ROTATING LEADERSHIP AND COLLABORATIVE INNOVATION: RECOMBINATION PROCESSES IN SYMBIOTIC RELATIONSHIPS

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ABSTRACT

Technological collaborations between organizations are central to the development of innovations in open and dynamic environments. Yet, how innovations emerge collaboratively is not been well explored. 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 more than possessing the appropriate structural antecedents (e.g., R&D capabilities, social embeddedness). Rather, it also involves dynamic organizational processes that address mechanisms that solve critical innovation problems related to recombination across boundaries. While domineering and consensus leadership processes are associated with less innovation, a rotating leadership process is associated with more innovation. It involves *alternating decision control* that access the complementary capabilities of both partner organizations, *zig-zagging objectives* that engender deep and broad technological search for potential innovations, and *fluctuating network cascades* that mobilize different participants who bring variable inputs to recombination. Broader contributions include identifying recombination mechanisms in the organization of collaborative innovation, explaining the performance of dynamic interorganizational ties, and describing how organizations develop symbiotic relationships that overcome the tendency of long-lived relationships towards inertia.

Technological innovation is central to how organizations create value, unleash gales of creative destruction, and enable human progress. Product development and acquisition have long been significant strategies for innovation (Ahuja & Katila, 2001; Brown & Eisenhardt, 1997). But in increasingly open and dynamic industries where resources are highly distributed and frequently changing, it is unlikely that single organizations can consistently develop or acquire the best innovations. Instead, technology collaboration has become an essential innovation strategy (Mowery, Oxley, & Silverman, 1998; Teece, 1986).

Technology collaborations are interorganizational relationships focused on the joint development of technological innovations across boundaries (Ahuja, 2000; Powell, Koput, & Smith-Doerr, 1996; Stuart, 2000). Examples 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). When successful, these collaborations allow partners to reap the benefits of both an open innovation approach that utilizes new external resources (Chesbrough, 2003; O'Mahony & Ferraro, 2007), and a closed innovation approach that ensures some proprietary protection of innovations through the use of contracts (Gans, Hsu, & Stern, 2001; Mayer & Argyres, 2004). The innovation-related outcomes of these collaborations include intellectual property, commercial products and platforms, and ultimately market success and firm performance. Yet despite their importance, many technology collaborations fail to achieve their technical and commercial objectives.

The alliance literature offers insights into the performance of technology collaborations. This research focuses primarily on structural antecedents of innovation. For instance, studies find that technology collaborations between organizations with strong R&D capabilities and relevant complementary technologies are likely to be high performing (Ahuja, 2000; Hagedoorn, 1993; Stuart, 2000). The broader alliance literature suggests that collaborations with efficient governance forms and between partners with extensive collaboration experience, dedicated alliance functions, and trusting relationships are also likely to be high performing (Anand & Khanna, 2000; Gulati, 1995a; Kale, Dyer, &

Singh, 2002; Uzzi, 1996). Overall, this literature makes a strong case for the importance of structural antecedents for innovative technology collaborations.

Yet while alliance research is instructive, outstanding issues remain. First, its performance measures are often limited. For example, most studies of technology collaborations rely on patent-based measures of innovation. Yet, many collaborating organizations use other forms of intellectual property protection such as trade secrets (Katila, Rosenberger, & Eisenhardt, 2008), and pursue other outcomes such as novel products (Katila, 2002). Studies of alliances per se often use performance measures like duration or subsequent alliance formation (Doz, 1996). But these outcomes lack linkage to innovation, and may even be misleading. For instance, duration is a problematic measure because partners often dissolve technology collaborations when innovation objectives are achieved (i.e., success) (Arino & de la Torre, 1998). These measurement limitations suggest that our understanding of the performance of technological collaborations may be less than it initially appears.

Second and more significant, this research strikingly neglects the collaborative process. Yet as a handful of process studies indicate, the interactions between partners in intensely participative alliances such as technology collaborations seem likely to influence performance (Arino & de la Torre, 1998; Doz, 1996). Indeed, the classic technological collaboration between Intel and Microsoft suggests the importance of process. This seemingly straightforward relationship involved repeated confusion and conflict about technological development, placing future technology collaborations in doubt (Casadesus-Masanell & Yoffie, 2007). Yet these two organizations overcame these problems in a series of collaborations that led to the lengthy dominance of the Wintel platform technologies (Bresnahan & Greenstein, 1999). As Intel CEO Andy Grove once described, these collaborations led to a “symbiotic relationship” that enabled both partners to mutually adapt to the changing demands of the computer industry (Burgelman, 2002: 341).

A central challenge in managing technology collaborations and organizing symbiotic relationships more broadly is that both partners have their own well-established processes for innovation which may conflict. They are likely to have different decision rules for managing R&D, pursue distinct product-market objectives, and have individuals with very different expertise (Allen, 1977; Brown & Eisenhardt, 1997; Clark & Fujimoto, 1991). Reconciling these differences requires recombining aspects of both organizations without excessively constraining innovation (Davis, Eisenhardt, & Bingham, 2009). While the appropriate antecedent conditions may be germane, this reconciliation of decision making, objectives, and participants primarily occurs during the collaborative process. Yet despite its importance, the literature lacks an in-depth account of how partners create high-performing technology collaborations.

Our purpose is to understand better the process by which some technology collaborations generate innovations while others do not. Given limited theory and empirical research, we use inductive, comparative case methods to examine eight technology collaborations among ten firms in the computing and communications industries. By selecting cases that share the antecedents recommended by the literature, we control for these rival explanations in order to focus on the less explored collaborative process. Strikingly, these collaborations have widely varied innovation performance – that is, even partners that possess strong innovative capabilities, appropriate governance forms, and longstanding embedded relationships can struggle with collaborative innovation.

The major results are theoretical insights linking the variation in innovation performance with different collaborative processes for managing recombination across organizational boundaries. Collaborations using two processes that may appear useful – *consensus leadership* and *domineering leadership* – ultimately generate less innovation than collaborations using a third process – *rotating leadership.* Rotating leadership has three components. First, rather than share responsibilities for decisions or allow one partner to monopolize decision making, innovative collaborations alternate decision control between partners across phases of the collaboration. Alternating decision control enables and motivates both partners to marshal their complementary capabilities. Second, innovative collaborations pursue deep and broad innovation search trajectories as partners change objectives across phases. In contrast to narrow trajectories involving few objectives or shallow trajectories in which slow progress is made towards objectives, zig-zagging objectives enable deeper and broader trajectories to search for potential innovations. Third, rather than mobilize the same participants across phases with stable network cascades, innovative collaborations mobilize different participants with network cascades that fluctuate across phases. Fluctuating network cascades access diverse participants to solve different problems at different times. Taken together, these three components constitute the rotating leadership process.

The primary theoretical contribution is to research on the organization of innovation. We highlight major recombination mechanisms that are relevant during collaborative innovation. These mechanisms include marshalling complementary capabilities from interdependent partners with redundant structures, conducting deep and broad search for potential recombinations with a common technological trajectory, and ensuring that diverse inputs to recombination emerge from different participants in the boundary spanning network. The study also contributes to network theory with a better understanding of the innovation performance of interorganizational relationships. While network studies often assume that network ties are likely successful if they are long lasting and produce new ties, we suggest that organizational processes that alter decision control, collaborative objectives, and boundary spanning participation may better explain performance in dynamic interorganizational relationships. A final contribution is to the study of organizational adaptation in interdependent and dynamic environments where a central question is how organizations with long-lived relationships can avoid the tendency toward less productive, inertial collaborations. We suggest that dynamic processes like rotating leadership may be part of the reason why a few organizations like Intel and Microsoft are able to achieve symbiotic relationships that combine longevity and adaptation.

BACKGROUND

The literature suggests three primary mechanisms underlying successful innovation. The first mechanism is the activation of relevant capabilities. As suggested by resource dependence theory, technological collaborations form between partners that are mutually interdependent (Casciaro & Piskorski, 2005; Gulati & Sytch, 2007; Katila et al., 2008). Examples include firms like Intel and Microsoft who produce different products (i.e., microprocessors and software) that are both needed for a complete solution (i.e., PC). To develop innovations together, these partners need to access their complementary capabilities.

The alliance process literature offers several insights into how partners might activate their relevant capabilities (Arino & de la Torre, 1998; Doz, 1996; Hamel, 1991; Larson, 1992; Uzzi, 1997). This work suggests that mutual learning, frequent interaction, and trusting relationships are likely to do so. To illustrate, consider Doz's (1996) study of three technology collaborations in minicomputers, jet engines, and drug delivery systems, respectively. He finds that reinforcing cycles of learning, evaluation, and adjustment allow both partners to use their capabilities. By contrast, when partners fail to learn, they dissolve the relationship prior to achieving their objectives (Doz, 1996). The implication is that learning from each other probably makes activating relevant capabilities more likely. In a study of relationships between garment firms, Uzzi (1997) finds that when partners have trusting, prior interactions, they are more likely to exchange fine-grained information and engage in complex problem solving that may possibly activate their distinct capabilities.

Other alliance studies suggest that when competitive tensions are reduced, partners are more likely to activate their relevant capabilities (Hamel, 1991; Katila et al., 2008; Khanna, Gulati, & Nohria, 1998). For example, in Hamel's (1991) study of two partnerships between European and Japanese firms, he finds that partners who competitively race to learn their partner's technologies often fail to deploy their own capabilities. An implication is that competition between partners limits the activation of capabilities. Taken together, the literature suggests that mutual learning, trust, interaction, and limited competition are helpful preconditions for accessing relevant capabilities. But since this literature addresses neither innovation outcomes nor activation of capabilities directly, it remains unclear how exactly partners activate their relevant complementary capabilities during the collaborative process.

The second mechanism underlying successful innovation is deep and broad innovation search trajectories. Drawn from the innovation literature, a search trajectory is defined as a series of "recombinations" of existing knowledge, technologies, and other resources (Galunic & Rodan, 1998; Helfat, 1994; Nelson & Winter, 1982; Podolny & Stuart, 1995)). This research suggests that pursuing deep search trajectories is conducive to innovation (Dosi, 1982; Fleming, 2001; Katila & Ahuja, 2002). Deep trajectories are composed of a series of elements that build upon prior elements in the series. The argument is that deep trajectories are likely to efficiently avoid useless or unvalued innovations because some familiar elements are reused during each recombination step. On the other hand, excessive pursuit of deep trajectories eventually reaches diminishing returns. Fleming's (2001) research on inventor's search trajectories using a sample 17,264 patents offers empirical support. He finds that patents that cite familiar patent subclasses tend to be cited more often, but that the value of this trajectory can be exhausted if too many of the combinations are utilized (Fleming, 2001).

Research also finds that broad search trajectories are conducive to innovation (Ahuja & Katila, 2004; Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001). Broad search trajectories are created when recombination includes novel elements and makes use of few (or no) prior elements. Broad search is conducive to innovation because it enhances novelty. For instance, in a study of US chemical firms, Ahuja and Katila (2004) find that firms often respond to search exhaustion in deep trajectories by developing broad trajectories that include new elements such as those from basic science. Rosenkopf and Nerkar (2001) find that the most innovative technologies come from a broad search that spans technological categories and organizational boundaries. The most innovative optical disk technologies use knowledge from distant technologies and from multiple organizations. For example, Sony combined error correction techniques with Philips' digital storage techniques to create the CD standard (Rosenkopf & Nerkar, 2001). Taken together, the innovation search literature suggests that both deep and broad search trajectories are necessary for innovation. Deep trajectories stimulate innovation at least until the limit of useful combinations is reached while broad trajectories stimulate innovation by introducing novelty. But since this literature typically only tracks patent citations and product outcomes, the process for how partners with might actually blend deep and broad trajectories search remains unclear.

A third mechanism underlying successful innovation is mobilization of diverse participants over time. Diverse participation is linked to innovation and firm performance in multiple contexts (Beckman, 2006; Mors, 2009; Reagans & Zuckerman, 2001). Maurer and Ebers's (2006) study of six new biotechnology firms makes the further point that this mobilization is particularly relevant over time. They find that the highest performing firms mobilize different individuals over time to make ties to new types of partners as new strategic imperatives emerged (Maurer & Ebers, 2006). But while this research is insightful, it does not examine how mobilization actually occurs.

In contrast, research on project teams that engage in creative actions offers insights into how mobilization might occur (Bechky, 2006; Edmondson & Bohmer, 2001; Klein, Ziegert, Knight, & Xiao, 2006; Obstfeld, 2005, 2010).[i] An exemplar is Edmondson and colleagues' (2001) research on 16 hospitals that implemented new minimally invasive cardiac surgery (MICS) technologies. They find that successful implementation involves an active enrollment process by which new team members are motivated to join by leaders, and subsequently to engage in practice sessions. A key lesson is that mobilization of diverse participants requires leaders to recruit and instruct employees. Mobilization is not automatic. A related study by Klein and colleagues (2006) in a trauma unit further emphasizes the role of leaders in mobilization of diverse participants. By observing treatment of 175 patients, they find that senior leaders repeatedly delegated leadership to and from junior leaders in order to generate reliable performance as well as skill building for novice team members.

While the above research describes the role of leadership in generating mobilization of diverse participants over time, other research on creative project teams emphasizes the complementary role of stable structures in dynamic participation (Bechky, 2006; Davis et al., 2009; Human & Provan, 2000). For example, in a study of four film projects, Bechky (2006) finds that well-established roles give participants enough stability to feel comfortable in producing innovative films. Similarly, stable boundary spanning brokers, defined as individuals who connect otherwise disconnected actors (Fleming & Waguespack, 2006; Tushman, 1977) aid innovation (Burt, 2004; Hargadon & Sutton, 1997). Yet intriguingly, brokers alone may not be enough to ensure diverse participation. As Obstfeld (2005) finds his study of 73 automotive innovations, some brokers are more likely to mobilize diverse participants than others. Brokers who more actively facilitate interactions among employees are more likely to be involved in innovations (Obstfeld, 2005). Overall, this literature indicates that mobilization of diverse participants over time underlies successful innovation, and that this mobilization requires active facilitation by leaders and stable roles especially brokers who bring together participants. Yet how leaders actually mobilize diverse participants across organizational boundaries at appropriate times is unclear.

Overall, research indicates three primary mechanisms that underlie successful innovation: accessing relevant complementary capabilities, pursuing deep and broad search trajectories, and mobilization of diverse participants over time. Yet, it does not clearly describe how these mechanisms are actually achieved, especially in the collaborative processes of technology collaborations.

METHODS

The research design is a multiple-case, inductive study. 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 & Graebner, 2007). Emergent theory from multiple-case research is typically more generalizable and better grounded than theory from single-case studies, making them more amenable to extension and validation with other methods (Davis, Eisenhardt, & Bingham, 2007).

The research setting is the computing and communication industries. This includes organizations that produce a wide range of information technology products including semiconductors, laptops, mobile handsets, and internet software. This organizational field is a particularly appropriate because the convergence of communications and computing created multiple opportunities such as internet services that required technological collaboration between organizations across sector boundaries such as between semiconductors, hardware, and software firms (Bresnahan & Greenstein, 1999; Mowery & Rosenberg, 1998). Thus, collaborations are essential and numerous.

We study technology collaborations between large, established organizations for several reasons. First, such organizations are likely to possess the antecedent characteristics associated with collaboration performance (e.g., extensive collaborative experience), enabling a focus on collaborative process without complicating variation. Second, they are likely to have sufficient resources to attract partners and engage in significant R&D, making collaboration likely. Third, their size is likely to preclude acquisition of one another, putting M&A in the background and making collaboration critical.

Dyadic Sample

We selected 8 technology collaborations between ten organizations. These collaborations lasted from 1-3 years, and occurred between 2001 and 2006. The collaborations are named for their primary technological area (e.g., Security). These areas span many relevant 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 are disguised with pseudonyms from Shakespeare (e.g., Macbeth). They engage in varied 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 have extensive prior relationships as complementors, buyer/suppliers, joint sales and marketers, and even competitors. Six organizations are headquartered in the US and four are headquartered internationally, reflecting the global nature of these industries and enhancing generalizability of our research. Sample details are in Table 1.

A major advantage of our design is its focus on collaborations between partners that possess the key antecedents of superior collaboration performance. These include extensive collaborating experience and dedicated alliance functions (Gulati, 1995a; Kale et al., 2002). They are also strategically interdependent partners in complementary sectors (e.g., hardware/software, circuits/systems) (Gulati, 1995b). In addition, these partners have multiple prior interactions which create some organizational structures and boundary-spanning ties between individuals and workgroups, and are likely to improve performance (Gulati, 1995a; Uzzi, 1997). Both partners also dedicate significant resources to joint development and appropriately 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 partners are technical and market leaders (i.e., 1st or 2nd in market share) in their respective domains. Thus, they are desirable partners who share the common language of the computing and communications industries (Ahuja, 2000; Dougherty, 1992; Lane & Lubatkin, 1998). Overall, by selecting collaborations with favorable structural antecedents, we can focus on the collaborative process and its implications for innovation performance.

Data Collection and Sources

We use several data sources: qualitative and quantitative data from semi-structured interviews, publicly available and private data from websites, corporate intranets, business publications, and materials provided by informants. We conducted 72 semi-structured interviews of 60-90 minutes over 24 months. This resulted in 1643 transcribed pages of primary source material. We interviewed informants at multiple times and from multiple levels of both organizations. Informants included the executive leads who oversaw the collaboration, strategic alliance directors, product-line general managers, laboratory and technical heads, scientists, and engineers. Multiple informants at multiple levels and different times lead to richer and more reliable emergent theory (Eisenhardt, 1989; Miller, Cardinal, & Glick, 1997). Finally, an author also worked for several months on R&D collaborations within a partner firm. Our triangulated, longitudinal data from primary sources in the field provide a rich view of technological collaboration.

We mitigated informant bias in several ways (Golden, 1992; Miller et al., 1997). First, we followed interview guides that focused informants on relating chronologies of objective events, behaviors, and facts of the collaboration. Second, we gathered thousands of pages of secondary data both on-site and from the media about these collaborations to triangulate our interview data. Third, we collected data in real-time as the collaboration progressed, and returned multiple times to conduct sitevisits. This generated both real-time data to mitigate bias and retrospective data to enable efficient data collection (Leonard-Barton, 1990). Finally, we promised confidentiality to motivate informant accuracy.

Data Analysis

We began by writing the chronological case histories of the collaborations. These ranged from 40 to 90 single-spaced pages, and took six months to write. We analyzed the chronologies using both within-case and cross-case techniques (Eisenhardt 1989; Miles & Huberman, 1994). We used a multi-factor measure of innovation performance that is described in the Appendix and displayed in Table 3. This measure captures both technical outcomes such as patents and commercial outcomes such as new products and platforms from the perspectives of both partners. It also includes both quantitative (e.g. patent counts) and qualitative (e.g., subjective assessments) data. Overall, this measure overcomes several shortcomings of prior research such as limited relevance to innovation (e.g., duration) and narrow focus (e.g., patents only), and is a major advantage of our design.

We iterated between the cases and emergent theory, and then weaved in relevant literature. Our phase-by-phase analysis of decision making, changes in objectives, and participation patterns is detailed in Figure 1. In the following sections, we describe our emergent theoretical framework that seeks to explain the striking variation in performance among our collaborations.

ROTATING LEADERSHIP AND COLLABORATIVE INNOVATION

Our collaborations have many similarities. They involve two experienced partners who are motivated to cooperate to develop new technologies, products, and platforms that they could not easily pursue alone. They seek to combine their complementary capabilities in pursuit of their own strategic objectives. For example, one executive asserts, *"This better help us build a new platform!"* while another echoes, *"New products are the only worthy objective."* As noted earlier, they all begin with favorable antecedent conditions. Finally, they even begin with the same initial process activities – i.e., Agreement phase to craft written contracts and Roadmapping phase to do detailed planning. Yet despite these similarities, the collaborations dramatically diverge into widely different leadership processes and innovation outcomes.

Some partners use what we term a *domineering leadership* process wherein a single partner controls decision making, determines innovation objectives, and mobilizes participants. Other partners use a *consensus leadership* process wherein they share decision making, agree to common objectives, and mobilize participants together. Yet, both of these processes have unexpectedly poor innovation performance. Rather, partners who use a *rotating leadership* process. Rotating Leadership involves three components: (1) alternating decision control between partners to access their complementary capabilities, (2) zig-zagging objectives for innovation to develop deep and broad search trajectories, and (3) fluctuating network cascades to mobilize diverse participants over time. We contrast these rotating leadership components and their influence on innovation performance with the alternative components of domineering leadership and consensus leadership below.

Accessing Complementary Capabilities: Alternating Decision Control

A key impetus for technological collaboration is combining the complementary capabilities of the two partners to produce superior innovation. But while this combination might seem easy to achieve, it is actually challenging to access capabilities that are embedded in often very different organizations with their own rules, unique personalities, and structures. Nonetheless, we find that the approach to decision making in the various phases of the collaboration is likely to facilitate this access. In particular, we find three decision making patterns are relevant.

One is decision making that is unilaterally controlled by a single partner who makes most decisions in most phases of the collaboration. A second is decision making that is mutually controlled by both partners through consensus choice for most decisions in most phases. A third pattern is decision making that alternates unilateral control between the partners through the various phases of the collaboration. While the first two patterns have speed and motivational strengths, the third seems to trigger greater access to both partners' capabilities and enhance innovation performance.

We assess the decision making patterns by examining the major decisions in the collaborations. First, we identified major decisions and decision makers, noting when partners made decisions unilaterally or mutually. We define a major decision as any explicit choice that materially affects the collaboration. These decisions are mainly related to specific technical and operational issues, but also include strategic issues such as which technologies to pursue and how to do so, and how to include particular technologies in specific products. We classified each decision as *unilateral* or *mutual* based on who made the choice – i.e., representatives from one partner or both partners, respectively. Fortuitously, informants from both partners typically gave highly consistent designations, explaining, for example: *"We let Mercutio control the marketing deadlines."* or *"Cleopatra's team made that decision."* The number of major decisions in each phase ranges from one to six. This analysis is detailed in Figure 1.

Based on the assessment above, we next analyzed who controlled decision making in each phase and across phases. Because collaborative innovation involves accessing the capabilities of different partners at different times, we focused on changes in decision control. Of particular importance are decision control alternations. These alternations occur when the organization making most of the unilateral decisions in one phase is different than the organization making most unilateral decisions in the prior phase.[ii] Alternations can be either planned or unplanned. Sometimes partners agree that one firm's capabilities are better matched to activities in the next phase and so decision making switches (planned). At other times, one partner seizes (or is given) decision control, often triggered by unexpected external events (unplanned). Collaborations fell into three categories based on whether phases were predominantly characterized by *unilateral* decision control by one partner, *mutual* decision control among partners, or *alternating* decision control between unilateral phases of control by both partners. As Table 2 notes, the number of decision control alternations is our first measure of rotation leadership.

A telling example of alternating decisions is the VPN System collaboration between Rosalind and Prospero. The aim was a novel virtual private network (VPN) system that allows users to access corporate intranets from offsite locations. This required both *applications* expertise from Prospero, a leading software vendor, and *operating system* (OS) and *mobile* expertise from Rosalind, a prominent hardware and systems vendor. From the beginning, both partners agreed that Prospero should control decisions in the Design phase (see phase #2 in Figure 1) because their applications expertise would have the more significant influence on customer adoption. At first, Prospero's managers assumed they would also lead the subsequent phases – Platform Development (phase #3) and Application Porting and Design (phase #4) – because of the importance of applications in these activities.

But after discussions between Rosalind's and Prospero's managers, it became clear that the operating system, which Rosalind controlled, was critical. Rosalind manager explained their control: *"The way it works is they don't have our source code, and <we don't have theirs>. That's the way it is."* While Prospero could design applications with the current operating system, they realized that they could develop significantly better applications if Rosalind applied their operating system expertise to rewrite their OS using Linux. This was a real dilemma for Prospero's managers. Although ceding decision control of the next phase (Platform Development (#3)) to Rosalind would mean accessing Rosalind's considerable operating system expertise to develop a valuable new Linux-based operating system, Prospero would probably be unable to control other decisions that would simultaneously occur. A Prospero manager explained why they ultimately agreed 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."*

Managers from both partners concurred that this planned shift in decision control enabled tapping into Rosalind's operating system expertise to develop a robust, new Linux OS 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."*

After the Platform Development phase (#3), Rosalind returned decision making control to a Prospero team with application expertise in graphical user interfaces (GUI). Based on their GUI expertise, they led the interface design for the security application, making major decisions affecting the customer-experience during the Application Porting and Design phase (#4). As a Rosalind manager reflected, "*We found that somebody really had to take the lead.*"

Although they would use a joint engineering team from both partners, managers from both sides intended for Prospero to retain control in the next phase, Application Development (#5). The expectation was that many innovative application features would emerge. But in parallel, Prospero's senior technical executives were pursuing a major acquisition. An executive explained,

> *" 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, the acquisition stumbled. As a result, several Prospero managers, who were intimately involved with the collaboration, turned their attention to the acquisition fallout. After weeks of silence, Rosalind's managers chose to take over the joint engineering team and continue the phase without Prospero's key executives. As Rosalind manager said, *"We took over!."* Consequently, Rosalind's executives made unilateral decisions about the technical scope of the product that reflected their expertise and strategic objectives. For instance, they directed the team to prioritize mobile security technologies and features because Rosalind had more strategic interest and deeper technical expertise in these technologies. Thus, Rosalind led an unplanned alternation of decision control.

Later, Prospero's executives returned to an on-schedule collaboration that was close to key milestones. While the emerging VPN product reflected Rosalind's expertise in mobile security, it also fit Prospero's requirements. A Prospero manager noted the value of shifting decision control:

> *"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."*

In contrast, less successful collaborations (E-Commerce; Wireless Networks; Web Services; VOIP Phone) used either mutual or unilateral decision making. Consider Lear's Web Services collaboration with Ophelia which combined Lear's *software* expertise with Ophelia's *internet infrastructure* and *database* expertise. Lear, a leading software developer, planned to make the major decisions 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 unilaterally develop software to access Ophelia's customer database. Ophelia's sole contribution would be to grant Lear access to their database and provide minor input on the design of the internet infrastructure. Asked about complementary expertise, Lear's technical lead focused on Lear's expertise and 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 informally influence Lear's decisions. 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 continued to make all major decisions.

In later phases, Lear managers continued to make all decisions. Consequently, Ophelia's managers abandoned their early optimism, and openly worried about how they would apply their Internet infrastructure 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>…"* In addition, this same Ophelia manager noticed that his colleagues lost the motivation to engage in the collaboration. They became *"afraid of working with Lear"* and fearful that *"bad things might happen."* Ophelia's participants worried that their inability to influence decisions would make it difficult to apply their capabilities to the project and lead to a failed collaboration. As described below, their fears were realized.

By contrast, Falstaff and Macbeth used mutual decision making in their Wireless Networks collaboration by engaging in consensus-building with agreements sealed "*on a handshake*". The collaborative objective was to combine Falstaff's *wireless systems* capabilities and Macbeth's *circuit* expertise to create new technologies and products in the "Wireless LAN" area. As one manager noted, *"<the main idea> is to use Macbeth's fast <silicon> and Falstaff's Ethernet IP on these new <wireless standards>."* The managers of both partners explicitly committed to mutual decision making, which they had previously used in a successful marketing collaboration. As one manager said, *"We really leveraged the smooth processes in the marketing collaboration."* As a result, they sought agreement on major decisions. But regrettably, this required extensive discussion that took time and created misunderstandings.

With mutual decision making, decision roles became increasingly unclear in later phases. For example, a key misunderstanding emerged about the complex issue of whether and how Macbeth would use Falstaff's technical certification process. Whereas Falstaff thought 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 this networking company needed to ensure that all 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 did not 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."* The two proceeded thinking that they were in agreement but they were not. Later, despite extensive discussion, Macbeth and Falstaff managers had difficulty reconciling their widely differing views on certification.

Alternating Decision Control and Innovation Performance. Alternating decision control is likely to improve innovation performance because it facilitates partners' access of their complementary capabilities. By controlling decisions at various times, each partner is able to make the crucial choices that bring in desired capabilities to the collaboration, and is more motivated to do so. For example, alternating control of VPN System collaboration (described above) three times allowed Rosalind and Prospero to apply their different capabilities. The alternation which gave Rosalind control of phase #3 allowed them to decide how to deploy their operating system expertise to create a particularly robust system. This in turn gave Prospero the Linux system that they desired because this system would allow development of more novel applications. This then led Prospero to bring in its advance applications expertise. Further, designing a new GUI (graphical user interface) for applications on Rosalind's new Linux-based operating system led to unexpected innovations in Prospero's prototyping methods. More unexpectedly, the unplanned alternation to Rosalind during Prospero's acquisition distraction accessed Rosalind's deep mobile capabilities and produced VPN mobility 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)"*

Moreover, Rosalind's unexpected assumption of decision control allowed Prospero to then use its own capabilities in a complementary, but unanticipated, way in later phases. Ultimately, this collaboration generated a VPN product with superior mobile features, speed, memory, and unusually robust mobile integration that would become a market leader.

A key point is that the high-performing collaborations had both planned and unplanned alternations. Indeed, the common pattern is to begin with planned alternations in the first few phases with unplanned alternations in later phases. Partners seemed to choose planned alternations in order to ensure that known capabilities from both partners are utilized. A Security manager noted, *"We want them as a co-creator of <technologies> and that means making them heavily involved. … We tried to stay out of their hair."* Unplanned alternations often emerge later when single partners unexpectedly recognize that their capabilities are well-suited to new problems or when external events trigger a change opportunity. The prior planned alternations may prepare them to adapt favorably to later unplanned alternations. Another manager summarized his view of planned and unplanned alternations, *"Does it really matter how we get there…as long as we get our shot?"*

In contrast, collaborations with unilateral decision making were less able to access the capabilities of the non-leading partner. For example, in the Web Services collaboration (described above), Ophelia engineers delivered specified internet technologies (e.g., APIs, database scripts) requested by Lear, but took little initiative to seek the "best" technologies within Ophelia. Ophelia's managers, for instance, knew that an elegant technical solution to an internet database problem existed in their search-engine division. But they did not bring it to the collaboration. They feared that without decision control, they would be unable to use this new technology well. As one said, *"I didn't really know if they needed it,"* and *"I didn't want to stick my neck out."* In retrospect, using Ophelia's leading-edge search technology would have substantially improved the resulting product by expanding the range of applicable web services. Indeed, Lear's technical leaders later regretted not finding this "*missing link*". According to one Lear manager, *"We wanted demonstrate <the product> as a smart client application. One of the things was that it needed to be able to consume web services."* Ultimately, the Web Services collaboration produced a simplistic prototype with narrow utility. As an observer said, *"Lear created a solution that looked pretty basic and rudimentary compared to what some of their developer communities [could] come up with."*

Finally, in collaborations with mutual decision making, it was ironically also difficult to access both partners' capabilities albeit for different reasons. Here, unclear decision making roles and slow pace stalled access to capabilities. For example, the confusion about whether to use Falstaff's certification process in the Wireless Networks case (above) led to circuits that did not fulfill these requirements and needed redesign. Without certified circuits, Falstaff was unable to apply its detailed knowledge of wireless interfaces in the next phase. Waiting for redesigned circuits drastically slowed the collaboration and postponed innovation. As a Macbeth executive complained, *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 for the collaboration. 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].*"

An alternative explanation to decision patterns is that some capabilities are inherently more difficult to access or combine. But this explanation is unlikely since similar capabilities were involved in both more and less innovative collaborations (see Table 1 for details). Furthermore, our collaborations typically join partners with the capabilities that are typical bases of complementarity throughout the numerous collaborations in these industries (e.g., circuits/systems, devices/software). Rather, alternating control seems to enable partners to access their complementary capabilities more effectively. When a partner controls decisions in phase, its managers are better able to know which of their own capabilities to access. Even when a partner does not control a phase, its managers are more motivated to assist by offering their own capabilities. Thus, 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 the tendency of partners to over-rely on their own resources.

Deep and Broad Trajectories: Zig-Zagging Objectives

Successful innovation relies on deep and broad search of the technology space (Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001). Deep search enables efficient cumulative improvements along specific technical trajectories while broad search such as by combining partners' complementary capabilities creates novelty. But while this blended search may seem easy to achieve, it is not so obvious how partners who have different objectives actually coordinate such search trajectories. We find three patterns of technology objectives are relevant.

One pattern often occurs when collaborations are led predominantly by one partner. Since such partners engage in little incorporation of their partner's perspectives, they rarely change objectives. They may make progress towards these objectives. But since other objectives are rarely explored, the resulting search is often narrow and lack breadth. A second pattern often both partners share leadership of the collaboration. Sometimes the partners may agree to change objectives, but they often make slow progress because they need to gain consensus about what to do. Given limited time, the resulting search is often shallow and lacks depth. In contrast, collaborations following what we term *zig-zagging objectives* often emerge in collaborations where partners frequently alternate control of phases. Zig-zagging objectives trigger search depth because the partners often use their phases of unilateral control to make cumulative technological progress towards their preferred objectives. But zig-zagging objectives also trigger search breadth because leading partners often shift objectives from those of their partner in prior phases. The number of changes to collaborative objectives is our second measure of the rotating leadership process. Table 2 summarizes and Figure 1 provides details.

A collaborative objective is defined as any high-level strategic goal related to the joint development of technologies, products, or platforms. Typically, partners agree to the initial objectives in the collaboration's first phase. Yet initial objectives often outline only the basic opportunity (e.g., Mobile Email, VOIP phone) and leave important objectives open (e.g., target market). We observed that objectives can change in three ways: partners can eliminate, switch, or add objectives (see Figure 1). Examples include when partners switch from a proprietary to open-source strategy, eliminate the use of an old technology, and add a target market. Partners change objectives when managers make explicit decisions to alter objectives, or when events force changes such as when R&D experiments indicate one technical alternative over others and when running out of time effectively eliminates an objective.

To illustrate zig-zagging objectives, consider Portia and Rosalind's Mobile Email collaboration. The initial objectives focused on building smart phones with email functionalities. The objectives changed nine times during the collaboration. For instance, when Portia led the Roadmapping phase (#2), they focused on the objective of making their mobile email software work on Rosalind's mobile devices. Yet soon Portia's managers realized that Rosalind's phone platform would need redesign 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 new objectives:

> *"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."*

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 objectives emerge because organizations adjust their objectives in response to decisions and outcomes resulting from their partner's control in a prior phase. For instance, when decision control switched to Rosalind in order to integrate Portia's email software with a new user interface during the Product Porting (#3) phase, 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 the related new search 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 disagreements, Portia's executives ultimately yielded to Rosalind's request to change the objectives by redesigning the back-end interface.

By contrast, when one partner dominates, this partner often blocks changes to objectives and thereby narrows search trajectories. For example, Lear's unilateral control 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 was expected to create value for both partners. The initial objectives involved access to various internet websites by combining Ophelia's web services technologies with Lear's software application suite. Ophelia's managers pushed the Lear team to consider the larger possibilities of Web 2.0 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 expand the objectives to other product-applications of web services technologies. As one Lear manager noted, *"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 search trajectory moved steadily towards Lear's lesser aspiration of integrating Ophelia's database with their application, missing major opportunities to innovate in the fast-growing Web2.0 space.

Finally, when partners share leadership, they often make no changes to objectives or a few changes that usually diminish initial aspirations. The collaboration ends up following shallow search trajectories. Consider the Wireless Networks case, where some participants wished to add new objectives during the Technology Development phase (#4). Yet since changes in objectives required sign-off from managers in multiple business units in both companies, they never received approval. As one manager said, *"This seems slow. We're just waiting <for Falstaff> to find the right manager. They need to bless the meetings."* These managers either questioned the collaboration's value or tried to impose competing requirements. The resulting delays prolonged engineering activities such that milestones were missed. Eventually, disappointing progress reviews led to new executive leadership at Falstaff. They tried to impose a new objective using resources from other business units in the hope of salvaging the collaboration. In so doing, they significantly lowered their aspirations to an easier 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."*

Zig-zagging Objectives and Innovation Performance. Zig-zagging objectives enable partners to search for potential innovations deeply within phases and broadly across phases as partners shift objectives. For example, early changes to objectives allowed Portia and Rosalind to ensure that a new set of carrier requirements was incorporated into the handset design in the Mobile Email case. Later changes in objectives led to an unexpected combination of a "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 search made it difficult for competitors to copy their solution. One Rosalind manager summarized the valuable innovative 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, when mangers refuse to change the objectives to incorporate their partner's perspectives, they often fail to explore alternatives within the broad technology space and, ultimately, to innovate.[iii] Moreover, when one partner dominates, the changes that do emerge often focus on responding to unexpected failures. For example, after limiting the product applications in the Web Services collaboration, Lear's managers refocused product development to target a much narrower market segment that 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 objective – combining web services software with their applications – but in a routine way that was not innovative. A Lear manager admitted, "*Now, the application itself, was it the most compelling broad reach? No, no it wasn't."*

Finally, when partners share control, they often initiate some changes to objectives but they progress slowly towards achieving them. Prior research suggests that failing to meet objectives can lead to early dissolution of collaborations (Doz, 1996). Consistent with this view, one of our consensus cases – VOIP Phone collaboration – was abandoned after a relatively short 21 months and 6 phases because of slow progress towards objectives. Yet slow progress does not always trigger dissolution. For example, after wireless chips were slow to develop during Technology Development (#4) phase of the Wireless Networks collaboration, the partners consensually chose to reduce the number of chip features but continued the collaboration. This collaboration lasted 34 months with 6 phases, approximately average for our cases. Eventually, the partners agreed to five changes in objectives that led to workable products based on moderate improvements in technological performance. *"Those changes really saved us."* The search trajectory was, however, relatively shallow compared with the trajectories of more innovative collaborations, and the resulting innovation was incremental at best. *"We ultimately did make a product. But it seemed we missed that strategic focus."*

An alternative explanation is that collaborations sometimes have inherently less ambitious objectives from the start. So changes to objectives are unlikely, and innovation will be limited. Yet this explanation seems unlikely because the initial objectives of the collaborations (see Figure 1) indicate comparably high aspiration levels across cases such as *"We bet the company on this."* Each collaboration also received extensive financial resources to fund day-to-day activities, extensive time and scrutiny from top managers, and assignment of multiple participants for many months (described below). Moreover, all collaborations initially pursued opportunities that ultimately became important markets. Taken together, there is little evidence that failed collaborations were inherently less ambitious.

Rather, the data indicate that changing objectives enables partners to search the technology space broadly for innovations as they seek to achieve new objectives. These changes to objectives often define new technical problems, and so engender search for new ways to solve them. As a result, the partners search for innovations along fresh technological trajectories, leading to broader search and better innovations. At the same time, the partners retain enough stability in their objectives to create relatively deep search that accumulates technical progress.

Mobilizing Diverse Participants: Fluctuating Network Cascades

Successful innovations typically require leaders to mobilize diverse individuals to participate at different times (Ibarra, 1993; Obstfeld, 2005). Yet prior research is relatively silent on how leaders might actually do this. In contrast, we observe a common mobilization pattern: in every phase of the collaborations, one or several people begin a cascading mobilization of participants by contacting other individuals who in turn involved others. These cascades often mobilize networks of executives, managers, and engineers that span the two organizations.[iv] But while all collaborations have cascades, there are differences in whether and how these cascades change across phases.

One pattern is a relatively stable cascade that repeatedly mobilizes the same participants who are predominantly from the same partner. That is, a stable cascade mobilizes the same participants from one organization throughout the collaboration. A second pattern is a stable cascade that mobilizes the same participants, but from both organizations. In contrast, a third pattern is fluctuating cascades such that leaders mobilize different, often new participants across phases and encourage others to involve different, new participants as well. The result is the mobilization of diverse participants over time. Like a waterfall whose flow shifts, fluctuating cascades vary the perspectives and resources applied to the collaboration.

We assess participation in a cascade by tracking who participates in each phase, who mobilizes them to do so, and in what order the mobilization occurs. For example, in the cascade Jane → Bob → Dave & Jill, Jane begins the cascade and enlists Bob. Bob then simultaneously enlists Dave and Jill. We measure an individual's participation in a cascade as occurring when two or more informants stated that this person worked on the collaboration, and we then track who enlisted his or her participation.[v]

Next, we assess cascade fluctuation in each phase. 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 the next phase – Bob and Dave provide continuity across phases while Andrew is new. We measure fluctuation in two ways. The first is the percentage difference in participants between successive phases. 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%. This measure captures the fluctuation between two phases. The second is the percentage of new participants in each phase. This captures entirely new participants. 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%. We compute both measures – (1) different participants and (2) new participants – for each phase, and average them across phases to generate two measures of fluctuation. Table 2 summarizes and Figure 1 provides the details. We also observe that fluctuations often occur because of qualitatively different tasks in the new phase where different expertise seems valuable – e.g., Dave brings Andrew into marketing activities because of Andrew's detailed customer knowledge.

To illustrate fluctuating cascades, consider the Security collaboration. This collaboration sought to develop new circuits to enable better network security. As Falstaff and Macbeth alternated control and changed objectives, managers mobilized many different and new participants in most phases. For example, the Design phase (#3) began when Macbeth's CTO directed his engineering Vice President to prepare a design proposal for Falstaff's executives to review. Macbeth's CTO further encouraged this VP to mobilize others with critical expertise from both organizations. As one Falstaff participant explained:

> *"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."*

Macbeth's VP continued the cascade by turning to his trusted subordinates, including two technical project managers, to help formulate the technical details of the "advanced Security" proposal for Falstaff. The team of three worked on the proposal until they found the "right language" for joint development. They then had a breakthrough meeting in which they mobilized Falstaff executives. As one member described:

> *"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."*

Unbeknownst to Macbeth's participants, Falstaff participants called upon their security product managers to assess Macbeth's proposals. As one manager explained, *"We had Peter and Maria in the room as Falstaff's executive sponsors,"* and it was not 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 new participants. Intriguingly, the resulting cascade added diverse participants from both organizations in ways that surprised the source of the cascade, Macbeth's CTO.

Participation fluctuated again as Falstaff's managers took the lead in the next phase, Prototyping (#4). Falstaff's VP began the new cascade when he mobilized a trusted alliance manager who, in turn, enlisted an experienced engineering director to lead a Falstaff security engineering team to build prototypes. During the Prototyping phase, seven different participants (88% of the total eight) were mobilized, six of whom were new to the collaboration (75%). A director and security team who had worked in prior phases were also mobilized in Phase 4 and provided continuity.

Mobilizing Falstaff's engineering director was critical in this phase because he had both deep connections into Falstaff's product groups and also knew security experts at Macbeth. Before this engineering director was mobilized, 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 this director was activated. Using a waterfall metaphor, one manager explained: *"The beginning of Falstaff's waterfall seems slow. It seems slow for the water to fall into their product groups….But he helped us reach their [security and hardware 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 then worked together to develop prototypes that would become the basis of their new products.

In contrast, some collaborations have stable cascades. For example, collaborations that are controlled by a dominating partner often mobilize the same cascade that goes down the chain-of-command of the controlling firm. Yet since this partner never relinquishes control, few participants are mobilized from the other firm. For example, Lear generated similar cascades in each phase as they retained unilateral control of their Web Services collaboration with Ophelia. After the Agreement phase (#1), Lear's executives always began cascades by calling upon the same two project managers. As a result, there was little participant diversity. For example, the Roadmapping (#2) phase mobilized 29% different and 29% new participants. The next Platform Development phase (#3) repeated the same cascade with 0% different and 0% new participants. Sometimes, however, Lear executives did mobilize Ophelia participants. But, Lear's co-leads would always call upon the same Ophelia manager who would then direct the lower level employees to work on the collaboration. Although as a Lear manager described, *"It took very little effort… We just talked to <Ophelia's project manager>."* Lear failed to mobilize diverse participants. Finally, after each phase was almost complete, the Ophelia project manager would mobilize his boss – Ophelia's VP of technology platforms – to approve the phase. 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.'"*

Limiting involvement of Ophelia to the same managers and engaging them in quick “sign-off” duties in early phases of the Web Services collaboration created obstacles to mobilizing Ophelia’s technical platform experts when they were especially needed in later phases. These experts waited until their executives became personally involved before becoming engaged themselves. Even then, they were reluctant. For example, only 14% different and 14% new participants were mobilized in the Product Development phase (#4). These stable cascade patterns can be traced back to the Roadmapping phase (#2) in which very few new participants were mobilized in the high-level planning of technology standards and milestones. The contrast with the innovative Security collaboration is striking – i.e., 29% new participants (i.e., 2 new people) compared to 70% new participants (i.e., 7 new people) during the equivalent Roadmapping phases (#2) in the Security collaboration.

Finally, collaborations with consensus control often also have stable cascades. These cascades often involve significant participation from both firms, and have a pattern of “maximum involvement” that the initiating managers hope will mobilize a single large team to work together in every phase. Yet because of the high time-commitment that these collaborations often require, managers were often able to mobilize fewer participants than they wished. They ended up with relatively stable cascades with stagnant participation from the same over-involved employees.

For example, the VOIP Phone collaboration produced stable cascades. 33% different and 33% new participants were mobilized in the Project Scoping (#2) phase, but 0% different and 0% new participants were activated in the subsequent Technology Development (#3) phase. The recurring cascade involved the same pair of managers from both organizations who always called upon the same executives and, then mobilized the same cross-functional team of functional experts and engineers. As one manager claimed, *“We aim for maximal involvement.”* Managers asked participants to stay involved in all phases of the collaboration, and waited until this lengthy activation cascade to complete before beginning the next phase.

This cascade pattern ossified over time. Team meetings became longer and more frequent. As one engineer described, *"This is just taking so long. We're just waiting."* Moreover, although many participants were obliged to attend most meetings in each phase, many phases actually required fewer participants. Not surprisingly, potential new participants avoided this project because of the high and seemingly pointless time commitment of mobilizing in every phase. For example, several prominent technology experts, who might have rescued the collaboration from technical failure, refused to participate because they did not understand why they should attend every marketing meeting. Thus, ironically, initiating managers were unable to change their cascades to mobilize valuable experts in later phases.

Fluctuating Cascades and Innovation Performance. Fluctuating cascades mobilize diverse, new participants. By initiating cascades with different individuals, and then encouraging them to continue mobilizing new and relevant people, the executives who initiate fluctuating cascade enhance the range of knowledge and perspectives without wearing down participants. The result is better innovation performance. The Security collaboration illustrates. As described above, its fluctuating cascades involved new and different participants from various labs, divisions, and functional groups in each phase. The partners initiated cascades that mobilized 67% different and 44% new participants, on average, across phases. CTOs from both Falstaff and Macbeth provided continuity and orchestrated the initiation of these cascades by mobilizing diverse, yet relevant, individuals, and directing mobilized individuals to do the same. The collaboration secured beneficial diverse technical expertise in semiconductor design, chipsets, firmware, interfaces, and systems software from both organizations.

Consistent with prior research (Klein et al., 2006), executives are crucial to fluctuating cascades. They assert control over the initiation of cascades in ways that fit with the task demands of the phase. For example, as described above, executives initiated a cascade that resulted in mobilizing a technical director with security expertise that was critical in later phases. But these executives also initiated a cascade that mobilized lower-level engineering teams with expertise in computer networking, operating systems, and servers that was also critical to solving problems. As a 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 obvious candidate. … Now we are able to deliver value to customers in new ways."* Indeed, managers attributed these and other innovations to their partner's expertise that was mobilized through fluctuating cascades. As a Macbeth manager noted, *"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 initiating executives also encouraged others later in the cascade to mobilize similarly diverse people. Moreover, these fluctuating cascades often engage only relevant individuals, and thus avoid the collaboration "fatigue" that plagues the stable collaborations that try to mobilize many individuals for every phase. Overall, the security collaboration was highly successful. It produced 19 patent applications as well as new and commercially successful products for both firms that solved complex security problems for enterprise customers and consumers. As one executive exclaimed, *"So, I really do feel strongly that this was a success."*

By contrast, stable cascades activate the same participants. When these cascades are dominated by one firm, knowledge diversity is limited and innovation performance diminishes. For example, the Web Services collaboration involved only 24% different and 18% new participants, on average. Lear's executives finally recognized during the Product Development (#4) phase of the Web Services collaboration that they lacked enough knowledge of Ophelia's technologies to reach milestones in time. Yet by that time, potential Ophelia participants were wary and even disinterested in the collaboration. Indeed, the disadvantages of stable cascades often become apparent only later in the collaboration. When it became clear that the collaboration would generate only rudimentary web services integration, Ophelia's VP proclaimed the collaboration *"dead on arrival."*

Finally, while collaborations that involve shared leadership are able to mobilize participants from both firms, they too often have stable cascades that limit diverse participation and diminish innovation performance. While attempting to gain broad participation, these collaborations also require extensive communication and complex coordination that drain participants and cause potential new participants to avoid participation. 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, and discouraged new potential participants with key expertise from joining. As a result, participation in these collaborations stagnated. Particularly in later phases, collaboration leaders were often unable to mobilize needed new participants. Overall, the Wireless Network collaboration suffered from too little diversity, especially in later phases, and had mediocre innovation performance.

An alternative explanation to fluctuating cascades for mobilizing diverse participants is that our collaborations differed in the degree to which diverse participants were needed. In this explanation, participants are assumed to automatically join relevant collaborations, and stable cascades simply reflect collaborations that did not require diversity. But, this explanation is unlikely to be true. Our collaborations often have many of the same phases, and yet have very different patterns of cascades (e.g., new participants in the Product Development phases of more v. less innovative collaborations like Security and Web Services). In short, while it seems that new participants might automatically join as appropriate, they in fact do not. Moreover, it is likely to be unrealistic to expect that participants can access the important knowledge of non-participants through informal practices like conversation because technical knowledge is typically tacit and difficult to transfer (Hansen, 1999; Rodan & Galunic, 2004). Fluctuating cascades are also important because those who initiate cascades often do not know which participants might be needed. They often have limited knowledge of participants beyond their local networks (Casciaro, 1998; Krackhardt, 1990). Overall, fluctuating cascades assemble diverse participants, a key mechanism that underlies successful innovation.

DISCUSSION

Our core theoretical contribution is a new theoretical construct, rotating leadership. This process explains *how* partners successfully innovate across organizational boundaries. Rotating leadership includes three components: *alternating decision control* which enables both partners to make unilateral decisions that access their complementary capabilities, *zig-zagging objectives* which frequently change technological objectives and re-direct search trajectories, and *fluctuating network cascades* which mobilizes different and new participants across phases of the collaboration. We also contribute related measures of each component (alternations, objective changes, different and new participants) and a rich multi-factor measure of the innovation performance construct. Explaining how rotating leadership better facilitates collaboration innovation than domineering and consensus leadership processes involves understanding how it activates three major mechanisms related to the recombination of knowledge, technologies, and other resources across boundaries.[vi] We describe these mechanisms below.

Recombination Mechanisms in Collaborative Innovation

The first mechanism that underlies successful collaborative innovation is accessing complementary capabilities and resources from both organizations. Prior research suggests that the tacit and complex technical knowledge of capabilities is difficult to transfer, integrate, and recombine (Hansen, 1999; Rodan & Galunic, 2004). While these features of knowledge certainly present challenges, we suggest that accessing complementary capabilities is particularly difficult because it requires alternation of control between partners. Although managers in dominating organizations believed they could access complementary resources from their partner without relinquishing control to them, they had troubles doing so because leading partners were unable to discern the basis of specific complementarity and non-leading partners were less motivated to assist them without having decision control. Marshalling complementary capabilities from both partners seems to involve a difficult paradox – unilateral control for *both* organizations – that is resolved by separating intervals of control over time through a series of alternations. And in contrast to shared control with consensus leadership, alternating control allows clear roles and the true basis of complementarity to emerge after participants examine their partner's behaviors and outputs in prior phases of control. Thus, temporal separation of control through alternating decision control allows both partners to access complementary resources.

The second mechanism is deep and broad search for potential innovations. This search pattern is by no means an inevitable outcome of simply accessing complementary capabilities. While deep search can simply emerge from cumulative invention, prior research suggests that broad search is particularly difficult to achieve because innovative development involves uncertainty about the value of various recombinations, potentially long timeframes, and a wide variety of possible technological trajectories that are difficult to evaluate *ex ante* or even *ex post* (Dosi, 1982; Dougherty, 1990; Henderson, 1995; Tripsas, 1997). We add to this literature by noting how objectives change collaboratively, and what happens when they fail to do so. The stable objectives that often occur with domineering leadership 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 incrementally). Instead, the failure is due to difficulty in taking their partner's perspectives to change objectives. Consensus trajectories fail not because of a lack of planning (actually many conflicting plans emerge). Instead, these partners struggle to select and execute a single plan and thereby improve technical performance. Zig-zagging objectives allow partners to extend deep search trajectories in new broad directions as partners change objectives.

A third mechanism is accessing different recombination inputs from the diverse participants in a boundary spanning network. Prior research suggests that brokers and boundary spanning ties spur innovation because they are more likely to access diverse information (Beckman & Haunschild, 2002; Burt, 2004; Obstfeld, 2005; Tushman, 1977). But each of the collaborations that we studied included brokers and boundary spanners. This alone did not guarantee that diverse participants would be mobilized to bring their unique resources to the collaboration. Mobilizing diverse resources is difficult not only because diverse resources may not be present in a given network structure. More importantly, it is also difficult to assemble different teams to access diverse resources that are present. When compared to domineering and consensus leadership processes – which share a reliance on mobilizing very similar participants across phases – the fluctuation pattern solves the problem of mobilization diversity.

Network Theory and Performance of Dynamic Interorganizational Relationships

This study also contributes to network theory by providing a better understanding of the performance of interorganizational relationships. Some prior studies drawing on network theory assume that interorganizational ties are successful if they are long lasting or if they produce new ties. Other studies argue that structural antecendent conditions such as firm size, age and experience will ensure successful ties. But while some structural conditions may be necessary (e.g., trust, capabilities, size) (Gulati, 1995b; Stuart, 1998; Uzzi, 1997), these conditions are not sufficient for success. They do not sufficiently constrain collaborative processes to determine a priori outcomes that unfold. This presents a fundamental challenge for managerial action and scholarly explanations of performance. For example, we observe that a leading partner's strong R&D capabilities can drive executives to prefer domineering leadership, whereas strong embedded relationships may lead partners to prefer consensus leadership. Yet strong capabilities and embedded relationships per se do not strictly determine whether consensus and domineering processes, respectively, emerge. Both of these structural antecedents can also yield rotating leadership. We conclude, therefore, that a process perspective productively complements the pervasive structural view to explain more fully the performance of network ties between organizations.

Considering process components separately and collectively may offer the most potential for explaining a broad range of innovation collaborations. 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 to alternate control. In this context, we might expect dampened alternation but sufficient fluctuation, resulting in partial innovation benefits at best. Thus, such differences in power and resources may imply a different weighting to process components.[vii] Our E-Commerce case is instructive since this moderately performing collaboration mixed domineering and rotating leadership. Although Lear's managers intended to control the entire collaboration, their plan was thwarted for one phase when control alternated unexpectedly to

Mercutio and then later unexpectedly back to Lear. As a result, this case provides our best test available for the idea that unplanned rotations can be effective even without support from planned rotations. The net effect of alternation in this collaboration was to break Lear's inward focus and central planning, radically change the objectives, and rescue this collaboration from total failure. This suggests that even a subset of rotating leadership components can provide some benefits. Future research could explore this further.

Rotating Leadership and Symbiotic Relationships

A final theoretical contribution resolves a puzzle in the network literature on interorganizational relationships and organizational adaptation. Typically, long-lived relationships are thought to become inertial and less beneficial as the opportunities for inter-partner learning and recombination become exhausted with time (Doz, 1996; Fleming, 2001; Hamel, 1991; Hargadon & Sutton, 1997). Even long-lived, socially embedded relationships which have been studied involved mostly routine exchanges in stable environments where adaptation is not a primary concern (Gulati, 1995b; Uzzi, 1997). The puzzle is how organizations maintain so-called *symbiotic relationships*, which continue to be adaptive for long periods of time despite the tendency to become inertial. An important example is the multi-decade relationship between Intel and Microsoft, as Burgelman (2002: 341) describes in his study of Intel:

> *"[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…"*

How do organizations develop symbiotic relationships which combine longevity and mutual adaption?

Rotating leadership may be part of the solution because of its capacity to facilitate innovative development over a series of collaborative alliances. Prior research shows that innovations are often precursors of adaptive changes to strategies and organizational structure (Greve & Taylor, 2000). We find some evidence linking rotating leadership with adaptive changes to strategy and structure. Specifically, partners use new technologies, products, and platforms from innovative technological collaborations 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). By contrast, less innovative technology collaborations lead 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). In dynamic environments, these positive adaptations may have a generative effect. Thus, by facilitating mutual adaptation, rotating leadership may create a context in which new collaborations emerge and symbiotic relationships are extended in time.[viii]

Boundary Conditions and Relevance to Dynamic, Interdependent Environments

As in all research, it is important identify key boundary conditions.[ix] We note two major ones. First, rotating leadership is likely to be particularly relevant in interdependent environments. In environments like the computer industry where value chains are disaggregated and technical leadership is divided among firms (Adner & Kapoor, 2009; Bresnahan & Greenstein, 1999), rotating leadership solves the underlying boundary spanning recombination problems that emerge. In these industries, building innovative products often involves changing architectures that span sector boundaries (Jacobides, 2006; Ozcan & Eisenhardt, 2008). By contrast, non-interdependent industries may contain many competing firms that lack clear complementarities that render technology collaboration is less common and less important.

Second, rotating leadership is likely to be particularly relevant in dynamic environments where collaborations are highly unpredictable. Rotating leadership often involves unplannesd alternations, unexpected changes to objectives, and a shifting array of participants that are useful in contexts where unforeseen combinations must be developed for value to be created. Therefore, we expect rotating leadership to be most useful in dynamic markets where genuinely new technological opportunities are emerging and a process that generates unpredictable outcomes is likely to be germane (Davis et al., 2009).

Overall, our theoretical framework reaches boundary conditions in non-interdependent and non-dynamic industries where organizations lack useful technological complementarity and the need to develop surprisingly novel and useful combinations (i.e., innovations). In these industries, domineering or consensus processes may be well-suited to collaborations, given the costs of alternating control.[x] Finally, rotating leadership is likely to be relevant beyond inter-organizational collaborations. We expect that it applies to any technology collaboration in unpredictable environments that crosses the boundaries of groups that have complementary capabilities. These collaborative innovation phenomena include cross business-unit collaborations within an organization, cross discipline collaborations within an R&D unit, and cross group collaborations in innovation communities outside of organizations where the fundamental mechanisms that underlie innovation are the same.

CONCLUSION

Our theoretical contributions focus on recombination processes like rotating leadership that marshal capabilities, change search objectives, and vary participation in ways that activate collaborative innovation mechanisms, change network content, and generate adaptive symbiotic relationships. These ideas differ from perspectives emphasizing structural antecedents like R&D capabilities, embedded relationships, and dedicated alliance functions. These structures may be useful preconditions for innovation but do not capture the fundamental mechanisms and problems of collaborative innovation. An important lesson is that, without methods for exploring such processes, the structural variables that are often readily found in public databases can easily mask dynamics that are at the heart of organizational phenomena. Critical in this regard is an important methods contribution of this study: selection of cases that share antecedent structural characteristics generates quasi-experimental control and so sharpens the focus on less well explored process phenomena that offer an important explanation of innovation. Indeed, if our emergent theory of rotating leadership survives empirical test, it could provide a richer account of collaborative innovation phenomena that are increasingly relevant in dynamic and interdependent industries.

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Table 1: Description of Collaboration Cases

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

Table 2: Summary of Evidence Linking Rotating Leadership and Collaborative Innovation

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

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)

								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	
Alternation			(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)

								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	
Alternation		(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	#2	#3	#4	#5	#6	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	
	Transition			P (between #2 and #3)	P (between #3 and #4)	U (between #4 and #5)		
Decisions	**(R)osalind** unilateral	R		R,E		R,R,R	R	(Extensive Alternation) 3 Alternations
	mutual		R&P		R&P		R&P	
	(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	#2	#3	#4	#5	#6	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	
	Transition			P (between #2 and #3)		U (between #4 and #5)	P (between #5 and #6)	
Decisions	**(R)osalind** unilateral			R,R	R,R		R,R	(Extensive Alternation) 3 Alternations
	mutual	R&P	R&P		R&P			
	(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)

		#1	#2	#3	#4	#5	#6	Totals (Summaries)
Phase (Length)		#1 (3 mo)	#2 (3 mo)	#3 (1 mo)	#4 (5 mo)	#5 (3 mo)	#6 (3 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	Testing - ensuring the new technologies, products, and platform work effectively	Marketing - creating interest in new technologies, platforms, and products that were developed jointly	
					(U)	(U)		
Decisions	**(L)ear** unilateral	L,L		L		L,L	L,L	(Moderate Alternation) 2 Alternations
	mutual		L&M,L&M,L&M		L&M			
	(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)

		#1	#2	#3	#4	#5	#6	Totals (Summaries)
Phase (Length)		#1 (12 mo)	#2 (6 mo)	#3 (4 mo)	#4 (5 mo)	#5 (4 mo)	#6 (3 mo)	6 Phases (34 Months)
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	
Decisions	**(M)acbeth** unilateral		M					(No Alternation) 0 Alternations
	mutual	M&F	M&F,M&F,M&F	M&F,M&F	M&F,M&F,M&F	M&F	M&F	
	(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.

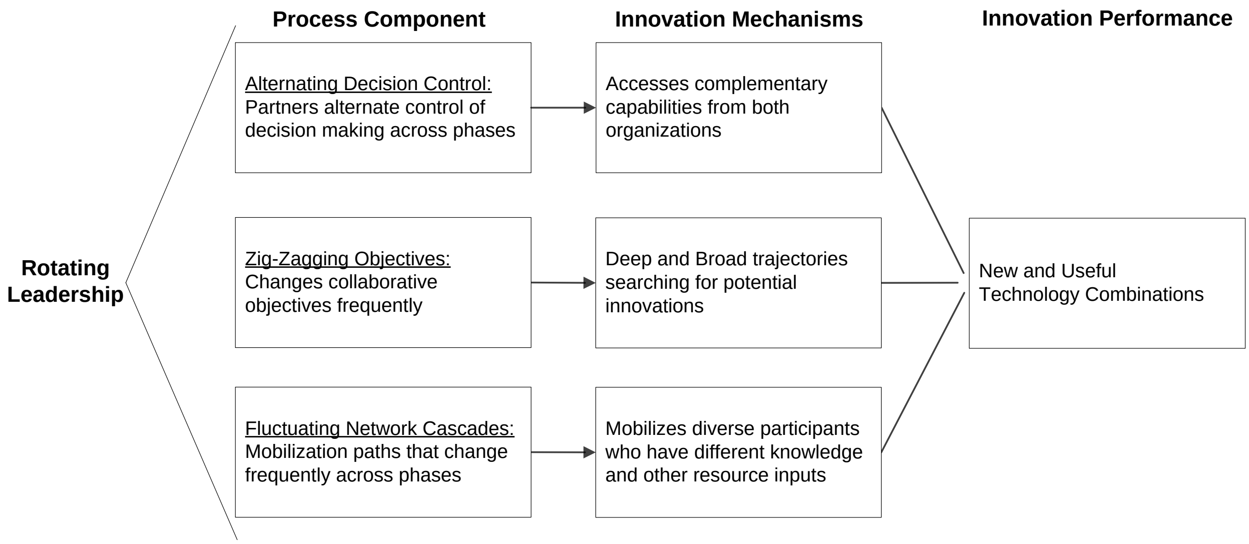
Case #7: Web Services - (L)ear & (O)phelia (Domineering Leadership)

		#1 (3 mo)	#2 (3 mo)	#3 (2 mo)	#4 (3 mo)	#5 (2 mo)	#6 (5 mo)	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)
New to Collaboration			29%	0%	14%	17%	29%	18% New Participants (Weighted Average)
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 (10 mo)	#2 (2 mo)	#3 (2 mo)	#4 (3 mo)	#5 (4 mo)	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)
New to Collaboration			33%	0%	0%	0%	8% New Participants (Weighted Average)
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



Appendix: Demarcating Phases and Measuring Innovation Performance

Analyzing Phases of Each Collaboration

The primary unit of analysis in these collaborations is the phase.[xi] We define a phase as an interval of time when qualitatively similar work activities occur that differ from activities that come 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 and 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 they 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.

Measuring 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.

Table 3: 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. 18 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."

Endnotes

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

[ii] Of course, not all transitions between phases involve alterations (e.g., sometimes one partner maintains control). 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 operationalzations. For this we appreciate the suggestion of an anonymous review.

[iii] 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 as a thought experiment. So for example, while domineering partners may have found other means to incorporate partner's perspectives, rotating leadership forces partners to do so.

[iv] 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 also important to understand how organizational processes shape how actors in the network come to participate in the collaboration. We appreciate the suggestion of an anonymous reviewer to clarify this distinction.

[v] We measure a set of cascade mobilizations 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". 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 the network structure of hierarchy.

[vi] Because these measures and problems are common to collaborative innovation at multiple levels of analysis, it is possible to generalize the theory to collaborations between any two groups, whether these are organizations or different divisions, units, or teams within organizations, or groups outside organizations. While acknowledging this possible generalization, we focus on organizations because these are the collaborating groups in our data.

[vii] We thank an anonymous review for suggesting we consider rotating leadership in the context of asymmetric power and resources.

[viii] Of course, not all managers in complex organizations employ the same processes in all collaborations, and not all collaborations between symbiotic partners need always use rotating leadership. For example, only 1 of 3 of Macbeth and Falstaff's collaborations in this study used rotating leadership (the collaboration which innovated most extensively). Yet it is still reasonable to expect that even the occasional use of rotating leadership could underlie the longevity of these relationships if the resulting innovations generate new collaborations.

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

[x] We thank an anonymous reviewer for this suggestion.

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