HOW DO FIRMS MANAGE TECHNOLOGY COLLABORATIONS?

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February 1, 2006
Grant Proposal

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PROJECT SUMMARY

The purpose of this project is to examine how organizations successfully innovate using inter-organizational collaborations. A striking feature of research on such collaborations is that it rarely examines the actual collaboration process. Rather, this research often relies on archival data to examine the formation of collaborations, effects of initial conditions on collaborations, and impact of collaborations on firm performance. Although a few studies examine the process, they typically use limited data, and emphasize collaboration as either a competitive learning race or a cooperative evolution into a trusting relationship. Overall, there is little research into how inter-organizational collaboration happens, including the competitive vs. cooperative tension that is fundamental in these relationships. Our project addresses this gap.

The primary research question is: How do organizations collaborate effectively? Given the lack of detailed research on how collaborations actually occur, we propose an inductive, grounded theory-building approach. This method expands the opportunity to develop truly unexpected findings, and is particularly appropriate for uncovering complicated temporal patterns that are likely within collaborations. We propose an in-depth, comparative case study of 8 technology collaborations by established firms in the computing and communications industries.

Intellectual Merit: We address a significant research gap in the organization, innovation and strategy fields by focusing on how firms actually collaborate. As such, we open the "black box" of collaboration, a pervasive and fundamental activity that occurs within groups, organizations, and industries and yet is unexpectedly challenging to accomplish. We also add important new considerations (e.g. firm strategy, timing, and competition) that are missing in most prior research. We rely on a method that is particularly likely to yield insight into under-studied phenomena. Our focus on technology collaborations enables study of discrete collaborations while our emphasis on established firms enables some control over antecedent factors that affect performance. These methods advantages mitigate left and right censoring and extraneous factors, allowing a sharp focus on collaboration. The team is experienced in multiple technologies, field research methods, relevant theories, and academic and managerial publication.

Broader Impact: We address a critical national issue in the context of firms that are central to economic growth. In particular, for large firms in fast-paced and interdependent technology industries, effective technology collaboration with peer firms is essential. Yet there is little research into how technology collaborations among these important firms actually occur, why some work while others do not, and how they extend into novel products and new business creation. Finally since collaboration relies heavily on cyber-infrastructure, we may uncover useful information about its strengths and weaknesses.

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PROJECT DESCRIPTION

1. Introduction

Scholars and practitioners have long been interested in successful innovation. The reason? Since many firms engage in highly competitive and global markets, the ability to develop innovations, infuse them into novel products, and launch them into fresh businesses is central to their performance. Research has noted internal product development and acquisition as paths for innovation. But when markets are fast-paced and technologies are intertwined, the likelihood that any one firm can possess sufficient resources to develop the best innovations is unlikely (Powell et al., 1996; Ahuja, 2000a). Therefore, collaboration across firms is an important path to innovation. In fact, considerable literature indicates that technology collaborations between firms can generate innovative new products and businesses, and increase firm performance (Powell, Koput, and Smith-Doerr, 1996; Stuart, Hoang, and Hybels, 1999; Ahuja, 2000; Baum, Calabrese, and Silverman, 2000; Dyer and Nobeoka, 2000).

A striking feature of the research on inter-organizational collaboration, however, is that it rarely examines the collaboration process. Instead, it relies primarily on archival data to study the formation of collaborations (Gulati, 1995a; Ahuja, 2000b), effects of antecedent conditions on collaborations (Dussage et al., 2000; Kale et al., 2002), and impact of collaborations on firm performance (Stuart, 2000; Baum et al., 2000). Although a few studies take a process view (Hamel, 1991; Larson, 1992; Doz, 1996), these studies typically characterize collaboration as either a competitive learning race between the partners or as a cooperative evolution into a trusting and integrated relationship. As a result, there is little insight into the competitive-cooperative tension that is fundamental within these relationships, or into issues such as firm strategy, the distribution of intellectual property (IP), power dynamics, managerial roles, and changing market conditions that are likely to be influential. In addition, this research is not focused on technology collaborations, and is limited by some methods issues (Das and Teng, 2000). Thus, while considerable research supports the importance of inter-organizational collaboration, *how* effective technology collaborations evolve is unexplored. Our purpose is to fill this research gap.

The primary objective is to explore how firms engage in effective inter-organizational collaborations. Specifically, we propose to focus on technological collaborations in the context of major established firms in the computing and communications industries. We chose *technology collaborations* because they involve the creation of science- and engineering-based innovations for use in novel products, technical platforms, and businesses. As such, they are central to a broad concern with innovation and economic growth, and yet are relatively unstudied. From a research perspective, technology collaborations are attractive because they have discrete start and end times, making it possible to track the entire collaboration from inception. This enables more accurate observation of the collaboration process and measurement of performance. In addition, technological collaborations are attractive because they highlight the inherent tension within collaborations especially well. That is, they require deep cooperative interaction with significant competitive implications. The uncertain nature of technical development may also reveal unexpected contrasts with more routine collaborations. Our setting is the *computing and*

communications industries (e.g., semiconductors, networking, software, and Internet security). From a pragmatic standpoint, these industries are central to economic competitiveness. Given the convergent and interdependent nature of these industries (Bresnahan and Greenstein, 1999), technical collaborations (e.g., collaborations that combine mobile and microprocessor technologies) are essential. From a research standpoint, collaborations among these industries are sufficiently complicated to create theoretical interest, but of moderate duration (e.g., roughly 18 months) to enable effective observation. We chose *established firms* with significant size for several reasons. From a pragmatic standpoint, these firms have enough resources to engage in important R&D. From a research standpoint, since these firms typically share antecedent characteristics associated with collaboration performance (e.g., extensive experience with collaborations), they allow us to focus on the collaboration process without the complication of varied antecedent factors. Also, their size is likely to preclude their acquisition of each other, and so make collaboration necessary and important to these firms.

Overall, the proposed study asks: how do organizations effectively collaborate? This question is of growing importance for business and government leaders operating in dynamic, global industries. By using inductive logic and in-depth case studies, this research is likely to examine technology collaborations with rich granularity and scope. Such an approach is likely to generate novel and accurate findings regarding effective technology collaboration. An important feature of our study will be to examine not only technical success, but also success in terms of new products and businesses.

2. Theoretical Background and Prior Work

2.1 Collaboration Performance: Antecedent Factors

Much research focuses on how antecedent factors that exist prior to the collaboration influence performance. Some of this research examines partner characteristics. For example, prior collaboration experience improves performance (Barkema, et al., 1997; Simonin, 1997) because executives are able to learn how to conduct and extract value from their previous collaborations. They then translate that learning into more effective future ones. In a related argument, codification of that learning into specialized functional groups that manage collaborations also improves performance (Larson, 1992; Helper, MacDuffie, and Sabel, 1999; Kale, Dyer, and Singh, 2002). Empirical evidence supports these arguments. For instance, Kale et. al. (2002) find that firms with a dedicated alliance function (i.e., a group focused on managing and extracting value from alliances) had higher performing collaborations and higher stock valuations than those without.

Other research links characteristics of the partners collectively to collaboration performance. One such characteristic is partner similarity (e.g., similar size, national background, and culture). Partner similarity increases performance by improving communication and mitigating unproductive conflict. Empirical evidence supports this view for similar status (Chung, Singh, and Lee, 2000) and cultural background (Barkema, et al., 1997). In addition, Luo (2002) finds that similarity of product markets increases collaboration performance because communication and mutual learning are more effective between partners who share a common market perspective. Previous experience together or with a mutual third party also improves collaboration performance (Ring and Van de Ven, 1994; Gulati, 1995; Zaheer, McEvily, and

Perrone, 1998). Previous experience increases performance by building on prior gains in trust, understanding, commitment and communication. For example, Uzzi (1997) finds that collaborations in which partners with prior experience with each other had very effective communication, high trust and high commitment to mutual assistance. These factors, in turn, increased performance in terms of speed and efficiency of collaborative activities, and effective mutual adaptation to unexpected events. Finally, while similarity improves collaboration performance, some resource complementarity typically also increases performance because it creates the interdependence that motivates the relationship (Dussauge et al., 2000).

Still other research links governance and collaboration performance. Using agency and transaction cost economics reasoning, the argument is that appropriate governance improves collaboration performance by reducing coordination costs (Dyer, 1997; McEvily and Zaheer, 1999). In particular, when uncertainty is low, governance should rely on behavioral monitoring. In contrast, when uncertainty is high, governance should rely on outcome incentives. These arguments are supported by evidence. For example, Dyer and Nobeoka (2000) observe that the performance of Toyota's supplier collaborations is increased by the ease of behavioral monitoring in this low uncertainty setting. In research that directly addresses uncertainty, Gulati (1995b) finds that governance through equity relationships is more effective than non-equity ones when uncertainty is high (e.g. no past relationship, lack of cultural similarity, multiple partners). Similarly, collaborations that involve uncertain technologies are more effective when governed in a joint venture than when governed by non-equity contracts (Mowery, Oxley, and Silverman, 1996).

Finally, some research explores the effects of geographic distance on collaboration performance (Hinds and Kiesler, 1995; Cramton, 2001; Hinds and Bailey, 2001; Kiesler and Cummings, 2001). Although much of this research examines collaborations within organizations, the drawbacks of distance probably also damage collaborations across organizations. As Hinds and Bailey (2001) note in their extensive review, distance decreases collaboration performance by increasing conflict and free rider behavior, and by reducing group cohesion and the ability to take coordinated action. Distance also creates a lack of a common understanding of collaborative goals and activities that in turn decrease performance (Bergen, 1986).

While studies of antecedent factors offer useful insights on collaboration performance, research opportunities remain. First, this research uses inconsistent measures of performance that make it challenging to compare results across studies. For example, performance is measured from the perspective of a partner in some studies, but from the perspective of the collaboration as a whole in others. Among partner perspective studies, performance is sometimes measured directly by collaboration outcomes (e.g., knowledge transfer, duration), and sometimes is inferred from firm outcomes (e.g., stock price, patenting rates). Second and more significant, the research on antecedent factors neglects *how* the collaboration process actually unfolds. While antecedent factors are probably germane, they are likely to provide only a partial explanation of performance. Moreover, the collaboration process is particularly likely to be important in the competitive, high-velocity environments that often provide the context for technology collaborations.

2.1 Collaboration Performance: Process Factors

A second category of research links process factors with collaboration performance. Some of this research examines specific characteristics of the relationship between the partners such as trust, communication, and commitment. For instance, when trust is high, partners more effectively reach their goals, cooperate with one another, and share information (Mohr and Spekman 1994; Zaheer et al., 1998; Kale et al., 2000; Dyer and Chu, 2003). For example, Dyer (1997) finds that Japanese firms achieve more effective collaborations by investing in building trust in their collaborations. Similarly, Arino and de la Torre (1998) describe a joint venture in household products in which trust and commitment within the relationship increased performance.

A smaller set of studies offers deeper insight into the evolution of collaborations, and the relationship to collaboration performance. Some of this research emphasizes the cooperative aspects of collaboration that center on the emergence of trust, commitment, and integrated action over time. Although stage models (e.g., initation, execution, dissolution) are often presented, these studies are broadly characterized by the notion that collaboration unfolds along an evolutionary path with positive feedback. A good example is Ring and Van de Ven's (1994) theoretical work that argues that collaborations occur in stages. Collaborations begin with formal mechanisms and reliance on personal relationships between senior executives. As time goes on, formal mechanisms give way to informality, and senior-level relationships are replaced by dense, lower-level relationships Thus, collaborations evolve toward lower formality and greater density of connections with an emphasis on personal relationships. Similarly, Larson's (1992) study of high-performing collaborations between entrepreneurial and established firms offers empirical support for evolutionary paths and stage models. Specifically, this research highlights the incremental development of collaboration. Collaborations begin with pre-conditions for collaboration such as prior friendships. They then enter a phase of mutual monitoring as trust emerges and expectations become clear. This phase is followed by one of greater cooperation, commitment to the collaboration, and operational and strategic integration of the partners as trust deepens and the partners become increasingly interdependent (Larson, 1992). Overall, the emphasis is on the incremental strengthening of the collaboration by reciprocated actions that slowly build trust. Finally, related research emphasizes repeated contact among partners and creation of cooperative structures that further increase trust and improve collaboration performance (Gulati, 1995; Arino and de la Torre, 1998; Doz, Olk, and Ring, 2000). For example, Browning et. al.'s (1995) study of the SEMATECH R&D consortium indicates how contact increases collaboration performance among these numerous partners. Further, while an initial period of ambiguity existed, the collaboration became more harmonious as cooperative structures emerged.

Finally, some research places particular emphasis on cycles within the collaboration process. An illustration is the Doz (1996) study of six collaborations in several technology-based industries. He finds that high-performing collaborations follow an evolutionary path consisting of successive sequences of interactive learning, reevaluation and adjustment. Most important is the interaction of learning and commitment as these cycles progress: as organizations learn valuable information, they become increasingly committed to the collaboration's success which, in turn, enables them to learn and contribute more. In contrast, low-performing collaborations are inertial. Building on this study, Arino and de la Torre (1998) examine a failed international joint venture in consumer products. They conclude that positive feedback cycles are necessary for high performance. In contrast, when there is no renewal of mutual understanding, the relationship deteriorates and the collaboration dissolves.

In contrast, a few process studies note the competitive aspects of collaboration. An example is the Dyer and Nobeoka (2000) study of the emergence of the Toyota supplier collaboration network. While this research does support many aspects of the cooperative evolutionary path (e.g., collaborations evolve from formal to less formal and from dyadic to more dense lateral connection, as above), the authors also describe the role that Toyota plays in orchestrating its alliances, enforcing collaborative behavior, and mitigating competitive behavior through incentives, deterrence, and the exercise of market power.

Hamel (1991) takes a more extreme competitive view by conceptualizing collaborations as learning races. He examines several collaborations along the vertical value chain (i.e., product development and marketing, product development and manufacturing) between Japanese firms and U.S. and European ones. Significant differences in the learning rates of partners shapes the competitiveness of the collaboration process by creating increasing asymmetries with regard to what each partner gains from the collaboration and their resulting bargaining power in the relationship. The partners achieve high-performing collaborations (from their perspective) when they deliberately intend to learn the partner's skills, when there is high transparency in the partner firm (e.g., easy to imitate technology, lax restrictions on employee's communication), and when they are receptive to new knowledge (Hamel, 1991).

While the process research offers valuable insights into collaboration performance, it also provides research opportunities. First, there are very few process studies. This is particularly problematic since it is not clear how the findings from one type of collaboration may generalize. For example, to what extent are Larson's (1992) findings influenced by her buyer-supplier pairings of established firms with more fragile ventures? Similarly, understanding how Toyota dominates its manufacturing suppliers might not capture its own process in major technology collaborations with firms like Bosch in areas like hybrid technology. Overall, there is little information about technology collaborations such as those that are our focus. Second, the methods are limiting. Some research is either purely theoretical (Ring and Van de Ven (1994) or relies primarily on single cases (Browning et al., 1995; Arino and de la Torre, 1998). Some research examines only successful collaborations (Larson, 1992). As Das and Teng (2000) observe in their review, the data are often spotty and the stage models are inconsistent. Third and most important, the studies often assume either an overly cooperative view that effective collaboration is simply a matter of trust or an overly competitive view that effective collaboration is winning a learning race at the expense of the partner. Both views are incomplete. Broadly, they miss important competitive realities (e.g. necessity of collaborating with potential competitors), and ignore the often changing strategic, technical and competitive contexts in which collaborations typically occur.

3. Conceptual Framework

We propose to study how organizations engage in effective technology collaborations. While research on antecedent conditions and processes discussed earlier offers some guidance, there are also a few studies that offer some fresh directions that seem promising. As we discuss below, however, while this work suggests possibly important constructs, it neither precisely conceptualizes them nor offers clear theoretical predictions.

3.1 Strategy: Competition, Cooperation, and Pace

A key issue that may affect collaboration performance is firm strategy. As noted above, the extant research does not adequately develop the tension between competition and cooperation, and more broadly, the strategic context in which firms operate. However, some work touches on these issues. Khanna et al. (1998) explore, for example, how conditions shape whether the collaboration is likely to unfold as more competitive vs. collaborative, and so whether the partners focus on the collective gain. These theoretical arguments are likely to be particularly relevant in technology collaborations, given that technical and competitive change commonly alters strategic positions and networking effects are often critical. This work has, however, received criticism for its lack of granular understanding of the process. This debate signals the opportunity for field-based, process research such as ours.

Some field research is beginning to look at collaboration in the context of firm strategy. Recent research by Santos and Eisenhardt (2005) indicates that entrepreneurial firms may attempt collaborations with established firms that are potential competitors with the hope that these firms will become complementers. Thus, these collaborations are dominated by strategic, not operational and trust, issues. Related research (Ozcan, 2005) in the wireless gaming industry indicates that partners may strategically and repeatedly realign their commitments and work effort with partners based upon industry events, competitor actions, and the activities within technology platforms. Taken together, this work reveals the instability of new technologies, the fluidity of relationships among partners, and the dependency of focal collaborations on strategy and the related external environment.

Some research also suggests the importance of temporal pacing as an aspect of strategy, especially in dynamic markets and technology-based companies. For example, Brown and Eisenhardt (1997) find that rhythmic pacing of new product innovations is a critical aspect of strategy, and important for firm performance. Research by (Bingham and Eisenhardt, 2005) also finds that rhythmic pacing and synchronization are central to the strategy of technology-based firms in their international expansion. The more general observation is that differences and changes in temporal strategy between partners (e.g., pace of new product innovation) may influence the performance of technology collaborations that rely on synchronization of different components of technology, and company-specific technology and product roadmaps.

To sum up, research suggests that strategy and the broader market context are likely to influence the collaboration process and performance. But research is less clear about how. Questions remain such as 1. how do partners partition technology into new products and businesses? 2. how do they share or distribute intellectual property?, 3. how are differences in timing managed effectively? 4. how do executives cope with the tension between cooperation and competition?

3.2 Managerial Roles and Collaborative Leadership

Explicit managerial roles and collaborative leadership may also influence the collaboration performance. But the research is inconsistent. For example, Ring and Van de Ven (1994) point to the critical role of strong senior leadership in support of the collaboration at the outset. In contrast, Doz (1996) suggests that lower level managers are critical and that it is difficult to initially define the collaborations. Rather, effective collaboration is emergent. Despite this

conflict, it seems likely that there are important managerial roles, but also that they have not been clearly supported by research.

In addition to within-firm roles and leadership, roles and leadership with regard to the collaboration itself also seem germane. For example, Dyer and Nobeoka (2000) indicate that Toyota takes the lead in its collaborations, particularly around creating transparency, efficiency and commitment. Larson (1992) indicates that one partner often takes the lead in the emergence of cooperation within effective collaborations. But she also notes that the leading partner may oscillate. Kale et al., (2000) point to the importance of an alliance function to collaboration performance. But research is not specific about the specific roles and their activities that may lead to high performance.

Overall, managerial roles and collaborative leadership are likely to influence effective collaboration. But, the related extant research is sparse, and focused primarily on successful collaborations with no contrast with unsuccessful collaborations regarding these issues. Questions remain such as 1. what are the key managerial roles within and across firms? 2. are there particular types of executives that are best suited to these roles? 3. is balanced leadership among partners most effective? Or is it better to oscillate leadership or have a dominant partner?

3.3 Product Development Process

A third issue that may influence collaboration performance is the actual process by which the work of the collaboration is conducted. In the particular case of technology collaborations, there is an extensive literature on product development that is probably germane. One set of key themes centers on the importance of cross-functional teams, high communication, and "heavyweight" team leadership for effective product development (Ancona and Caldwell, 1992; Brown and Eisenhardt, 1995). For example, Clark and Fujimoto (1991) find that product development teams within the automotive industries develop new vehicles more quickly and efficiently when they have these characteristics. In addition to these characteristics, related research suggests the importance of improvisation in the creation of new products (Eisenhardt and Tabrizi, 1995).

Other research points to the importance of diverse information flows, including gatekeeping and boundary spanning activities (Allen, 1997; Katz and Allen, 1985). More recent work by Hinds and Bailey (2001) suggest that the negative impact of distance can be mitigated by more face-to-face communication (i.e., temporarily eliminating bridging distance), less interdependence among team members who are not co-located, and by more use of communication technologies that emulate the richness of face-to-face communication.

To sum up, it seems like that an effective product development process will influence collaboration performance. But at the same time, questions remain: 1. how will these within-firm practices will play out across firms? 2. how (if at all) will recent innovations in the cyber-infrastructure change the implications of previous research findings? 3. do findings that relate to product development generalize to more research-intensive innovation?

Overall, the above review suggests several constructs that may influence collaboration performance. Yet their precise conceptualization and theoretical relationship with performance

are not well-explored. For example, firm strategy seems relevant to collaboration performance because it should affect commitment, motivation, and the tension between cooperation and collaboration. But, the exact linkages are unclear. Given the lack of in-depth understanding of collaboration process and its relationship with performance, we propose a theory-*building* study in which we have some a priori ideas about possibly important constructs, but probably not all constructs, and no a priori hypothesized theoretical relationships (see Figure 1).

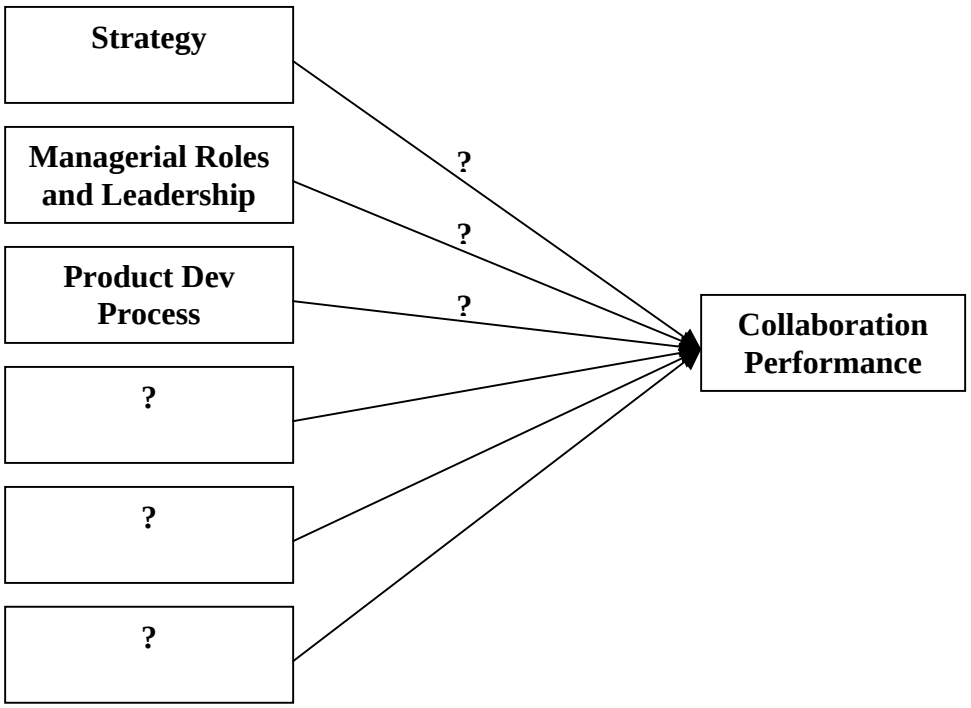

Figure 1: Organizational process constructs for technology collaboration performance

4. Proposed Method

Given the limited understanding of how inter-organizational collaborations occur, this study relies on an inductive, grounded theory-building approach (Glaser and Strauss, 1967; Eisenhardt, 1989) in which data are used to develop theory. Inductive logic is appropriate in research such as ours where there are no clear a priori hypotheses, and likely constructs (e.g., synchronization) are not well-understood.

The research design is a multiple-case, embedded study. Multiple cases allow a replication logic in which cases are viewed as a series of experiments. Each case serves to confirm or disconfirm the inferences drawn from the others (Yin, 1994). A replication logic typically yields more generalizeable and accurate results than do single case studies. Cases are also particularly useful for studying longitudinal, non-linear relationships because they permit an understanding of the mechanisms that may underlie seemingly contradictory views (Hedstrom and Swedberg, 1998). The study also uses an embedded design – i.e., multiple levels of analysis including:

organization, collaboration, and industry. Although complex, an embedded design improves the likelihood of inducting richer and more reliable models (Yin, 1994).

4.1 Research Setting

The research setting is eight technology collaborations between major firms in the computing and communications industries. By technology collaborations, we mean collaborations in which the primary goal is the development significant technological innovations that are likely to lead to new products and potentially, novel platforms, and businesses. For instance, a recent dramatic example of technical collaboration is the joint work necessary to make Apple's computer products run on Intel processor architectures since it required the pair of companies to jointly create new platform technologies. We chose technical collaborations for several reasons. First, they involve the creation of innovations, and ultimately new products, platforms and businesses that are central to firm performance and the strength of the national economy. Moreover, given the convergence and interdependence of many industries, such collaborations are likely to be an increasingly important innovation path. Second, technology collaborations are understudied within the literature, particularly in granular detail. Rather, the emphasis has been on archival data, and collaborations such as marketing agreements, and buyer-supplier relationships. From a research perspective, technological collaborations often have clear start and end dates, making it possible to track the entire collaboration from its birth. Therefore, there may be more accurate observation of the collaboration and its performance. Finally, technology collaborations are an attractive research setting because they highlight the fundamental tensions within collaborative relationship between cooperation and competition. That is, they require intense technical cooperation, but also typically have important competitive implications. Moreover, given their uncertain nature, technical collaborations may also reveal unexpected insights that differ from those of other types of collaborations.

We chose the computing and communications industries (e.g., semiconductor, computing, networking, Internet security, and telecommunications) as the research setting because of their importance to the national economy and their emphasis on technology innovation. Moreover, given the interdependence among the various industries, rapid pace, and uncertainty, technology collaborations are an important innovation path within these industries (Mowery, 1996). From a research standpoint, collaboration among these industries is sufficiently complicated to be of theoretical and practical interest, but of moderate duration (e.g., roughly 18 months is typical) to permit effective observation.

Our sample includes eight technology collaborations between established firms with significant size. These firms are attractive because they typically have the resources necessary to undertake significant innovations. From a research standpoint, since these firms typically share antecedent conditions (e.g., prior experience with collaborations, similarity, prior experience with each other) that previous research has found to be relevant to high-performing collaborations, they allow us to focus on the collaboration process with unnecessary variance due to varied and perhaps dysfunctional antecedent characteristics. Their size is also likely to preclude acquisition of one another, thus eliminating another complicating issue that is unrelated to the collaboration per se (Doz, 1996; Larson, 1992).

The specific collaborations under study will involve significant dedication of resources (at least 6 full time employees from each firm) and sufficient time frame (at least 9 months) in order to have sufficient resources for major technical advances. Our exploratory observations (below) suggest that these size and time are suitable lower bounds. We will also select collaborations that executives in the partner firms regard as having important strategic implications and significant technical content. We anticipate tracking collaborations that begin no sooner than 2004 in order to enhance participant recall, and tracking these collaborations through early 2007 in order to span the full life of the collaboration and to assess its immediate technical success as well as its longer-term performance implications such as new products, platforms and perhaps businesses. This approach will enable data collection that is both retrospective and real-time data which increases data accuracy, scale, and the generalizability of the results (Leonard-Barton, 1992).

3.2 Exploratory Observations

In order to hone the research question, constructs, and data collection methods, we have conducted exploratory work 1) extensive lit review, 2) interviews with knowledgeable individuals in several technology-based firms, and 2) detailed pilot interviews with individuals from a major technology based company about its portfolio of technology collaborations (approximately eight collaborations with six different partners) that were either ongoing or recently completed.

We learned from this exploration that the evolution of technology collaborations is often be highly negotiated and improvisational throughout its life, and that a number of unique challenges exist for the participants. For instance, participants are often repeatedly challenged with understanding and performing in the face of differing schedules as well as by changing and controversial collaboration goals and readjustments as firm strategies shifted. We also learned that technology collaborations tend to be concentrated in established firms with significant size such that they have enough resources to do R&D. Our informants at the major technology firm, in particular, pointed to their collaborations with other large firms as their most important (and in contrast to the lesser importance associated with technology collaborations with universities and small firms). Such large firm collaborations were also more important because they had a larger potential to produce more radical innovations for future product roadmaps.

This exploratory phase provided several important benefits. First, it helped to validate the richness of the research topic, and the study's potential to reveal novel insights and theory. Second, it aided in the development and testing of interview questions as well as in understanding the types of informants that would be particularly valuable. A preliminary interview guide with several variations has been created and tested. Third, it gave us insight into which companies and collaborations would be most appropriate for the research. We developed a sense for typical time frames and staffing levels. Fourth, it helped us to gain contact information for accessing potential sample firms.

3.3 Data Collection

This research will use four primary data sources: (1) quantitative and qualitative data from semi-structured interviews with company leaders; (2) e-mails, observations, and phone calls to follow-up on interviews and to track collaborations over time; (3) quantitative data on companies'

collaboration performance from company and public sources; and (4) extensive archival data including company websites, business publications, and other materials produced inside the firm.

The primary data source will be the semi-structured interviews from employees from each collaborating firm. There are three types of interviews corresponding to the three types of informants: corporate executives (e.g., CEO, CTO, SVP) who are responsible for firm-wide activities including firm and technical strategy, collaboration managers who are responsible for the overall progress of the collaboration, and lower level managers who are engaged in the day-to-day execution of the collaborative work. We anticipate approximately 90 interviews.

The interviews will be semi-structured with both open and closed-ended questions. The closed-ended questions will gather quantitative measures of constructs that a priori might be relevant for collaboration performance (e.g., number of people involved, communication, trust, disagreement, meeting specific technical milestones, skill levels, and performance). The open-ended questions will gather in-depth qualitative chronologies of the technology collaborations as well as information about firm and technical strategies and competitive context.

The interviews are comprised of three parts with some variation depending upon the hierarchical level of the informant, as noted above. The first part of the interview begins by briefly asking about background information for the informant. The second part is the heart of the interview, an open-ended chronology of the collaboration project. Informants are asked to relate the story of the collaboration as they witnessed it by asking them to place themselves back at the time of the events and then to move forward as the events occurred. Their accounts are supplemented by probing questions from the interviewer as appropriate. In order to ensure more accurate information, a "courtroom" procedure is used where questions center on concrete facts and events rather than on personal interpretations, especially of the motives of others (Eisenhardt, 1989). Contingent upon the informant, we focus this part of the interview on either the collaboration strategy in this technological area or the story of this particular collaboration. We will note particular activities like significant personnel changes, shifts in the business model, and introduction of new products, and encourage the informants to give details. We will also note particular actions related to collaboration management, leadership and managerial roles, technology development, and strategy including communication, pacing, power asymmetries, and differences in partner identities. Consistent with grounded methods, we will not ask direct questions about these actions in order to avoid "leading" the informant. The final part of the interview is a series of closed-ended questions to measure constructs that might be relevant.

All interviews will be tape-recorded and transcribed as soon as possible with a goal of 24 hours. Immediate observations of the interviewers will be added to the end of the interviews. Additional questions, as needed, will be asked by phone or email. Ongoing collaborations will be tracked in real time. These data will be supplemented with quantitative information on the operations and finances, observations, and extensive archival information from corporate websites and the media. Overall, as a result of this research design, we anticipate developing a deep understanding of these eight technical collaborations as well as their performance as a whole and in the context of the partnering firms.

Informant bias is an important consideration. We address this issue in several ways. First, we combine both real time and retrospective data. Such a combination is ideal, with the retrospective

data enabling efficient data collection of more observations (thus enabling better grounding) while real time data collection allows further depth in understanding how events evolve (Leonard-Barton 1990). Second, experience with previous research (e.g., Brown and Eisenhardt 1997; Galunic and Eisenhardt 2001) suggests that the proposed interview techniques (e.g., "courtroom" questioning, event tracking, non-directive questioning, establishing a "back in time" cognitive frame) typically yield accurate and convergent information among informants and with archival data. Third, reliance on informants at multiple levels of hierarchy is likely to yield a more complete and thus, accurate picture of events due to complementary perspectives and granularity. Combining qualitative stories with quantitative measures further strengthens the accuracy of the accounts. We also will rely on informants who are particularly knowledgeable about the relevant events and for whom those events were important, thus improving memory accuracy. Fourth, the use of anonymity for both companies and informants encourages candor. Finally, we supplement these data with archival information from the time period in question. In sum, although no method is perfect, we anticipate that our methods will yield rich, detailed, and accurate accounts of the processes of technology collaboration.

3.4 Data Analysis

As is typical in inductive, grounded theory-building, we will first write individual case histories (Eisenhardt, 1989). These will be created by synthesizing the interview and archival data of the focal firm. Each case history will describe (1) the chronological story of the collaboration project, (2) key constructs including experiences such as mistakes and experiments, (3) key activities such as the formation and progress of alliance relationships and personnel changes, and (4) outcomes including technological milestones and breakthroughs. Based on past experience, we anticipate that these histories will be between 50 and 70 double-spaced pages, and include selected narrative quotes, tables, and timelines summarizing key facts about the collaboration as well as conceptualization of emergent constructs. One researcher will initially write the case for each firm, developing tables, graphs and timelines to facilitate analysis. A second researcher will independently read through the original interviews and archival information, forming an independent perspective on each case. The added perspective of this second reader will be incorporated into each case in order to provide a more robust and triangulated summary for each firm. As necessary, we will return to the companies for further information.

After the individual case histories are written, they will be used for two types of analysis: within-case and cross-case. We begin with no a priori hypotheses. Within-case analysis will concentrate on developing constructs, emergent themes, and theoretical relationships linking collaboration mechanisms and innovation outputs based on the insights from each firm. Researchers will first develop independent views of each case and then compare their insights. Once the researchers have some convergence on their analysis of each case, cross-case analysis will begin.

As is typical in inductive, grounded theory-building, cross-case analysis involves looking for the emergence of similar themes and constructs across multiple cases (Eisenhardt, 1989; Miles and Huberman, 1994). The cross-case analysis will proceed with a variety of lenses including grouping sample firms according to similar theoretical constructs as well as random groupings. We will also engage in successive paired comparisons in order to develop an understanding of similarities and differences that might be emerging using a replication logic. With each iteration, we anticipate using new permutations of case pairs and new sorting themes to refine the emergent

insights. This nested design is likely to provide particularly rich data and theoretical insights. We will also bring in extant literature to sharpen the conceptual underpinnings of our findings. The overall analysis will involve iterations between data, theory, and later extant research until a strong match between data and the theoretical framework emerge.

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