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Determinants of Success in ATP-Funded R&D Joint Ventures

A Preliminary Analysis Based on 18 Automobile Manufacturing Projects

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A Preliminary Analysis Based on 18 Automobile Manufacturing Projects

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Economic Assessment Office
Advanced Technology Program
National Institute of Standards and Technology
Gaithersburg, MD 20899-4710

By
Jeffrey H. Dyer
Donald Staheli Professor of Strategy
Marriott School, Brigham Young University
790 Tanner Building
Provo, Utah 84602
Jdyer@byu.edu

Benjamin C. Powell
Wharton School, University of Pennsylvania
3620 Locust Walk, SH-DH 2070
Philadelphia, PA 19104-6370

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U.S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary

TECHNOLOGY ADMINISTRATION
Phillip J. Bond, Under Secretary of Commerce for Technology

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Arden L. Bement, Jr., Director

Abstract

This study explores the growing importance of collaborative ventures to the nation's economic strength, the difficulty in making them work, and the role of government in fostering collaborative ventures. The focus of the study is on factors that increase or decrease the likelihood of success of collaborations as seen from the perspective of participants in 18 Advanced Technology Program (ATP) funded joint ventures in the automotive industry. The 18 joint venture projects studied are in automotive manufacturing and are ones in which ATP funding was initiated between 1991 and 1997. The interviews for this study took place in 1999. Findings suggest that factors fostering trust and information sharing among joint venture participants improve their chances for success. Factors that decrease participants' coordination costs also improve success rates. Other success factors include an optimal number of participants (not too few and not too many) within a given joint venture, vertically structured joint ventures populated by companies with complementary skills, experience of members working together, personnel stability, and a high level of company commitment. Findings also suggest that ATP is accelerating and improving the successful outcome of collaborative projects and encouraging them to take on higher risk and longer-term research than collaborative endeavors without government involvement. Moreover, the findings suggest that ATP is providing funding during the critical stages. In addition, ATP helps joint ventures to overcome barriers to collaboration, and then helps collaborative projects run more smoothly, albeit with some perceived loss of flexibility on the part of the companies. This is a preliminary study that provides the foundation for a full-scale survey of ATP joint ventures planned for 2002.

Acknowledgments

We would like to thank the Advanced Technology Program joint venture participants who generously gave their time to explore the determinants of success in their projects. We would also like to thank the members of the Advanced Technology Program staff who participated in interviews, reviewed our report, or otherwise supported our research. In particular, we would like to thank Clare Allocca, Michael Daum, David Hermreck, Jeanne Powell, Rosalie Ruegg, Susannah Schiller, Stephanie Shipp, Andrew Wang, and Connie Chang from the ATP staff.

Executive Summary

This study examines how participants in Advanced Technology Program (ATP) funded R&D joint venture projects view success, as well as the factors that influence the R&D venture's success in achieving its technical and commercialization objectives. Success is viewed as a multi-dimensional construct, with the following indicators of success: (a) achieving technical objectives, (b) reaching commercialization, (c) obtaining patents, and (d) acquiring unanticipated knowledge (technology) or forming unanticipated networks of relationships. Success, as perceived by the individual firm, may vary considerably within a joint venture. In some cases, firms felt that they achieved important technical and commercial objectives while other firms in the same joint ventures did not feel the same way. Findings from the interviews also revealed a number of factors that may influence the achievement of commercial and technical objectives, including:

- *Prior collaborative relationships*: Joint ventures run more smoothly when the individual participants from different companies have experience working together.

- *Working with competitors:* "Vertical joint ventures" (participating organizations provide complementary goods and services) are easier to manage than "horizontal joint ventures" (participating organizations are direct competitors), owing to the difficulties associated with collaborating with competitors.

- *Consortium size*: Joint ventures with an optimal number of members are more likely to work together and to experience fewer coordination problems.

- *Personnel stability*: Joint ventures with low turnover of individuals were more likely to succeed in achieving technical and commercialization objectives.

The above factors are highlighted, reflecting the frequency and emphasis with which participants mentioned them. Other determinants of success were also cited, including:

- *Member motivation.* Joint ventures formed to combine complementary resources have a higher level of motivation than those formed only to share research costs.

- *Customer (technology) champion.* A customer who is willing to take risks in adopting the new technology developed by the joint venture can help drive the joint venture forward.

- *Geographic proximity.* Shorter distance contributes to joint venture success by making face-to-face meetings more convenient and less costly.

- *Professional project management.* Hiring a non-profit organization skilled in managing government contracts, for example, contributes to the success of the joint venture especially in preparing the application for funding and in managing the ongoing relationship with ATP.

- *Effective governance.* Working out governance issues with regard to intellectual property rights at the start of the project is important to making the joint venture work well.

Findings from the interviews also suggest that, compared to collaborative R&D alliances without government involvement, ATP is accelerating and improving the successful outcome of collaborative endeavors. Moreover, the findings suggest that ATP is providing funding during critical stages. In addition, ATP helps joint ventures to overcome barriers to collaboration, and then helps collaborative projects run more smoothly, although with some loss of flexibility on the part of companies. The results are considered suggestive rather than conclusive. A larger survey of ATP joint ventures is planned for 2002. Statistical analysis of the data from the follow-on survey will allow generalization of results to a larger population. The study described here lays the framework for that future work.

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Introduction

Innovation and knowledge management are increasingly important dimensions of competition in technology-intensive industries. For firms in such environments, learning is the key to acquiring the capabilities needed to produce innovations that result in superior performance (Teece, Pisano, and Shuen, 1997). Yet, individual firms are often limited in their ability to generate new knowledge and produce innovative new technologies and products. As a result, companies are increasingly seeking collaborative relationships with other firms in order to access complementary resources, capabilities, and knowledge that reside outside the firm, but which may be important to producing innovations.

COLLABORATION: IMPORTANT AND DIFFICULT

During the past two decades there has been an extraordinary increase in the number of interfirm collaborations that are often referred to as alliances or joint ventures among firms. Indeed, alliances have become one of the most important organizational forms with more than 20,000 alliances reported in just the last two years (Anand and Khanna, 2000). Many of these collaborations are research and development (R&D) alliances designed to generate innovations by tapping into the knowledge that resides in multiple firms. Alliances have become a popular organizational form for bringing together the complementary skills of firms although these alliances are also fraught with risks. Indeed, there is considerable evidence that interfirm collaborations are difficult to manage, and a large percentage fail to live up to expectations. Most studies indicate that 30 to 70 percent of the alliances formed end up failing (Kogut,1989; Bleeke and Ernst, 1995; 1996). Harrigan (1985) conducted one of the first studies on alliance success and found that almost 50 percent of alliances end in failure. Similarly, Kogut, in a study of joint ventures in the United States, found that 54 percent were terminated within the first seven years (Kogut, 1989). Kogut observes that "the significant number of terminations of joint ventures in the early years suggests that many of these terminations are a result of business failure" (p. 184), though some may have been terminated because the venture met its objectives. A more recent study of alliances by Arthur Andersen found that 30 percent of alliances were reported as outright "failures" and another 27 percent were "unsatisfactory" (Alliance Analyst, 1996). These studies indicate that while alliances may be mushrooming in unprecedented fashion, alliance success is difficult to come by. Thus, understanding what firms can do to enhance the probability of success in collaborative ventures is an intriguing and important question for both managers and alliance researchers.

GOVERNMENT AS A CATALYST FOR COLLABORATION

Though most of these inter-organizational collaborations are among "private" firms, some are collaborations among private firms, universities, and governments (Powell, Koput, and Smith-Doerr, 1996). In fact, recent research suggests that government can play an important role as a catalyst for interfirm collaboration (Ouchi and Bolton, 1988; Kelley and Cook, 1998). Not only can governments play an important role in facilitating R&D collaboration, but some researchers argue that under some conditions the government's involvement in facilitating collaboration may also be critical to success. Private firms can effectively develop "private property," but "leaky property" requires collaborative arrangements across firm boundaries. (By leaky property, we mean intellectual property that is of value as a platform or infrastructure for all firms in a particular industry. Its value derives from its utility as the basis for subsequent innovations by multiple firms. Hence, technical advance in the industry will be enhanced by firms in the industry cooperating with one another to develop such a common infrastructure. The creator of the intellectual property cannot appropriate the benefits of its investments.) Although university and government laboratories are well suited for developing public property, interfirm collaboration may be a more effective means of pursuing leaky property. Because of the high degree of technical risk or an inability to appropriate sufficient benefits from the developed technology, single firms are unwilling to act alone to develop "leaky" technology.

According to Ouchi and Bolton (1988, p. 12), the lack of appropriate institutional forms will have a detrimental impact on international competitiveness: "A society which fails to fully provide for the creation of multi-firm industry collaboration will inefficiently produce leaky property and, in a world market, will suffer in competition with a society which is more completely equipped with a range of institutional forms." They argue that the government can play a key role in facilitating multi-firm industry collaboration to produce leaky property.

Other research suggests that firms that collaborate on a government-funded research project may develop or refine routines for interfirm collaborative innovation. Research by Kelley and Cook (1998) provides indirect support for this conjecture. Kelley and Cook, observing that the U.S. government requires defense contractors to provide information on their business practices to the government and to other contractors, proposed, and confirmed, that firms within this defense industry network learned about information technology applications more quickly than firms outside the network. Furthermore, companies, by participating in government-sponsored multi-firm collaborations, increase their alliance experience and their capability at managing alliances. This improves alliance success rates as noted by a number of studies that show a positive relationship between alliance experience and alliance success (Anand and Khanna, 2000; Dyer, Kale, and Singh, 2001).

These studies suggest that government intervention to catalyze interfirm collaborative innovation could be socially beneficial. By identifying opportunities to develop leaky property and by funding interfirm collaboration to pursue these opportunities, governments could

assist firms in developing knowledge and capabilities that have value to society exceeding the funding costs.

Given that collaborative ventures are increasingly important for innovation and the fact that collaborative ventures have a high probability of failure, this study seeks to develop an understanding of success in government-funded research joint ventures and to identity the key determinants of success. In addition, we explore the role of government in facilitating the development of R&D collaboration in industry. By applying these insights our study explores what, if any, practices and policies both firms and governments can implement to improve the likelihood of success in government-funded research joint ventures.

METHODOLOGY

The research design employed in this study follows the fundamental prescription of Glaser and Strauss (1967) called "grounded theory." We establish a specific area of study and a general theoretical framework without specifying hypotheses *a priori*. Instead, we allow these to flow from the phenomenon being studied. We conducted semi-structured interviews of both government project managers and representatives of companies participating in 18 joint venture R&D projects on manufacturing technologies of special relevance to the automobile industry. These projects were public-private partnerships with ATP and the companies participating in the R&D project. The ATP awarded grants that covered part, but not all, of the costs to those companies. The interviews consisted of open discussion around a few general discussion points provided by the interviewer. The same set of discussion points was used with both the government project managers and with the joint venture participants. Below are the discussion points:

- How would you define success in a venture like this? What makes one joint venture more successful than another?

- Is achieving the technical and commercialization objectives provided to ATP in the project proposal a good measure of success? Did the joint venture achieve these objectives?

- What factors influenced the success or failure of the joint venture? What are the barriers to success? What are the enablers?

- What was the role of ATP in this joint venture? Did ATP have any influence beyond the provision of funding?

Hypotheses with regard to the determinants of success have been developed from the interviews and will be empirically tested by using a survey instrument. This report contains the findings from the interviews and the tentative hypotheses.

RESEARCH CONTEXT

The government actor involved in this study is the Advanced Technology Program within the National Institute of Standards and Technology (NIST), an agency of the U.S. Department of Commerce's Technology Administration. The primary objective of ATP is "to stimulate U.S. economic growth by developing high risk and enabling technologies through industry-driven cost-shared partnerships." (See ATP's website at http://www.atp.nist.gov.) The ATP implements this mission by selecting promising, high-risk research projects from single company and joint venture applicants. A single company applicant can receive up to $2 million to cover the direct costs of R&D activities for up to 3 years and must cover all indirect costs related to the project. To encourage the broad diffusion of the new technology, ATP encourages the formation of research joint ventures. A joint venture can receive funds for R&D activities to cover direct costs for up to five years. There is no funding limitation for joint ventures, but participants must cover more than half of the total project costs. Firms initiate the formation of ATP joint ventures by submitting R&D proposals. An ATP joint venture must have at least two for-profit companies, each substantially performing the research and contributing to the cost share requirement.

Until 1994, ATP conducted only "general competitions," or competitions that were open to proposals in all types of technologies. "Focused program competitions," for which ATP set goals for the development of specific types of technologies, were conducted between 1994 and 1998. The ATP developed focused programs based on input from industry and academia (in the form of white papers, conversations, and workshops). These focused programs included specific research and business goals. The ATP, by tying competitions to specific programs, sought to generate synergies from the sponsorship of similar research projects. The ATP received more than 1,100 white papers, and, after discerning the viability of each paper's thesis, created 17 focused programs. One of these programs is the Motor Vehicle Manufacturing Technology focused program, which held its first competition in 1995. The mission of this program was "to foster innovations in manufacturing technologies that can strengthen capabilities and lead to dramatic advances along the entire automotive production chain, including more versatile equipment, better control and integration of processes, and greater operational flexibility at all levels. Automotive suppliers are key partners and players in this program." (See http://www.atp.nist.gov/atp/focus/mvmt.htm.)

DATA SET

The data set examined in this study consists of 18 research joint ventures that received an ATP award between 1991 and 1997. Only joint ventures are examined in this study because of our emphasis on interfirm collaboration, although single company projects often involve subcontractors and other informal partners. These 18 joint ventures came from both general competitions and focused program competitions. To increase comparability, the set of joint ventures was restricted to those focusing on technology having potential applications in the automotive industry. Thus, in our study we include all 18 automotive joint ventures in which

funding by ATP was initiated between 1991 and 1997. (Appendix Table A1 lists these joint ventures.) Interviews for this study took place in 1999.

Each of the 18 joint ventures had invested $5 million or more in their projects with approximately half of the funding provided by ATP. The joint ventures varied in size from 2 to 21 member organizations. (See Appendix Table A2 for further descriptive statistics concerning the 18 projects.) There was also variation in the age of the joint ventures, but we examined only those joint ventures that had been in existence for at least one year. Of the 18 joint ventures we studied, 10 were still ongoing, 7 had completed all technical work, and 1 project was terminated before the project was completed.

What Constitutes Success from the Perspective of Participants?

DEFINING JOINT VENTURE SUCCESS

Assessing the performance of R&D activities is difficult. Assessing the performance of collaborative R&D projects is even more difficult because of the potential existence of multiple perspectives. But an even greater challenge, one which ATP faces regularly and which this study sought to address, is defining success in a way that allows comparisons across different R&D joint venture projects (because each project is attempting to achieve different technical objectives). This study focuses on success from the perspective of the participants. ATP's measures of success would be somewhat different, going beyond benefits to the participating firms to encompass benefits to the broader public. A common acid test for joint venture success, according to participants, was whether the project produced a commercializable technology or product and, related to that, the extent to which the joint venture achieved the technical objectives identified at the beginning of the project. A project that was terminated before its completion date was generally deemed a failure. (One exception was a joint venture that transferred its source of funding from ATP to another government agency.) The views of success expressed in our interviews can be grouped into five categories:

- The extent to which the venture *achieved the technical objectives* identified at the beginning of the ATP-funded project.

- Whether or not the *technology was commercialized* (and the economic value of the commercialization).

- Whether or not the venture *generated patents* (though this was not an appropriate measure for all ventures).

- Whether or not the venture built *important networks of relationships* with key individuals in other firms (that may have resulted in other unanticipated ventures or business opportunities).

- The extent to which the venture generated *benefits that were unanticipated* at the beginning of the project (e.g., unanticipated technical knowledge, knowledge that convinced the firm to move in different technology directions).

Successful ventures were those that met the technical objectives (including generating patents) and produced a new technology worthy of commercialization. One participant said that, "Certainly one measure of success is whether or not we were able to meet the technical

objectives we laid out at the beginning of the program. But an even more important measure of success is whether or not the technology resulted in a commercializable product."

However, ventures could also be deemed somewhat successful if those ventures generated benefits to firms that were not directly related to the ATP technical objectives (e.g., the formation of relationships with other firms that resulted in other ventures or business opportunities, or the development of unexpected technologies, knowledge that convinced the firm to move in different technology directions). Naturally, the most successful ventures were described as those that met the technical objectives, generated patents, produced a commercializable technology or product, and produced unanticipated benefits of the types described above. We interviewed participants who, in some cases, reported wide differences in perceived success within their ventures. Some claimed that the projects did not really meet the milestones or produce anything of value for their company while others claimed that the project achieved the technical milestones and produced a technology or product that was in the process of being commercialized.

Meeting ATP Technical Objectives

One of the measures of success employed by ATP is the extent to which technical objectives are achieved relative to the joint venture's approved time and budget schedule. The participants we interviewed agreed that this was one reasonable measure of venture success. However, in some cases the participants claimed that they might achieve the technical objectives without producing any technologies that were of real value to the participants. One manager explained that even if the technical objectives can be achieved, it might not make sense to do so. The value of achieving the technical objectives may not be as high as was expected. Joint venture participants described situations in which less expensive alternative solutions became available during the course of achieving subtasks within a joint venture. Consequently, in those cases the participants had less incentive to achieve the technical objectives. Likewise, a joint venture may hit an obstacle but see a very promising low-risk alternative. If the joint venture decided to pursue this alternative, then the ATP joint venture must be terminated (thus, it is possible that even ventures terminated early may produce something of value). However, every joint venture monitored its progress against technical objectives in part because such information must be reported to NIST and also because this provided a means of helping to structure the joint venture's activities. Thus, as a performance measure it is available for every research joint venture.

Reaching Commercialization

Joint venture participants viewed commercialization of a new product or technology as the most important measure of success. However, our interviews revealed that achievement of this goal was rare (again, this was a small sample and most projects were ongoing). Small firms placed much more emphasis on commercialization than large firms did, especially when they were or could be suppliers to larger firms within the joint venture. One participant from a

small firm said, "Commercialization is ultimately the only relevant measure of success. As a small firm it is critical to us." Small firms were often the potential suppliers of the new technologies to larger firms, and they were hoping that the project would lead to a product/technology that they could sell. Participants in larger firms were more likely to recognize that the knowledge acquired through participating in an ATP project could be useful in the future and was valuable as part of the company's stock of knowledge. Thus, the knowledge acquired might lead the large firm to move in new technology directions, to instigate other R&D projects, or to purchase other technologies.

Participants also made a distinction between commercialization and the value from commercialization. For example, in one case the participant claimed that the joint venture had developed a commercializable product that could not be sold. In this particular case no market existed for the product outside of the auto industry and the automakers in the joint venture refused to buy the product because internal engineers assured them that an alternative solution was being developed independently. In another case, a commercializable product was developed, but less expensive alternative substitutes arrived at roughly the same time. Thus, the value of the commercialized technology or products may be a better measure of success than simply whether or not the technology reached commercialization.

We found that one effective method for evaluating success of the research joint venture from the participants' perspective was to have the participants estimate (using 20-20 hindsight) how much money their organization would have been willing to pay to participate in the joint venture. Again, the range of answers on this question was varied, even within the same joint venture. Some participants reported they would not pay a single dollar to participate in the joint venture while others provided much higher estimates. One participant said, "We didn't get very much out of the venture, but company X (a small firm) was able to develop a product that will have a dramatic increase on their sales. I'm sure they view the program as a great success."

Obtaining Patents

All interviewees reported that patents and copyrights are measures of technical success, but they noted that firms and joint ventures vary in their propensity to patent and that some types of technology lend themselves to patenting more than other types of technology. Interviewees also noted that the value of patents varies dramatically so that the number of patents is not necessarily informative. According to one participant, "If you want to look at number of patents, I guess there are about three or four that came out of this particular program. But you don't make a profit on patents. You've got to sell a product to make a profit on it." Yet, patents did seem to be valued as an indirect measure of technical progress. One representative said, "Management and the ATP want these patents in order to show technical success." For those projects where patents are possible, the number (and estimated value) of those patents is a reasonable measure of success. We would expect a positive correlation between the number of patents and the first two measures of success (whether they met ATP technical objectives and whether they produced a commercializable product). But the strength of the correlation is still an unanswered, empirical question.

Unanticipated Benefits: Extending Network of Technical Experts

A common theme among participants was that ATP joint ventures frequently led to unanticipated benefits for both the individuals involved and for their employers. Participants benefited from extending their personal network of experts with technical skill in their area. A few participants argued that historically it had been especially difficult in the auto industry to develop relationships among researchers at different employers. Antitrust laws had resulted in very strong policies and norms against interfirm contact, and individuals were socialized against contact through training programs designed to prevent all types of social interaction. Some participants saw ATP joint ventures as a means of transforming the anti-collaboration "culture" in the auto industry. One participant said, "Before the ATP program, we never would have gotten together with our competitors to collaborate in developing a new technology."

To summarize, while interviewees' interpretation of research joint venture success varied, all related to one of five categories: achieving technical objectives, achieving commercialization objectives, generating patents, extending networks, or providing valuable but unexpected benefits. On average, companies stressed the first two categories, that is, the attainment of technical and commercial objectives. However, we find that companies place different weights upon these different categories and that these heterogeneous priorities can contribute to a high variance in perceived success from the perspective of different companies in the same research joint venture. Not surprisingly, companies tend to equate joint venture success with benefits to themselves, but even similar benefits can translate into different levels of perceived success because of different weights.

Our analysis of success from the perspective of participants thus suggests that companies in research joint ventures apply similar criteria but different weights in assessing joint venture success. Any single weighting, even an average, is likely to closely match that of some participants at the expense of others. We note that the value of an operationalization or measure depends on its usage. *Ex post* assessments of economic impact are an appropriate measure of the return to society from funding research joint ventures. However, any "in process" measures intended to monitor and facilitate research joint venture success need to reflect the heterogeneity of the participating firms' priorities.

DETERMINANTS OF SUCCESS

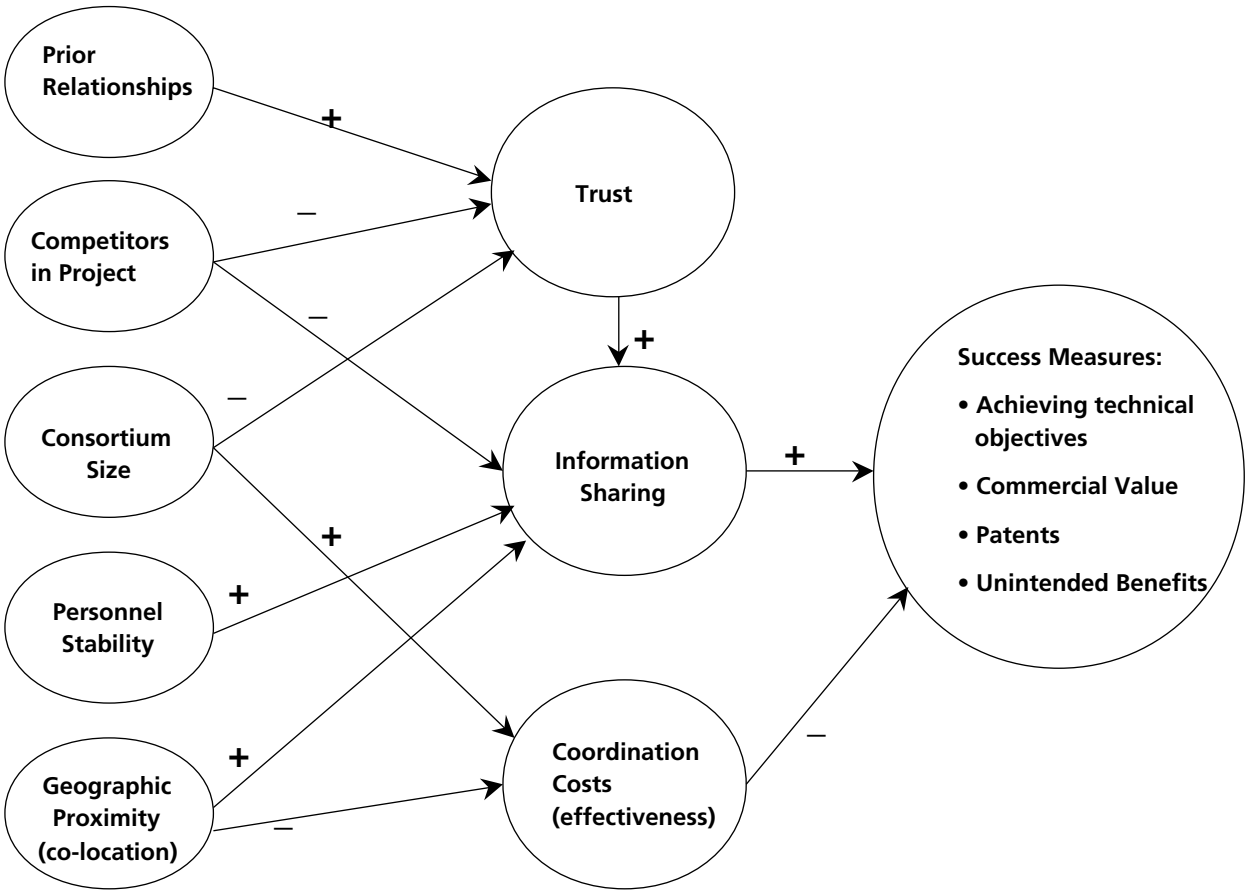
Our interviews revealed a variety of factors that influence the performance of ATP joint ventures. We were able to triangulate perspectives and to develop a more robust assessment of each joint venture by comparing different perspectives across interviewees in the same joint venture. However, differences in perceptions of performance naturally translated into differences in perceived determinants of success. Cross-case comparison was the most useful tool in our induction of the determinants of success. At a basic level, we found that more successful joint ventures were characterized by (a) greater knowledge sharing among participants and (b) more effective coordination (lower coordination costs) among

participants. A variety of factors influenced the willingness or ability of joint venture partners to share knowledge (e.g., the extent to which the participants trusted each other) and the cost of coordinating the venture's activities.

Figure 1 captures participants' responses about what determines success. It is a path diagram that shows key factors that participants said influenced their joint venture success, or lack thereof. The direction and nature of the impact, and the linkages from these factors to outcome success measures, are shown. The first set of circles on the left contains five of the factors that participants said influence their collaborative success. On the right side of the figure is the participants' list of success measures. The two characteristics that the more successful joint ventures exhibited are greater knowledge and information sharing and lower coordination costs among participants. This is shown in the center of the figure, together with "trust," which is more closely linked to information sharing. These are the key mechanisms through which the five factors influence success.

The greater the trust, the more information is shared, and the greater the likelihood of a successful outcome. The higher the coordination costs, in contrast, the lower the likelihood of a successful outcome. Reading from left to right along the directional lines, the plus and

Figure 1. The Determinants of Success in ATP-Sponsored Joint Ventures



minus signs reveal the nature and direction of impact. Each factor contributes to, or detracts from, success. For example, geographic proximity lowers the costs of coordination and, hence, is positively associated with success (shown by the two negative signs linking these directional arrows in Figure 1).

Prior Collaborative Relationships

Prior relationships among individuals at different joint venture companies were influential in several joint ventures and instrumental in at least one. By prior relationships we are referring to the history of interactions among individuals participating in the joint ventures. When the individuals initiating the joint venture had experience working together, the member participants were more likely to trust each other and share information, thereby increasing the probability that the project would achieve its objectives. To illustrate, a central actor who had worked for each of the Big Three U.S. automakers and had extensive contacts among their research personnel initiated one joint venture, deemed quite successful by its participants. Drawing on these relationships from each automaker, this individual selected a relatively small and close-knit group of individuals to include in the joint venture. Thus, prior relationships served as a catalyst for effective inter-firm collaboration even if these relationships were indirect, that is, through a common or central individual.

In another joint venture that "functioned smoothly," a participant noted that prior personal relationships were important. The participant said, "To be honest, there was virtually not a single member of the joint venture who I did not know at least some of the people involved before the thing started…. So I had had some experiences working with them, and they had all been pleasant working experiences." In another case, deemed "unsuccessful" by a participant, the participants did not know each other very well before the ATP project began. As a result, "We spent the first year just getting to know each other and trying to build trust," said one participant. This participant added, "There were too many participants and too many of the participants were competitors. Nobody knew each other well enough or trusted each other enough to share any really valuable information." Thus, our interviews suggest that the probability of success was enhanced when the participants had previously interacted or had prior relationships (and came into the joint venture trusting their ATP partners). Participants with a history of working together were more likely to trust each other and openly share the knowledge necessary to achieve the project's technical objectives.

Working With Competitors

Some participants indicated that an important determinant of success was the relationship among the participants, which influenced the degree of trust and information sharing within the joint venture. One participant said,

> It is my experience that vertical joint ventures are more effective than horizontal joint ventures. With vertical joint ventures, there are no direct competitors and everyone is

> in a win-win situation. As a result, everyone is more likely to lay their cards on the table. But that's not true with horizontal joint ventures. When you are direct competitors, you are more guarded and keep your cards close to the vest. That's the main reason we didn't get anything out of our horizontal joint ventures.

Another participant said, "Having direct competitors in the joint ventures definitely inhibited information sharing. I don't take guys who talk too much to the meetings; sometimes I have to say to them 'That's enough. You are talking too much.'" This participant felt that having competitors in the same joint venture caused the competitors to "rush in and try to get as much as they can…but they keep their cards close to the vest." One participant from an automaker said that the mantra in vertical joint ventures was "we are all going to make money along the value chain" while in horizontal joint ventures it was "we are fundamentally competitors."

Though some participants indicated that having competitors in the joint venture was a problem, at least one said that he did not think it was a problem working with competitors. "We've developed a good working relationship with our counterparts at the other automakers. We all share information and do what we can to make the project successful. I don't see this as a problem." (It is worth noting that this was the joint venture that was initiated by an individual who had worked for all three automakers and, therefore, had prior relationships with other joint venture participants.) Overall, the interviewees' assessment of the impact of competition on joint ventures performance was mixed. One project manager described three competitors who "were not even talking to each other" until they participated in an ATP-funded joint venture together. According to this manager, ATP facilitated the development of relationships among these competitors to share knowledge in areas of common interest. It was his opinion that "this never would have happened without the glue provided by the ATP."

Generally speaking, our interviews suggest that joint ventures with competitors have greater difficulties achieving the high levels of trust and information sharing necessary for success. This suggests that "horizontal joint ventures" must be managed with greater care because it is harder to achieve an obvious "win-win situation," which many participants claimed was important. One participant said, "In all of these programs, you have to have a win-win situation for it to work." Another said that, "you always like to see your partners in a joint venture be successful as well." Still another participant claimed that his company would not participate if they felt they had a substantial lead in the targeted technology (because it wouldn't be "win-win"). Prior relationships among participants (or other trust-building experiences) are likely to be an even more important condition for success in "horizontal joint ventures" than in "vertical joint ventures."

Consortium Size

Although no interviewee mentioned having too few joint venture members, several cited the problems associated with having too many participants. One participant was quite critical of large joint ventures:

> When we joined the ATP program we didn't realize there would be so many participants. From my perspective, there were just too many. First, it took too long getting to know everyone. In addition, scheduling meetings was a nightmare; we had to schedule meetings a year in advance. It was just too difficult to coordinate…. I would never get involved in such a large one again.

Another participant said, "The more people you have, the more people you have to coordinate. It gets unwieldy at some point." This participant was glad to have just three members in the joint venture and said that only three companies were invited to join because "between the three of us, we cover the areas of expertise necessary to achieve the goals." Still another participant said, "I would not have wanted our program to have had any more companies than it did. This one had about 10 companies. If you need more than that…it's best that they are a vendor who we could call on for support but not necessarily a member of the joint venture." It is interesting to note that this member felt that as many as 10 companies were not too many while other participants believed that coordinating the efforts of 10 companies would have been very difficult. These observations by participants suggest that there may be a maximum number of companies that can effectively coordinate on an R&D project. Otherwise the coordination costs and free-rider costs become significant and inhibit the ability of participants to share information (which is critical in research joint ventures). There seem to be important contingencies that affect the optimal size of the joint ventures, for example, the project's complexity and decomposability, but the size of our sample was not adequate for attempting to spell out these important contingencies.

We should note a curvilinear relationship between number of participants and research joint venture success. The downside of too few companies would be a lack of critical complementary resources (which might only become evident by systematically examining the relationship between number of participants and joint venture success). As previously indicated, none of the participants we interviewed complained about too few companies in their joint ventures (but, then again, they may not have realized that there would have been benefits associated with adding members).

Personnel Stability

The most frequently cited determinant of success was the stability of the personnel involved in the joint ventures. It was viewed as influencing success because it affected both information sharing (not just the willingness but the ability to share information) and coordination costs. There were two dimensions to this issue. One was the impact of turnover on the relationships among participants; that is, it took time for new researchers to meet and develop relationships with the other participants in the joint ventures. One participant said, "Turnover is a real problem. Whenever people change, we have to bring the new people up to speed, and we lose time, if not capabilities." Thus, turnover increases coordination costs. The other dimension was labeled the "beer truck syndrome" by one of the participants. "What happens," he asked, "if you are hit by a beer truck on the way home? How can your knowledge be replaced?" Participants believed that some portion of the knowledge of the joint ventures was

stored only within the individuals involved. (This is called "tacit knowledge" in the literature.) This knowledge was either lost or only remotely accessible when turnover occurred. Some participants felt that turnover was a bigger problem with small companies than larger companies, which have greater resources to draw on. One participant said, "There was some turnover on the GE Corporate Research and Development side, but they have such a stable of Ph.D.'s there, you never know the difference…. In a little company like us, it would have killed it. There's no way in a small business that you could transition on a project that big without *noticeable* loss in efficiency." Turnover was raised as a problem (or potential problem) by virtually every participant interviewed. All participants agreed that the higher the turnover of individuals in a joint venture, the lower the probability of success. However, some participants claimed that while turnover was a potential problem, they did not believe it had hurt their particular joint venture because transitions in personnel had been effectively managed.

OTHER DETERMINANTS OF SUCCESS: MOTIVATION, MANAGEMENT, AND SHARING

The four factors just highlighted were the factors most cited by the participants. However, there were other determinants of success mentioned, including: member motivation, customer (technology) champion, geographic proximity, professional project management, and effective governance of the joint ventures (including the reliable protection and sharing of intellectual property rights).

Member Motivation

Participants cited member motivation as a potential factor affecting success but also noted that the rigorous ATP application process tends to weed out companies with low levels of motivation. One participant argued that the level of motivation corresponds to the type of motivation, that is, that joint ventures formed only to share research costs have a lower level of motivation than those formed to combine complementary resources. Yet, both in the case of top managers and of researchers, participants found assessing the true level of other participants' motivation *a priori* to be impossible. Only during the day-to-day operation of the joint ventures did it become clear who was committed to the project.

Customer (Technology) Champion

Some participants stressed the need for a technology leader or product champion to drive the joint venture activities. One participant noted, "If the customer isn't an active participant and doesn't show a willingness to buy the technology, then our efforts are wasted." Based on the interviews, Ford appeared to have played this role in one joint venture while GM failed in this role in another. The reason for GM's failure was that the GM employee driving the joint venture lacked or lost the support needed from his organization. Regardless of the reason, other members felt frustrated when customers were in the joint ventures but did not take an

active role in championing the technology, including committing to buy the technology when it was developed. One participant said, "To be honest with you, Ford, GM, and Chrysler are not buying a lot of equipment at present. I don't know what the reason for that is…. But if they are not developing engines and they aren't developing new transmissions, you can pretty much have the best technology in the world, and they are not going to buy anything. And that's kind of where we are right now." One participant expressed his belief that this is a bigger problem in the automotive industry than it might be in other industries. "A lot of this stuff is brand new, and I can't say 'Well, go see it running at such and such a facility or we've built ten of them before.' It's a problem you have with all new technology, and nobody wants to be the guinea pig. They all want to go see it running at six other places, where it's been running for 10 years. And you can't do it. It's brand new. So it's tough to get somebody to be the first buyer in spite of all your best efforts. This is especially true of the Big Three because of their volume, and the cost of stoppages." This suggests the importance of a customer willing to take some risks. This also suggests industry differences in the willingness of customers to adopt new technologies.

Geographic Proximity

While most participants did not offer this on their own (without prompting), participants generally agreed that geographic proximity contributes to joint venture success by making face-to-face meetings more convenient. One participant said, "If I were running the program from the start, I would make a point to try and meet with the other members a little more frequently." Some participants did send personnel to meet for a period at the premises of another participant, which they felt facilitated interaction and improved coordination. One company representative said,

> On one project we learned much more by meeting for long periods of time at each other's facilities. For example, our partner had assured us that moisture sensitivity would not be a problem. This was something that we had been concerned about. When we co-located our personnel for a period of time, we learned that they thought that preventing moisture problems for an hour was a long time, while we thought preventing it for a week was a long time. We sorted this out in a moment once we got together on each other's turf.

None of the joint ventures had personnel who worked at more than one location, but instead divided tasks among participants and subcontractors. Every joint venture had an annual meeting that was generally attended by the ATP project manager, and some also had quarterly meetings and some monthly meetings. A few joint ventures even had weekly teleconferences. Although there was variation in the type and frequency of interaction, it was not clear from the interviews whether or not the type or frequency of interaction was an important determinant of success. Nonetheless, geographic proximity seems to lower the costs of coordination and, hence, is positively associated with success.

Professional Project Management

Another factor that seemed to influence joint venture success was the use of a hired project manager. In some cases, an existing joint venture participant served as the project manager. In others a non-profit organization with experience in managing government contracts was employed as the project manager (e.g., National Center for Manufacturing Sciences). The cost of using professional project management was described as "high." Yet, the interviewees saw this as a necessary expense, especially in preparing the application for ATP funding and in managing the ongoing relationship with ATP. One participant said, "It helps to have someone involved who is experienced in working with the government. There's lots of paperwork that needs to be handled by a specialist. A non-specialist can't do it." Joint ventures may hire outside project managers in part because these outsiders are able to compile sensitive information that must be reported to ATP (e.g., salary information) without leaking it to companies within the joint venture.

Effective Governance

Governance issues were especially important at the start of the joint venture project. Creation of joint venture agreements is an ATP requirement before an award can be made so that issues of property rights would not stall a project later on. According to participants, company lawyers were very intent on protecting their employers' existing intellectual property. A participant in one case had a company policy of not signing a non-disclosure agreement with other firms. Consequently, this participant was excluded from certain meetings because other participants felt they could not maintain their intellectual property rights. At least one participant felt this hindered the joint venture's ability to achieve its objectives. Participants also complained about the amount of time that it took to complete this stage of joint venture formation (though some recognized that it was necessary). Participants referred to non-ATP alliances that were started based solely on a handshake and stressed how these other collaborative efforts progressed much more quickly. However, they may be more likely to fail in the end because they had not hammered out an agreement up front.

Participants in some joint ventures contributed intellectual property as agreed without direct compensation. In other joint ventures the firms were compensated for their contributions of intellectual property at the start of the joint venture. The ATP allows the participants in a joint venture to reach their own agreements on the ownership of intellectual property produced by the joint venture, but it does require that at least one for-profit organization owns the rights to the intellectual property. By far, the most common feature of agreements regarding the intellectual property produced by the joint venture was to grant all participants full access to it. In general, the participants we interviewed felt that the governance issues with regard to intellectual property rights had been worked out to their satisfaction.

ATP'S CONTRIBUTIONS: ACCELERATION OF R&D, STABILITY, AND ORGANIZATION

Joint venture participants were prompted to compare the ATP joint venture to a similar collaborative project (not government sponsored) in which they were involved. The projects that ATP funded were described as riskier and more long term, which is consistent with ATP's intent. One participant noted, "I think the ATP accelerates the development of high risk technologies." ATP projects also require and get more upfront commitment from top management. This requirement allows for more concrete planning and lowers internal monitoring and budgeting costs because the project is not constantly being re-evaluated. Participants involved in the day-to-day operations of the joint ventures valued this commitment of time, funds, and resources because it allowed them to engage in long-range planning and stay on schedule. Yet, the commitment also made ATP projects less flexible.

The interviews revealed another potential role for ATP in the seeding of joint ventures, that is, carrying valuable joint ventures through difficult periods in their life cycles. This relates to a network or institution building function on one level. Some participants felt that there were barriers to collaboration in the U.S. automotive industry and that ATP played a role in overcoming these barriers. From our perspective, ATP played a similar role at a more micro level. Just as firms must overcome a "liability of newness" (Hannan and Freeman, 1984), so too do new R&D joint ventures face a similar, or perhaps even greater, liability owing to the complexity associated with governing a new collaborative venture with independent firms.

Another role that ATP plays is that it transforms what is usually an iterative and ad hoc innovation process into a more goal-directed and organized project. It does this primarily through its demanding application process. One participant claimed that, in addition to the funding, the application process enhanced the probability of success. "If all we did was write the proposal, it would be valuable. By going through the application process, we do much better upfront planning than we do in our private collaborative ventures." Another participant described this process as "both a plus and a negative. We don't have time to prepare that application. It is not like a non-specialist can prepare an application like that." Many joint ventures seek help from experienced, outside organizations with project managers who are skilled with working with the government. Yet, once the application process is completed, participants generally felt that this large amount of upfront planning led to a smoother running joint venture.

Conclusion

This study examined R&D success from the perspective of joint venture participants in ATP-funded projects and found general agreement on dimensions of success but differences in the weights placed by companies upon these dimensions. Thus, we recommend the use of multi-dimensional measures of success for monitoring success in ongoing research joint ventures. This study also examined the potential determinants of research joint venture performance and found that participants stressed four factors that affected knowledge sharing and coordination costs in managing the joint ventures. These four factors are:

- **Prior collaborative relationships.** Joint ventures where the participating firms have had prior collaborative experience with other joint venture members are more successful.

- **Working with competitors.** Joint ventures without direct competitors ("vertical joint ventures") are more successful than joint ventures with direct competitors ("horizontal joint ventures"). A bimodal distribution may exist; that is, collaboration with competitors may turn out to be either very unsuccessful or very successful.

- **Consortium size.** Joint ventures with an optimal number of participants are more successful (or, alternatively, there may be a curvilinear relationship between the number of participants and the degree of project success; that is, projects with too few, or too many, participants may be less successful).

- **Personnel stability.** Joint ventures with low personnel turnover are more successful.

Although many participants mentioned these factors, none of these was reported by all interviewees. The reason for this is, in part, that there seem to be important contingencies operating on these determinants of performance. Some of these contingencies began to appear when participants were asked to compare the research joint venture examined in this study with other research joint ventures in which the interviewee's company had participated. For example, turnover was a major issue in most research joint ventures, but turnover was not mentioned as an issue when the lead organizations in the research joint ventures had large, established research groups. Turnover seemed to have a more detrimental impact on joint venture performance when it occurred in younger joint venture participants and in small firms. Also, we found that horizontal joint ventures were in general more difficult to manage because of the presence of direct competitors. However, in at least one case the personal relationships of the researchers developed through prior collaborative research overcame this obstacle to effective collaboration. Our research methodology was capable of detecting some contingencies that the interviewees themselves recognized, but not of systematically mapping

all important contingencies in our data set, which was itself a relatively small subset of all ATP-funded research joint ventures.

FUTURE WORK

As intended, the exploratory methodology applied in this study has been more suggestive than conclusive. Our analysis of the interviews we conducted provides insight into the phenomena of interest, but our results can only be verified with a more comprehensive study that includes statistical analysis of a large sample. There are two major disadvantages to the exploratory approach used in this study that future research could address. First, the exploratory approach relies heavily on the perceptions of participants to disentangle complex causal relationships. It is impossible to verify the existence, or the strength, of the relationships among the factors identified in this study (that is, the strength of the correlation between the determinants of success, and success) without statistically analyzing the full set of participants' coded responses. The second weakness of our approach is that it generates results that cannot be accurately used to describe the actions of the entire population of ATP-funded research joint ventures, much less to the even larger population of all research joint ventures. Survey research could easily compensate for these disadvantages, and through triangulation with the qualitative research already completed, provide a much more complete picture of performance in research joint ventures. Survey research also relies on perceptions, and it can test many of these perceptions statistically by comparing them across many research joint ventures. Further, some determinants of success are not perceptual but are more objective in nature. Survey research enables inference to a larger population (e.g., number of participants, existence of competitors). In addition, interaction terms could be applied in the statistical analysis of the survey data to provide a much more complete mapping of important contingencies in the data (e.g., the effects of company size and the variance in company roles, the effect of the degree of trust among firms in the joint venture, the effect of the number of participants). Multiple measures of the benefits realized by each participant (and the aggregate measure of overall joint venture performance) could be applied, compared, and refined through statistical analysis of survey data on a larger population of firms participating in ATP-sponsored joint ventures. A larger survey of ATP joint ventures is planned for 2002. Statistical analysis of the data from the follow-on survey will allow generalization of results to a larger population. The study described here lays the framework for that future work.

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Appendix

Appendix Table A1. ATP Projects Included in the Study

Project Number	*Project Name*
91-01-0083	NCMS Rapid Response Manufacturing
91-01-0177	Development of Advanced Technologies and Systems for Controlling Dimensional Variation in Automobile Body Manufacturing
93-01-0244	Strategic Machine Tool Technologies: Spindles
94-01-0079	Engineered Surfaces for Rolling and Sliding Contacts
94-01-0178	Rapid Agile Metrology for Manufacturing
94-02-0027	Automotive Composite Structures: Development of High-Volume Manufacturing Technology
94-02-0030	Polymer Matrix Composite Power Transmission Devices
95-02-0008	Agile Precision Sheet-Metal Stamping
95-02-0013	Intelligent Resistance Welding
95-02-0026	Flexible Low-Cost Laser Machining for Motor Vehicle Manufacturing
95-02-0035	Springback Predictability in Automotive Manufacturing
95-02-0036	Plasma-Based Processing of Lightweight Materials for Motor-Vehicle Components and Manufacturing Applications
95-02-0058	Flow-Control Machining
95-02-0062	Fast, Volumetric X-Ray Scanner for Three-Dimensional Characterization of Critical Objects
97-02-0018	Flexible Robotic Assembly for Powertrain Applications (FRAPA)
97-02-0028	Sub-Micron Precision Grinding of Advanced Engineering Materials
97-02-0047	Nanocomposites New Low-Cost, High-Strength Materials for Automotive Parts
97-02-0055	Development of the 3D Printing Process for Direct Fabrication of Automotive Tooling for Lost Foam Castings

Appendix Table A2. Descriptive Statistics on the 18 ATP-Funded Joint Venture Projects Focusing on Technologies Having Potential Applications in the Automotive Industry (1991–1997)

18 joint venture projects involving 179 participants
- 18 Joint Venture Leads (JVLs)
- 161 Joint Venture Other Participants (JVPs)

Number of joint ventures, by type
- 10 horizontal joint ventures (the organizations in the joint venture are direct competitors)
- 8 vertical joint ventures (the organizations in the joint venture provide complementary goods or services)

179 participants, by type of organization
- 14 are non-profits (8%)
- 53 are large businesses* (30%)
- 52 are medium businesses* (29%)
- 51 are small businesses* (28%)
- 2 federal labs (1%)
- 7 universities (4%)

Project participants are located in 24 different states. The top 4 were:
- Michigan (97)
- Ohio (24)
- Pennsylvania (10)
- California (9)

Project costs
- ATP funding: $ 96,524,806 (46%)
- Industry Cost-Share: $112,371,099 (54%)
- Total Project Costs: $208,895,905

* Small business is defined as an organization with fewer than 500 employees; large business is defined as a Fortune 500 or equivalent organization; and medium businesses are all others.

ABOUT THE ADVANCED TECHNOLOGY PROGRAM

The Advanced Technology Program (ATP) is a partnership between government and private industry to conduct high-risk research to develop enabling technologies that promise significant commercial payoffs and widespread benefits for the economy. The ATP provides a mechanism for industry to extend its technological reach and push the envelope beyond what it otherwise would attempt.

Promising future technologies are the domain of ATP:

- Enabling technologies that are essential to the development of future new and substantially improved projects, processes, and services across diverse application areas
- Technologies for which there are challenging technical issues standing in the way of success
- Technologies where the development often involves complex "systems" problems requiring a collaborative effort by multiple organizations
- Technologies that will go undeveloped and/or proceed too slowly to be competitive in global markets without ATP

The ATP funds technical research, but it does not fund product development. That is the domain of the company partners. The ATP is industry driven, and that keeps it grounded in real-world needs. For-profit companies conceive, propose, co-fund, and execute all of the projects cost-shared by ATP.

Smaller companies working on single company projects pay a minimum of all the indirect costs associated with the project. Large, Fortune 500 companies participating as a single firm pay at least 60 percent of total project costs. Joint ventures pay at least half of total project costs. Single company projects can last up to three years, and joint venture prejects can last as long as five years. Companies of all sizes participate in ATP-funded projects. To date, more than half of the ATP awards have gone to individual small businesses or to joint ventures led by a small business.

Each project has specific goals, funding allocations, and completion dates established at the outset. Projects are monitored and can be terminated for cause before completion. All projects are selected in rigorous competitions that use peer review to identify those that score highest against technical and economic criteria. Contact ATP for more information:

- On the Internet: http://www.atp.nist.gov
- By e-mail: atp@nist.gov
- By phone: 1-800-ATP-FUND (1-800-287-3863)
- By writing: Advanced Technology Program, National Institute of Standards and Technology, 100 Bureau Drive, Stop 4701, Gaithersburg, MD 20899-4701

ABOUT THE AUTHORS

Dr. Jeffrey H. Dyer holds the Donald Staheli Chair in International Strategy at the Marriott School, Brigham Young University. Before accepting the Staheli Chair, Dr. Dyer was a professor at the University of Pennsylvania's Wharton School. Dr. Dyer received his doctorate (Ph.D.) in Strategy and Organization from the University of California, Los Angeles. His experience includes five years as a consultant and manager at Bain & Company. He has consulted at companies such as Motorola, Ford, Navistar, Bang & Olufsen, Kraft, Baxter International, First National Stores, Maryland National Bank, and General Motors. Dr. Dyer's research focuses on creating competitive advantages through strategic alliances and effective supply chain management. He has published a book, *Collaborative Advantage*, and has published in a variety of journals including the *Harvard Business Review*, *Sloan Management Review*, *California Management Review*, *Strategic Management Journal*, *Academy of Management Review*, and *Organization Science*.

Benjamin C. Powell is a doctoral candidate in the Management Department at the Wharton School, University of Pennsylvania. He holds an M.A. from the University of Pennsylvania in Applied Economics and Managerial Science and a M.B.A. from the Kenan-Flagler Business School, University of North Carolina–Chapel Hill. Benjamin's six years of professional experience includes working for Milliken & Company's alliance with TRW to develop air bag fabrics and work as a consultant with Heiniburg Corporation setting up automotive joint ventures in Thailand.