Holes and Good Ideas. ***American Journal of Sociology***, 110: 349-399.

Casadesus-Masanell, R., & Yoffie, D. B. 2007. Wintel: Cooperation and Conflict. ***Management Science*** 4: 584-598.

Casciaro, T. 1998. Seeing things clearly: social structure, personality, and accuracy in social network perception. ***Social Networks***, 20: 331-351.

Casciaro, T., & Piskorski, M. 2005. Power Imbalance, Mutual Dependence, and Constraint Absorption: A Closer Look at Resource Dependence Theory. ***Administrative Science Quarterly***, 50: 167-199.

Centola, D., & Macy, M. 2007. Complex Contagions and the Weakness of Long Ties. ***American Journal of Sociology***, 113(3): 702-734.

Chesbrough, H. 2003. ***Open Innovation: The New Imperative for Creating and Profiting from Technology***. Boston: Harvard Business School Press.

Clark, K., & Fujimoto, T. 1991. ***Product Development Performance***. Boston, MA: Harvard Business School Press.

Cohen, M. D., & Levinthal, D. 1989. Innovation and learning: the two faces of R&D. ***Economic Journal***, 99(397): 569-596.

Comanor, W. S., & Scherer, F. M. 1969. Patent statistics as a source of technical change. ***Journal of Political Economy***, 77(3): 392-398.

Davis, J. P. 2010. Agency and Knowledge Problems in Network Dynamics. ***Working Paper, MIT Sloan School of Management***.

Davis, J. P., Eisenhardt, K., & Bingham, C. B. 2009. Optimal Structure, Market Dynamism, and the Strategy of Simple Rules. ***Administrative Science Quarterly***, 54: 413-452.

Davis, J. P., Eisenhardt, K. M., & Bingham, C. B. 2007. Developing Theory Through Simulation Methods. ***Academy of Management Review***, 32(2): 480-499.

Dobbin, F. 1994. ***Forging Industrial Policy: The United States, Britain, and France in the Railway Age***. New York: Cambridge University Press.

Dosi, G. 1982. Technological paradigms and technological trajectories. ***Research Policy***, 11: 147-162.

Dougherty, D. 1990. Understanding New Markets for New Products. ***Strategic Management Journal***, 11: 59-78.

Dougherty, D. 1992. Interpretive Barriers to Successful Product Innovation in Large Firms. ***Organization Science***, 3(2): 179-202.

Doz, Y. L. 1988. Technology Partnerships between Larger and Smaller Firms: Some Critical Issues. ***International Studies of Management and Organization***, XVII(4): 31-57.

Doz, Y. L. 1996. The Evolution of Cooperation in Strategic Alliances: Initial Conditions or Learning Processes. ***Strategic Management Journal***, 17: 55-83.

Dyer, J. H. 1997. Effective Interfirm Collaboration: How Firms Maximize Transaction Value. ***Strategic Management Journal***, 18(7): 535-556.

Edmondson, A. C., & Bohmer, R. M. 2001. Disrupted Routines: Team Learning and New Technology Implementation in Hospitals. ***Administrative Science Quarterly***, 46: 685-716.

Eisenhardt, K. M. 1989. Building Theories from Case Study Research. ***Academy of Management Review***, 14: 532-550.

Eisenhardt, K. M., & Schoonhoven, C. B. 1996. Resource-based view of strategic alliance formation: Strategic and social effects in entrepreneurial firms. ***Organization Science***, 7(2): 136-150.

Fleming, L. 2001. Recombinant uncertainty in technological search. ***Management Science***, 47: 177-132.

Golden, B. R. 1992. The past is the past -- Or is it? The use of retrospective accounts as indicators of past strategy. ***Academy of Management Journal***, 35: 848-860.

Grant, R. M. 1996a. Prospering in Dynamically-competitive Environments: Organizational Capability as Knowledge Integration. ***Organization Science***, 7(4): 375-387.

Grant, R. M. 1996b. Toward a Knowledge-Based Theory of the Firm. ***Strategic Management Journal***, 17(Winter Special Issue): 109-122.
Greve, H. R., & Taylor, A. 2000. Innovations as catalysts for organizational change: shifts in organizational cognition and search. ***Administrative Science Quarterly***, 45: 54-80.
Griliches, Z. 1990. Patent statistics as economic indicators: a survey. ***Journal of Economic Literature***, 28(4): 1661-1707.
Grossman, S. J., & Hart, O. D. 1986. The Cost and Benefits of Ownership: A Theory of Vertical and Lateral Integration. ***The Journal of Political Economy***, 94(4): 691-719.
Gulati, R. 1995a. Familiarity breeds trust? The implications of repeated ties on contractual choice in alliances. ***Academy of Management Journal***, 38: 85-112.
Gulati, R. 1995b. Social Structure and Alliance Formation Patterns: A Longitudinal Analysis. ***Administrative Science Quarterly***, 40: 619-652.
Hagedoorn, J. 1993. Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences. ***Strategic Management Journal***, 14(5): 371-385.
Hamel, G. 1991. Competition for competence and inter-partner learning within international strategic alliances. ***Strategic Management Journal***, 12(Summer special issue): 83-103.
Hamel, G., Doz, Y. L., & Prahalad, C. K. 1989. Collaborate with your competitors -- and win. ***Harvard Business Review***, January-February: 133-139.
Hansen, M. T. 1999. The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge Across Organization Subunits. ***Administrative Science Quarterly***, 44(1): 82-111.
Hargadon, A., & Sutton, R. I. 1997. Technology Brokering and Innovation in a Product Development Firm. ***Administrative Science Quarterly***, 42: 716-749.
Helfat, C. E. 1994. Evolutionary trajectories in petroleum firm R&D. ***Management Science***, 40: 1720-1747.
Henderson, R. 1995. Of life cycles real and imaginary: The unexpectedly long old age of optical lithography. ***Research Policy***, 24: 631-643.
Henderson, R. M., & Clark, K. B. 1990. Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. ***Administrative Science Quarterly***, 35: 9-30.
Human, S., & Provan, K. 2000. Legitimacy building in the evolution of small-firm multilateral networks: A comparative study of success and failure. ***Administrative Science Quarterly***, 45(2): 327-365.
Ibarra, H. 1993. Network centrality, power, and Innovation Involvement: Determinants of technical and administrative roles. ***Academy of Management Journal***, 36(471-501).
Jacobides, M. G. 2006. Benefiting from Innovation: Value Creation, Value Appropriation and the Role of Industry Architectures. ***Research Policy***, 35: 1200-1221.
Jick, T. D. 1979. Mixing Qualitative and Quantitative Methods: Triangulation in Action. ***Administrative Science Quarterly***, 24(4): 602-611.
Kahney, L. 2004. Inside Look at Birth of the IPod, ***Wired***.
Kale, P., Dyer, J. H., & Singh, H. 2002. Alliance Capability, Stock Market Response, and Long-Term Alliance Success: The Role of the Alliance Function. ***Strategic Management Journal***, 23: 747-767.
Katila, R., & Ahuja, G. 2002. Something old, something new: A longitudinal study of search behavior and new product introduction. ***Academy of Management Journal***, 45(6): 1183-1194.
Katila, R., Rosenberger, J., & Eisenhardt, K. 2008. Swimming with sharks: Technology ventures, defense mechanisms, and corporate relationships. ***Administrative Science Quarterly (forthcoming)***.
Khanna, T., Gulati, R., & Nohria, N. 1998. The Dynamics of Learning Alliances: Competition, Cooperation, and Relative Scope. ***Strategic Management Journal***, 19: 193-210.
Klein, K. J., Ziegert, J. C., Knight, A. P., & Xiao, Y. 2006. Dynamic Delegation: Shared, Hierarchhical and Deindividualized Leadership in Extreme Action Teams. ***Administrative Science Quarterly***, 51: 590-621.
Kogut, B., & Zander, U. 1992. Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology. ***Organization Science***, 3(3): 383-397.
Krackhardt, D. 1990. Asessing the Political Landscape: Structure, Cognition, and Power in Organizations. ***Administrative Science Quarterly***, 35: 342-369.
Lane, P. J., & Lubatkin, M. 1998. Relative Absorptive Capacity and Interorganizational Learning. ***Strategic Management Journal***, 19: 461-477.
Larson, A. 1992. Network Dyads in Entrepreneurial Settings: A Study of the Governance of Exchange Relationships. ***Administrative Science Quarterly***, 37: 76-104.
Leonard-Barton, D. 1990. A Dual Methodology for Case Studies: Synergistic Use of a Longitudinal Single Site with Replicated Multiple Sites. ***Organization Science***, 1(3): 248-266.
Levin, R. C., Klevorick, A. K., Nelson, R. R., & Winter, S. G. 1987. Appropriating the returns from industrial research and development; Comments and discussion. ***Brookings Papers on Economic Activity***, 3: 783-831.
Martin, J. A., & Eisenhardt, K. 2009. Rewiring: Cross-business synergies and Performance in Multi-Business Organizations. ***Academy of Management Journal (forthcoming)***.
Maurer, I., & Ebers, M. 2006. Dynamics of Social Capital and their Performance Implications: Lessons from Biotechnology Start-ups. ***Administrative Science Quarterly***, 51.
Mayer, K. J., & Argyres, N. 2004. Learning to Contract: Evidence from the Personal Computer Industry. ***Organization Science***, 15(4): 394-410.
Miles, M. B., & Huberman, A. M. 1994. ***Qualitative Data Analysis*** (2nd ed.). Thousand Oaks, CA: Sage Publications.
Miller, C. C., Cardinal, L. B., & Glick, W. B. 1997. Retrospective reports in organizational research: A reexamination of recent evidence. ***Academy of Management Journal***, 40: 189-204.
Mowery, D. C., Oxley, J. E., & Silverman, B. R. 1998. Technological overlap and interfirm cooperation: Implications for the resource-based view of the firm. ***Research Policy***, 27: 507-523.
Mowery, D. C., & Rosenberg, N. 1998. ***Paths of Innovation***. Cambridge, MA: Cambridge University Press.

Narin, F., Norma, E., & Perry, R. 1988. Patents as Indicators of Corporate Technological Strength. ***Research Policy***, 18: 139-154.
Nelson, R. R., & Winter, S. G. 1982. ***An Evolutionary Theory of Economic Change***. Cambridge, MA: Belknap Press of Harvard University Press.
Obstfeld, D. 2005. Social Networks, the Tertius Iungens Orientation, and Involvement in Innovation. ***Administrative Science Quarterly***, 50(1): 100-130.
Obstfeld, D. 2010. Creative Projects: A Less-Routine Approach Towards Getting New Things Done. ***Organization Science, Forthcoming***.
Owen-Smith, J., & Powell, W. W. 2003. Knowledge Networks as Channels and Conduits: The Effects of Spillovers in the Boston Biotechnology Community. ***Organization Science***, 15(1): 5-21.
Ozcan, C. P., & Eisenhardt, K. M. 2008. Origin of Alliance Portfolios: Entrepreneurs, Network Strategies, and Firm Performance. ***Academy of Management Journal***, 52(2): 246-279.
Park, S. H., & Ungson, G. R. 2001. Interfirm Rivalry and Managerial Complexity: A Conceptual Framework of Alliance Failure. ***Organization Science***, 12(1): 37-53.
Parkhe, A. 1993. Strategic Alliance Structuring: A Game Theoretic and Transaction Cost Examination of Interfirm Cooperation. ***Academy of Management Journal***, 36(4): 794-829.
Podolny, J. M., & Stuart, T. E. 1995. A Role-Based Ecology of Technological Change. ***American Journal of Sociology***, 5: 1224-1260.
Powell, W. W., Koput, K. W., & Smith-Doerr, L. 1996. Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology. ***Administrative Science Quarterly***, 41: 116-145.
Rodan, S., & Galunic, D. C. 2004. More than network structure: How knowledge heterogeneity influences managerial performance and innovativeness. ***Strategic Management Journal***, 25: 541-562.
Rosenkopf, L., Metiu, A., & George, V. 2001. From the Bottom Up? Technical Committee Activity and Alliance Formation. ***Administrative Science Quarterly***, 46(4): 748-772.
Rosenkopf, L., & Nerkar, A. 2001. Beyond Local Search: Boundary-Spanning, Exploration and Impact in the Optical Disc Industry. ***Strategic Management Journal***, 22: 287-306.
Rosmarin, R. 2007. Brought To You By Goopple, ***Forbes***.
Schoenborn, G. 2006. ***Entering Emerging Markets: Motorola's Blueprint for Going Global***: Springer.
Schumpeter, J. A. 1934. ***The theory of economic development*** (R. Opie, Trans.) (7 ed.). Cambridge, Massachusetts: Harvard University Press.
Stuart, T. E. 1998. Network Positions and Propensities to Collaborate: An Investigation of Strategic Alliance Formation in a High-Technology Industry. ***Administrative Science Quarterly***, 43(3): 668-698.
Stuart, T. E. 2000. Interorganizational Alliances and the Performance of Firms: A Study of Growth and Innovation Rates in a High-Technology Industry. ***Strategic Management Journal***, 21: 791-811.
Stuart, T. E., Hoang, H., & Hybels, R. C. 1999. Interorganizational Endorsements and the Performance of Entrepreneurial Ventures. ***Administrative Science Quarterly***, 44: 315-349.
Takahashi, D. 2006. ***The Xbox 360 Uncloaked: The Real Story Behind Microsoft's Next-Generation Video Game Console***: Lulu Press.
Teece, D. 1986. Profiting from technological innovation. Implications for integration, collaboration, licensing, and public policy. ***Research Policy***, 15: 285-305.
Teece, D. J. 1996. Firm organization, industrial structure, and technological innovation. ***Journal of Economic Behavior & Organization***, 31(2): 193-223.
Trajtenberg, M. 1990. ***Economic Analysis of Product Innovation: The Case of CT Scanners***. Cambridge, MA: Harvard University Press.
Tushman, M. 1977. Special Boundary Roles in the Innovation Process. ***Administrative Science Quarterly***, 22(4): 587-605.
Uzzi, B. 1996. The sources and consequences of embeddedness for the economic performance of organizations: The network effect. ***American Sociological Review***, 61(4): 674-698.
Uzzi, B. 1997. Social Structure and Competition in Interfirm Networks: The Paradox of Embeddedness. ***Administrative Science Quarterly***, 42: 36-67.
Van de Ven, A. H., & Poole, M. S. 1995. Explaining development and change in organizations. ***Academy of Management Review***, 20(3): 510-540.
Yin, R. K. 1994. ***Case Study Research: Design and Methods*** (Second ed.). Thousand Oaks: Sage Publications.
Zollo, M., Reuer, J. J., & Singh, H. 2002. Interorganizational Routines and Performance in Strategic Alliances. ***Organization Science***, 13(6): 701-713.

Endnotes

[i] We greatly appreciate the advice of an anonymous reviewer to focus on leadership processes underlying broad patterns of participation.

[ii] We appreciate the advice of our editor and anonymous reviewers to clarify the definition and measurement of phases.

[iii] We also tried alternative measures of alternations, for example also including transitions from mostly mutual to mostly unilateral. The general findings are robust to these other operationalizations. We appreciate the suggestion of an anonymous reviewer which led us to detail this.

[iv] We appreciate the suggestion of an anonymous reviewer to look for patterns related to planned and unplanned alternations.

[v] We appreciate the suggestions of an anonymous reviewer to decouple broad and deep search, and consider how different processes might be modified to achieve different outcomes. So while domineering partners may have found other means to incorporate partner's perspectives, rotating leadership forces partners to do so.

[vi] In other research, we found that managers intentionally rewire these networks, sometimes forming and sometimes dissolving ties, to ensure that participants are connected at multiple levels in the hierarchies of both organizations. While rewiring is no doubt important, these networks stabilize quickly – typically after the first phase – and most managerial efforts are spent facilitating interactions between participants who already have ties, suggesting that it is important to understand how organizational processes shape how actors in the network come to participate in the collaboration. We appreciate the comments of an anonymous reviewer in suggesting we clarify this point.

[vii] We measure a set of cascade activations as occurring in a sequence (e.g. Bob then Dave) when two or more informants could confirm that one person's activation followed another's activation; otherwise, we conservatively record two activations as occurring in parallel (e.g., Dave & Jill) if we could not confirm this sequence. For ease of exposition, we term the first active participant in a phase as the cascade "source". It should be noted that the source need not be senior to the next active member. In fact, cascade sources are often (but not always) project managers who enlist executives later in a cascade. In that sense, these activation cascades are not synonymous with directed network ties by which hierarchy is typically measured. We appreciate the comments of an anonymous reviewer in suggesting we distinguish fluctuating cascades from network hierarchy.

[viii] We appreciate the comments of an anonymous reviewer that we clarify boundary conditions and generalizability of this process.