COOPERATIVE SCIENCE: A NATIONAL STUDY OF UNIVERSITY AND INDUSTRY RESEARCHERS

ASSESSMENT OF THE INDUSTRY / UNIVERSITY COOPERATIVE RESEARCH PROJECTS PROGRAM (IUCR)

PRODUCTIVITY IMPROVEMENT RESEARCH SECTION

DIVISION OF INDUSTRIAL SCIENCE & TECHNOLOGICAL INNOVATION

NATIONAL SCIENCE FOUNDATION

VOLUME I
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Productivity Improvement Research Section

CONTENTS

LIST OF ILLUSTRATIONS

Tables

Tables

Figures

Executive Summary

This report presents data from a national study of 118 Industry/University Cooperative Research (IUCR) projects supported by the National Science Foundation. Questionnaire responses were gathered from 226 industry and university scientists working on these projects. The purpose of the study was to describe how IUCR projects develop, how they are implemented, and discover what project features contributed to successful technical and organizational outcomes.

In general the variables that seemed to contribute to all aspects of project success were those related to interpersonal interaction. The IUCR program was conceived as building on dialogue between university and industry scientists; this study uncovered abundant evidence that this design approach was realized in practice.

As a point of departure, it seems clear that these IUCR projects rested on a previous existing foundation of social and professional exchange. Prior relationships between the university and industry participants were extensive, with consulting relationships being particularly important. These were relatively senior scientists, and in many cases their prior relationships were of many years standing. These previous contacts spanned the gamut: collegiality, friendship, joint authorship, faculty-student relationships.

This pre-existing network of interactions was essential to initiating the work, and contributed to interaction during the course of the projects. Frequent and informal interaction in implementation seemed a crucial ingredient in all aspects of project success for both university and industry scientists. It also contributed to their learning how to cooperate with the other sector. Phone calls, meetings, "bull sessions," and personnel exchanges were integral parts of these projects.

The university participants did play more of a leadership role in initiating the projects, and in performing the various research tasks. In fact, university impetus in project initiation was seen by both university and industry participants as an important correlate of perceived commercial outcomes such as improvements in products and processes. Also important in project initiation were the NSF program and NSF staff. Most of these projects would not have been undertaken as cooperative efforts in the absence of NSF funding, and NSF staff were often crucial in brokering the relationship between the investigators or informing them about the program.

Both university and industry scientists were generally pleased with their participation, and there was a high degree of consensus about goals that could or should be achieved in the projects. This satisfaction tended to be a function of the intraproject "networking" interaction alluded to above. University scientists were slightly more optimistic about the likelihood of achieving commercial outcomes (e.g., improvements in products or industrial processes); both groups felt that improvements in instrumentation and methods would likely result from the projects.

Interesting results emerged pertaining to the nature of the scientific inquiry conducted in these projects. A majority of both university and industry scientists felt that improved research projects would result from participation in the projects. Moreover, perceived changes in research topics and issues seemed to result from participation, particularly so for university scientists.

For the industry scientists, changes in the science seemed to be correlated with commercial advances, scholarly output, and general satisfaction; in this group all of the various outcomes—publications, product/process improvements, and general satisfaction—tended to be interrelated. This was less so for university scientists.

The factors that were correlated with the nature and results of the research performed also centered around interpersonal interaction. For example, major factors correlating with written scholarly output included the degree of interpersonal contact and the amount of intellectual exchange. In the case of changes in research topic and method, the amount of interaction was again important. Prior interaction was more important for firm scientists; interaction during the project was more important for university scientists.

Commercial outcomes in the form of project/process improvement were heavily contingent for industry scientists on relationships within their firm. To the extent that "significant others" (e.g., top R&D planning and management and production staff) were aware of and involved in the project, the more likely commercial outcomes were anticipated. Similarly, the actual exchange of personnel between the two sites seemed to be associated with commercial outcomes for industry respondents. Industry scientists with prior personal links to the participating university (e.g., as former students) seemed to be attached to projects in which there were greater expectations of commercial outcomes.

In summary, participation in IUCR Projects seemed to have had a significant effect on the individual scientists and their respective organizations. Overall, it appears that the theoretical orientation of the university reacted synergistically with the more practical concerns of industry scientists and yielded both scholarly outcomes and perception of commercial success.

OVERVIEW OF THE STUDY

Introduction

This report presents results of a national survey of university and industry scientists who have been involved in Industry/University Cooperative Research (IUCR) projects supported by the National Science Foundation. The study represents an instance of "research-on-research" in the Federal Government. The IUCR program was selected as the focus of this study because it is a major component of NSF efforts to link university and industrial science. The innovative nature of the IUCR program, the interest in how IUCR projects operate and the results they produce, and an increasing general concern with issues of university/industry research cooperation, provided impetus for this study.

The Industry/University Cooperative Research Projects program of the Division of Industrial Science & Technological Innovation (ISTI) is an organizational innovation in itself. The program sponsors research projects in the physical, biological, and engineering sciences, all of which are performed *jointly* by university and industrial scientists. Projects focus on fundamental science, but are also expected to be relevant to industrial operations and technology development. The program is designed to sensitize researchers in both sectors to the research goals, practices, and priorities in the collaborating organization. The expectation is that the projects will change the nature of inquiry in both university and industrial research, and ultimately enhance both the quality of basic science and the pace of industrial innovation.

The extent to which these projects have in fact produced changes in the conduct of research in collaborating organizations is a primary focus of this study. Heretofore the lack of retrospective or real-time data on program operations or impact has precluded definitive statements about IUCR on these issues. This report will present data which can significantly enhance an understanding of the process and results of industry-university collaboration, and also add to the literature on innovation processes and organizational behavior.

Overview of Assessment Activities

This study is one component of a three-part assessment of the IUCR Projects Program. The first phase of that assessment was a descriptive analysis of 118 grants awarded in FY 1978-80, the first three years of program operations. Information on grants, participants and their organizations was obtained from archival sources, primarily grant files. The study was completed in April, 1982.[1] Other parts of the assessment include the structured survey of university and industry researchers reported here, and a set of case studies of representative projects.[2] The latter volume presents a qualitative description of the same phenomena which the current study examines quantitatively.

Issues and Questions

While much has been made of the importance of knowledge transfer and dissemination in the innovation process,[3] there have been few organized attempts to influence that process on a significant scale. The IUCR program is one of a very few Federal efforts to create explicit bridges between the world of academia and the world of commerce. A major premise of the program is that university basic science can be improved by expanded awareness of technical problems and opportunities in industry and correspondingly that industrial science can be enriched by linkage to basic research. The issue, of course, has become how to facilitate this reciprocal knowledge relationship between university and industry organizations. The IUCR program attempts to encourage and increase such interorganizational interaction.

Within the short history of the program there have been both recurrent themes and considerable variability in how IUCR projects evolve, and in the technical and intellectual successes achieved. The purpose of this study was to describe how IUCR projects usually develop, and, if possible, discover what project features contributed to successful technical and organizational outcomes.

[1] Elmima C. Johnson, Louis G. Tornatzky, Patti Witte, and Claire Felbinger, *Assessment of the Industry/University Cooperative Research Program (IUCR): Interim Report 1. Descriptive Analysis of Projects FY 1978-1980* (Washington, D. C.: National Science Foundation, 1982).

[2] Elmima C. Johnson, Louis G. Tornatzky, and Lynne Schlaaff, *Cooperative Science: Case Studies* (Washington, D. C.: National Science Foundation, 1984).

[3] Louis G. Tornatzky, J. D. Eveland, Myles G. Boylan, William A. Hetzner, Elmima C. Johnson, David Roitman, and Janet Schneider, *The Process of Technological Innovation: Reviewing the Literature* (Washington, D. C.: National Science Foundation, 1983), pp. 155-175.

In designing the study, it became clear that there is minimal empirical information on university-industry research interaction. An earlier review by the authors indicated that there were some useful concepts that could be borrowed from organizational sociology but few findings.[4] As a result, the selection of variables and variable domains for this study was less focused than it might have been in a more mature area of inquiry. However, our reading of the literature suggested several sets of factors which seemed useful to examine.

For one, we were interested in the *demographics* of participants. What kind of scientists, from what kind of institutions, became involved in cooperative projects? Were they "outliers" or well-known investigators?

A related issue concerned the *prior history* of interaction between participants. Could it be assumed that the IUCR program itself fostered research interaction between former strangers, or rather that it served as a catalyst after a long prior history of intellectual exchange? Similarly, what was the "track record" of cross-sector interaction between the participating institutions?

We were also interested in the *initiation* of the particular IUCR project. How did the principals hear about the program? What role did NSF staff play? Would the project have been implemented or even considered in the absence of an IUCR program? Who took the initiative in constructing the research project and proposal?

The *management* of these projects was also important. Given that the participants were by definition separated by affiliation and geography, how did this affect project management, group dynamics, and communication patterns? A particularly important aspect of this line of inquiry was how the two sets of investigators—university and industry—coordinated their activities and divided their responsibilities.

Finally, we were interested in the *outcomes* of IUCR projects. We were interested not only in intellectual and technical outcomes, but in possible commercial results. To what extent could new products or processes be expected to result in the cooperating company? What contributions to general science might result? Within the general category of effects was the question of how participation changed the participants themselves. Did university scientists become more aware of industrial needs and operations, and vice versa? Did scientists and students alter their career directions?

[4] Elmima C. Johnson and Louis G. Tornatzky, "Academia and Industrial Innovation," in *New Directions for Experiential Learning: Business and Higher Education—Toward New Alliances*, ed. by G. Gold (San Francisco, California: Jossey-Bass, 1981), pp. 50-53.

Methods and Procedures

Design

The study was a structured mail survey of the university and industry scientists involved in 118 IUCR projects. The purpose was to determine the nature of the relationships and activities involved in IUCR projects and to document the results realized by both university and industry participants.

Sample and Respondents

The sample of projects consisted of 118 IUCR awards made by NSF during Fiscal Years 1978-1980. Respondents were the 236 university and firm principal researchers involved in those 118 IUCR projects. A total of 226 or 96 percent of the researchers actually returned completed questionnaires.

In those cases where more than one university or firm researcher shared equally in the research tasks at his or her organization, one individual was designated as the "respondent of record" for the study. The primary criteria for this designation were whether an individual had been identified as the official Principal Investigator (PI) by either the NSF Division of Grants and Contracts or the collaborating PI, and how much time was spent on the project.

Instruments

Separate data collection instruments roughly parallel in format and content were constructed for the university and industry respondents.[5] The university questionnaire was 18 pages in length, covered 50 questions, and measured 141 specific variables; the industry questionnaire was 20 pages in length, encompassed 60 questions, and measured 162 variables. (See Appendices A and B).

The questions were organized into six categories of data: 1) descriptive information on participating scientists (education, research experience, current position); 2) prior relationships between the university and industry participants and cross-sector work experience; 3) factors influencing the initiation of the project; 4) project management and decision-making; 5) the nature of the research relationship; and 6) project benefits and outcomes—technical, organizational, personal.

Data Collection Procedures

Contact with the university and industry researchers was initially made by the NSF program manager who had responsibility in that scientific area. (Prior to the initiation of the study the program managers had been briefed and their cooperation solicited.) This initial

[5] OMB Clearance (3145-0076) was granted in August, 1982.

phone contact[6] briefly described the nature and purpose of the study. Subsequently, there was a call from study staff confirming respondents' willingness to participate. A questionnaire was then mailed with an explanatory cover letter. Follow-up mailings and calls were made as needed to maximize the response rate. A total of 226 of the researchers returned completed questionnaires (a 96 percent response rate).[7]

Coding Procedures

A 303-item coding protocol was developed for the six categories of data. Three persons were involved part time in the data collection and coding processes over the course of the project. They were randomly assigned questionnaires to code and each questionnaire was coded by two persons. Variables were generally structured as dichotomous, ordinal, or interval scales or questions. More than 34,000 individual data points were coded. A mean interrater reliability of 99 percent, computed as a percent of perfect agreement on each item, was maintained.

Analysis and Presentation of Results

Two general types of analyses were performed on the survey data. One effort was primarily descriptive in nature, attempting to capture the "typical" IUCR project. Embedded in this approach were some comparative analyses of university versus industry response patterns. The descriptive analyses are reported in Chapter 2, with a summary of results at the end of the chapter.

A second set of analyses attempted to make relational statements about what seemed to predict "outcomes" of interest to researchers. To accomplish this purpose, various data reduction techniques were employed (e.g., factor analyses) to collapse the huge array of descriptive variables to a workable number. These were in turn separated into independent and dependent variable sets and subjected to correlational analyses. These analyses are presented in Chapter 3, with a summary of findings at the end of the chapter.

[6] Some principal investigators were initially contacted by letter, although the vast majority received a brief phone contact.

[7] There was only one project in which neither the university nor the industry researcher responded.

Chapter 2

DESCRIPTIVE RESULTS

This chapter will provide a summary of descriptive findings in each of the six data categories. The intent is to portray the typical IUCR project, and to highlight important contrasts between university and industry responses. Each of the sections that follow will initially present a brief summary of findings, and then present a more detailed exposition of descriptive results. An overall summary of descriptive results is at the end of the chapter.

Researcher Descriptors

A total of 236 researchers were involved as principal investigators in IUCR projects. This included one industry researcher and one university researcher working collaboratively in 118 projects. Both groups were experienced researchers and established mid- to upper-level professionals in their respective fields and organizations. Both the university and industry scientists were rich in prior administrative and research management experience. The majority had minimal full-time work experience in the other sector. (Researcher characteristics are summarized in Table 1.)

University Respondents. These scientists had spent an average of 18 years working in academic settings and had been employed at their current institutions an average of 14 years. The overwhelming majority of them (94 percent) had achieved the rank of associate or full professor and had held this position for an average of 10 years. Thirty-five percent had been a chairperson or administrator in their department. In contrast to their academic experiences these scientists had limited industry exposure; 52 percent had never been employed full-time in industry since completing their terminal degree.

Table 1
Researcher Characteristics

Descriptor	*University Scientists*	*Industry Scientists*
	N = 114	N = 112
No. Years Employed in Field (Mean)	18	16
No. Years with Current Organization (Mean)	14	13
Associate/Full Professor	94%	—
Department Administrator/Chair	35%	—
Previous Employment in Industry (F-T)	52%	—
Mean Number of Persons Supervised	—	13
Degree/Courses at Collaborating University	—	19%
Previous NSF Grant Experience	75%	17%

These scientists also had previous experience with federal grant programs. Seventy-five percent had been involved in previous NSF grants; 74 percent had served as the principal investigator on NSF grants. In addition 74 percent had received at least one grant from another government agency within the last five years.

Industry Respondents. The company researchers had been employed in industry an average of 16 years and had worked in R&D an average of 15 years, 13 of them with their current firm. Eighty percent held the doctorate degree, with 19 percent having earned a degree or taken courses at the collaborating university.

These were primarily senior scientists. Eighty percent ranked 1-5 levels below the CEO and 90 percent ranked 1-4 levels below the chief technical officer. They held supervisory positions. Sixty percent had up to four persons reporting directly to them, while there was an average of 13 persons reporting to them through subordinates. In contrast to the university scientists, the industrial researchers (83 percent) generally had no previous NSF grant experience.

Prior Relationships

It is clear from these data that the principal investigators were well acquainted with each other prior to the initiation of the project. Further, the university scientists as a group had a variety of industrial work experiences (e.g., consultancies), some of them with the collaborating firm. The seed of the collaborative relationship had already been planted; the IUCR program permitted its growth. (see Table 2)

University Respondents. University IUCR team members had a variety of contacts with industry prior to the initiation of the IUCR project: across all projects in the sample, 81 percent of team members had had consultancies; 52 percent had had prior research contracts; and 50 percent had been involved in industrial student placement activities. In contrast, only 13 percent had been involved in faculty exchange programs with industry. The majority of principal investigators (79 percent) had prior contact with some member of the collaborating industrial team at least several times a year.

Table 2
Prior Relationships Between Participants/Organizations

Activity	*University Team Members*	*Industry Scientists/ Firms*
Prior Contact with Collaborating Team	79%	70%
Consultancies	81%	50%
Research Contracts	52%	19%
Industrial Student Placement	50%	26%
Student Thesis Research	—	19%
Faculty Exchange	13%	15%

Industry Respondents. The majority of industry scientists (70 percent) had prior personal contact (at least several times a year) with some member of the university team. In addition their firms had supported IUCR university team members in a variety of activities. These included: consulting relationships (50 percent of the firms); student placement (26 percent); faculty contract research (19 percent); student thesis research (19 percent); and faculty exchange (15 percent).

Initiation of the Collaboration

Three themes emerge from the data on project initiation: 1) the crucial role played by the NSF program and NSF personnel; 2) the lead role often played by university researchers in initiating the project; and 3) the fairly routine nature of the approval process for the project by the industrial as well as academic organizations. (see Table 3)

University Respondents. The university scientists learned of the NSF program from three principal sources: NSF personnel (57 percent); a university colleague (20 percent); or an industry colleague (19 percent). Other sources of information included NSF program announcements, and professional journals.

Table 3
Initiation of the Collaboration

	Major/Equal University Role	*Major/Equal Industry Role*
	Initiation of the Project	
University	89%	11%
Industry	86%	14%
	NSF Brokering Role	
	Yes	*No*
University	69%	31%
Industry	72%	28%

The university researchers also saw themselves as instrumental in initiation of the projects: 37 percent of university respondents felt they had taken the lead in project initiation; 52 percent said it evolved from mutual discussions with industry; and only 11 percent gave primary credit to the firm. Considering the data in another light, the university researchers saw themselves as a primary or co-equal initiator in the vast majority (89 percent) of cases. The majority (69 percent) further stated that this type of collaborative research would not have been undertaken by their university in the absence of the IUCR Projects program, pointing out the crucial brokering function of NSF.

Once the decision was made to submit a joint grant the approval process was fairly routine. In fact 94 percent of the university scientists indicated that this process was not substantially different from that used in normal grants.

Industry Respondents. Sixty-one percent of the industry scientists listed a university colleague as a source of information about the IUCR projects program. Almost equal numbers listed NSF personnel and a firm colleague as additional sources of information (22 percent and 25 percent respectively). Some respondents listed more than one source of information.

As with the university scientists, close to one-half of industry researchers (47 percent) felt the project evolved from mutual discussion. The second largest group (39 percent) gave credit to the university, while only 15 percent indicated that the firm initiated the project. This group also saw the IUCR program as playing a significant role in facilitating these collaborative efforts. That is, 72 percent indicated their firm would not have initiated the project in the absence of the IUCR program.

The approval process within the firm was also fairly routine, with 63 percent of the investigators indicating that it was not substantially different from that employed with non-collaborative projects. At least two higher levels of approval were needed in 73 percent of the cases.

Project Management and Decision-Making

In considering project management, it should be realized that each project was usually comprised of two subsets of activities under a common umbrella. There was concurrence across respondent groups on the formulation of research tasks and primary managerial and intellectual tasks. That is, both university and industry scientists saw task formulation primarily as a responsibility of the principal investigators with some team input. Both groups identified their major management functions as prioritizing team objectives and disseminating team results, and their primary intellectual functions, in addition to contributing new ideas, as encouraging and evaluating team member ideas. However, researcher *involvement* in major R&D tasks differed significantly between groups, with the university investigators reporting more involvement in all tasks.

University Respondents. These were relatively small research teams with 96 percent of the projects having three or less faculty actively participating in the research at one time; fifty-nine percent of the projects had only one faculty member involved.

According to the university respondents the research tasks were formulated primarily by the principal investigators in 55 percent of the teams, devised through team discussion in 25 percent of the teams, and self-assigned by individual team members in 6 percent of the cases. Major input was solicited from other disciplines in only 11 percent of the grants. Work priorities for team members were determined primarily by the principal investigators in 83 percent of the projects. Similarly, task assignment in 86 percent of the projects was either made by the team leader alone or with a senior team member. This hierarchical decision structure follows usual academic practice in that non-faculty team members were primarily graduate students using the IUCR project as their dissertation research, with the university investigator serving as the advisor.

In terms of management duties the university researchers saw their three most important functions as supervising the team's work (64 percent), prioritizing team objectives (49 percent), and disseminating team products/results (46 percent). Joint management activities (with industry) were perceived as covering an average of 42 percent of the research tasks.

The intellectual functions highlighted as the three top tasks by university investigators focused on idea generation: encouraging team members to contribute new ideas (82 percent), evaluating team member ideas (60 percent) and consulting others for new ideas (34 percent).

Industry Respondents. The industry teams were also relatively small in size; 89 percent had no more than four persons involved in each project. The make-up of these teams included central R&D staff in 60 percent of the grants, divisional R&D staff in 36 percent of the grants and engineering/technical staff in 42 percent of the grants. An average of 8 percent of the grants had representatives from the corporate planning, marketing or production staffs.

The industry respondents paralleled their university counterparts in describing how research tasks were formulated. That is, the tasks were devised primarily by the principal investigators in 53 percent of the grants, devised through team discussion in 21 percent of the grants, and planned by individual team members in 5 percent of the grants. The university principal investigators assigned tasks in 83 percent of the cases, with collective team decisions on tasks made infrequently (16 percent).

There were further similarities in the managerial functions engaged in by the industrial and university scientists. The company scientists agreed that prioritizing team objectives (50 percent) and disseminating team products/results (37 percent) were two of three top managerial functions. Their third most important managerial function was evaluating team work (38 percent) rather than team supervision. These scientists also agreed with their university colleagues that approximately one-half of the work (45 percent) involved shared management responsibilities.

Regarding intellectual duties, the industrial scientists' top three choices paralleled those of their academic counterparts: encouraging team members to contribute new ideas (65 percent), evaluating team member ideas (55 percent), and consulting others for new ideas (30 percent).

Both groups of respondents were asked to indicate the *degree* of their involvement in major R&D activities: research design, problem formulation, data collection and analysis, report writing, administration and personnel decisions. As seen in Table 4, the university scientists compared with their industry colleagues reported a higher level of involvement in all areas and these differences were statistically significant for ten of the fourteen specific activities. These findings strongly suggest that the university researchers played a more active role in the research projects. While the research relationship is collaborative it is clearly not equal.

Project Coordination and Communication

The research collaboration was maintained through frequent and informal interaction between participants. For a majority of the participants there were contacts at least several times a month, and phone calls and informal meetings accounted for most of the interaction (approximately 90 percent of each group used both). In general there was no clear pattern as to who initiated these contacts, although the university respondents somewhat overestimated their role as communication facilitators. Less frequently utilized by both groups were letters/memos and formal project meetings. Meeting sites were almost equally divided between the university and the firm, and in the majority of projects at least one team member from each group worked at the collaborating site.

Communication and reporting relationships external to the project differed between industry and university researchers. To illustrate, only 35 percent of the university scientists were required to submit project reports to anyone in their university, while 76 percent of the company researchers were required to submit formal reports covering project activities. Ninety-

Table 4
Degree of Researcher Involvement in Project Activities*

R&D Activity		Very High	High	Medium	Low	Very Low	
Identify Interest Area[1]	University	90	8	1	—	1	100%
	Industry	73	19	6	1	1	100%
Literature Review[1]	University	21	38	27	8	5	100%
	Industry	14	27	36	14	9	100%
Problem Definition[2]	University	85	11	2	3	—	100%
	Industry	57	31	9	1	2	100%
Determine Methods	University	46	35	14	5	—	100%
	Industry	33	35	28	2	2	100%
Formulate Hypotheses[2]	University	61	31	6	1	1	100%
	Industry	30	39	22	6	4	100%
Research Design	University	53	33	10	4	—	100%
	Industry	41	38	16	4	1	100%
Data Collection	University	10	24	24	25	17	100%
	Industry	11	20	26	23	22	100%
Analyze Results[2]	University	45	38	15	2	—	100%
	Industry	33	35	18	9	5	100%
Report Writing[2]	University	54	30	14	1	1	100%
	Industry	29	26	24	10	12	100%
Administration/ Budget[2]	University	45	30	15	6	5	100%
	Industry	18	22	23	19	18	100%
Work Allocation[1]	University	34	29	26	6	6	100%
	Industry	13	35	30	11	10	100%
Coordination	University	26	22	23	17	12	100%
	Industry	14	32	23	19	12	100%
Personnel[2]	University	49	20	13	9	8	100%
	Industry	18	14	24	20	25	100%
Equipment Selection[2]	University	29	28	27	8	7	100%
	Industry	11	31	27	17	14	100%

* The *t* tests were computed on the basis of different scores—university minus industry—for each project.
[1] $p \leq .05$
[2] $p \leq .001$

four percent of industry scientists reported that the top R&D officials in their company were at least aware of the project's existence, and in 51 percent of the projects they were at a minimum kept informed of the general progress of the project. Internal requests for project information averaged four per grant for both groups. Both groups also received more requests from external sources, which tended to focus on the technical nature of the research rather than administrative or operational issues.

Project Benefits and Outcomes

In considering the outcomes of these IUCR projects, it should be realized that there were results common to both industrial and university participants, and other outcomes unique to each group. Moreover, the results achieved at this point in time—early in the research and development process—were more in the nature of estimates by the respondents. However, there were some interesting differences in perceptions about outcomes between university and industry scientists.

Tangible Products. A number of intellectual and other outputs were produced in conjunction with the IUCR projects. The total written products reported across all projects are reported in Table 5.

University scientists reported a statistically significant larger number of books and articles published in the open literature. Two explanations for these differences are possible: either university scientists are in fact producing more books and articles, or they are simply providing a more complete record than their industrial counterparts. The previously reported greater involvement of university versus industrial scientists in report-writing activities (Table 4) may explain this outcome. In addition the reward structure for university scientists emphasizes publications, i.e., "publish or perish," and results are consistent with what one would expect from this set of incentives.

Participants were also asked to indicate the number of prototypes and other undocumented products produced in their organizations. None of these differences was statistically significant. The reported results are given in Table 6.

Goal Congruity and Compatibility. The primary goal of the IUCR Projects Program is the advancement of basic scientific and engineering knowledge. While it is clear that basic scientific knowledge is enhanced

Table 5
Written Products Resulting from IUCR Projects*

	Researchers	
	University	Industry
Books (including editorship)[1]	20	8
Scientific or technical articles published in the open literature[2]	642	364
Patents or patent applications	17	13
Algorithms, blueprints, flowcharts, drawings, etc.	225	400
Reviews and bibliographies published in the open literature	37	24
Internal reports on work pertaining to the project	225	242

*The *t* tests were computed on the basis of different scores—university minus industry—for each project.
[1] $p \leq .05$.
[2] $p \leq .001$.

Table 6
Prototype/Undocumented Products Resulting from IUCR Projects*

	Researchers	
	University	*Industry*
Experimental prototypes of devices, instruments and apparatus, components of devices, etc.	149	126
Experimental materials such as fibers, plastics, glass, metals, alloys, substances, chemicals, drugs, plants, etc.	205	121
Prototype computer programs	187	103
Audio-visual materials/productions	129	128

*The *t* tests were computed on the basis of different scores—university minus industry—for each project.

through project activities, the immediate goals of the participants in any particular project appear to be somewhat more direct. Respondents were asked to rate the importance of eleven possible project goals. There was considerable agreement between the university and industrial respondents on the importance of various project outcomes. According to Table 7 the three most important goals for both groups were identical. They were: 1) the development of patentable products; 2) the development of commercialized products; and 3) improvements in manufacturing processes. In effect the majority of participants felt project results would be useful to industry in the long run. Further, when the goals were ranked from high to low priority for both groups, the rank order correlation for the entire list of goals was .75. There were some minor differences between the university and industry ratings, and the difference in the importance of graduate student technical training was statistically significant ($chi^2 = 18.668$, $p \leq .001$). Surprisingly, the industrial researchers saw the graduate training function as a higher priority goal than did their university peers. The expansion of technical knowledge ranked low for both groups, indicating that this was not a direct priority for the participants in particular projects. When asked about the importance of the IUCR project in stimulating new research projects, 56% of the industrial scientists versus 37% of the university scientists rated this project goal as "extremely" or "considerably important." This difference was also statistically significant ($chi^2 = 9.359$, $p \leq .05$).

To summarize, there was a very high degree of goal congruity among researchers from very different kinds of institutions. According to the literature on interorganizational behavior this compatibility should contribute significantly to successful interaction. (As will be seen in Chapter 3, correlational analysis tended to confirm this hypothesis.)

Conduct of Research. One evaluative question about IUCR concerned its spillover effect on other research in which the participants are involved. As one result, the industrial respondent in 53 projects reported a total of 91 new research projects, totaling approximately nine million dollars, which were stimulated by IUCR project activity. Given that one of the goals of the IUCR Program is to "leverage" research initiatives above and beyond the IUCR project per se, these preliminary data are encouraging.

In addition to this new research activity, both industrial and university scientists were optimistic regarding the likelihood of *improved research projects* resulting from their IUCR involvement; 54 percent of industrial respondents and 73 percent of university respondents saw this possibility as "almost certain" or "pretty likely." (Table 8) The fact that a majority of senior university and industry researchers saw their future research as being improved as a result of the IUCR collaboration speaks well for the Program.

As can be seen in Table 8, the university scientists were even more positive than their industry collaborators on the likelihood of improved research resulting from IUCR involvement. This difference, which was statistically significant (matched difference $t = 3.54$, $p \leq .001$) is difficult to explain on the basis of these data since the exact nature of the expected improvement was not specified.[8] However, the data reported in subsequent tables is suggestive.

The participants were also asked to rate the extent to which their participation in the projects had changed research topics and/or research methods in their own institutions. The results of this inquiry are seen in Tables 9 and 10. The most noteworthy finding is the extent to which research topics/issues were affected in the university setting (Table 9). Approximately half of the university scientists (48 percent) indicated that topics shifted either "a lot" or "some." This influence on research topics was not equally felt by industrial scientists. Only 30 percent of industry scientists felt that topics were changed "a lot" or "some." This difference between groups was statistically significant ($chi^2 = 13.499$, $p \leq .01$.), and parallels the findings reported in Table 8. Clearly the IUCR project has its most pervasive effect on university scientists. In a comparison of respondents' perceptions of changes in research methods/procedures, the university-industry differences were not statistically significant (Table 10). Both groups indicated that the IUCR project had moderate impact in this area.

[8] For a qualitative case study treatment of these issues the reader is referred to Elmima C. Johnson, Louis G. Tornatzky, and Lynne Schlaaff, *Cooperative Science: Case Studies* (Washington, D. C.: National Science Foundation, 1984).

Table 7
Importance of Project Goals/Potential Outcomes*

Goal/Outcome		*Extremely Important*	*Considerably Important*	*Somewhat Important*	*Not at all Important*		*Rank***
Develop Patentable Products	University	67	17	9	8	100%	1
	Industry	66	26	6	2	100%	1
Develop Commercialized Products	University	57	21	14	9	100%	2
	Industry	58	24	10	9	100%	2
Improve Manufacturing Processes	University	48	25	13	14	100%	3
	Industry	59	21	10	11	100%	3
Redirect University/ Industry Research to Industry/University Problems	University	17	39	29	15	100%	4
	Industry	19	34	31	17	100%	6
Instrumentation Development	University	27	28	28	16	100%	5
	Industry	33	27	28	12	100%	4
Enhance Quality of Industry Research	University	12	37	34	17	100%	6
	Industry	11	26	44	19	100%	8
Enhance Graduate Student Understanding of Industry	University	12	33	32	22	100%	7
	Industry	10	27	44	19	100%	9
Enhance Quality of University Research	University	15	28	39	19	100%	8
	Industry	11	29	40	20	100%	7
Development of New Research Projects in Your Organization	University	14	23	35	28	100%	9
	Industry	22	34	30	14	100%	5
Enhance Graduate Student Technical Training	University	4	6	35	56	100%	10
	Industry	6	20	44	30	100%	10
General Expansion of Knowledge in this Technical Area	University	0	2	21	78	100%	11
	Industry	0	6	33	61	100%	11

* Percentages may not total 100 due to rounding.
** Ranking in order of perceived importance: 1 = most important; 11 = least important.

Table 8
Likelihood of Improved Research Projects

	Almost Certain	*Pretty Likely*	*Somewhat Likely*	*Scarcely Likely*
University Researchers	*36*	*37*	*23*	*5*
Industry Researchers	*20*	*34*	*31*	*15*

Table 9
Changes in Research Topics/Issues

	A Lot	*Some*	*A Little*	*Hardly Any*
University Researchers	17	31	24	28
Industry Researchers	4	26	28	43

Table 10
Changes in Research Methods/Procedures

	A Lot	*Some*	*A Little*	*Hardly Any*
University Researchers	11	27	19	44
Industry Researchers	4	25	29	43

Tangible Benefits to the Firm. While definitive economic returns from the Cooperative Projects Program probably will not accrue to participating firms for several years and are not a primary goal of the program, university and industry scientists were nonetheless asked if they thought the IUCR project had resulted in specific outcomes in the firms. These outcomes included product development or improvement, cost reductions, and improvements in the company's ability to deal with government regulations or cooperate with university scientists. As seen in Table 11 the university scientists were in general more optimistic than their company counterparts regarding positive outcomes. Six of these differences were statistically significant: "improvements in products and services"; "new products developed"; "changes in cost of products"; "reduction of production costs"; "improvement in processes and methods of production"; and "improved product or process design." The optimism of the university respondents should be taken with some caution, given the less than overwhelming enthusiasm of their industrial colleagues, who were, in fact, more knowledgeable about industrial realities.

Both groups agreed that the IUCR program had its greatest effect on the relationships between the two sectors. That is, 65 percent of the industry scientists and 60 percent of the university scientists felt project participation had improved the firm's ability to cooperate with university scientists. This is a significant result since one of the major goals of the IUCR project is to stimulate cooperative research by increasing linkages between university and industries.

These scientists were further asked to make a probability estimate of future benefits in four areas: 1) patentable products/technology; 2) commercialized products/technology; 3) improved instrumentation/methods; and 4) improvements in manufacturing processes. The results are presented in Tables 12, 13, 14, and 15.

Table 12 indicates that the vast majority of both groups saw the possibility of patentable products as either "somewhat" or "scarcely" likely (76 percent and 86 percent). This is in spite of the fact that both groups had indicated that this was an "extremely" or "considerably important" goal of the research, (e. g., Table 7). The difference between university and industry respondents scores, by project, was statistically significant ($t = 3.26, p \leq .01$), with the university respondents being more optimistic.

Table 11
Perceived Effect of Project Participation on Outcomes in Firms*

Outcome	*Respondent*	*Yes*	*Maybe*	*No/Not Applicable*	
Improvements in products and services[2]	University	23	28	50	100%
	Industry	17	19	65	100%
Changes in warranty and complaints in view of improvements in products	University	2	6	93	100%
	Industry	3	3	95	100%
New products developed due to related efforts[1]	University	17	26	58	100%
	Industry	12	17	72	100%
Changes in cost of products to users (price changes of decreased product maintenance)[2]	University	5	18	77	100%
	Industry	5	6	90	100%
Reduction of production costs[2]	University	4	22	74	100%
	Industry	3	8	89	100%
Improvement in processes and methods of production[3]	University	18	30	53	100%
	Industry	11	14	75	100%
Increased uniformity of products	University	7	17	77	100%
	Industry	6	12	83	100%
Improved product or process design[2]	University	20	29	51	100%
	Industry	12	21	67	100%
Improved capability to deal with government regulations	University	6	25	69	100%
	Industry	8	19	73	100%
Improved capability to cooperate with university scientists	University	60	27	13	100%
	Industry	65	22	13	100%

*The *t* tests were computed on the basis of different scores—university minus industry—for each project.

[1] $p \leq .05$.

[2] $p \leq .01$.

[3] $p \leq .001$.

Table 12
Likelihood of Patentable Products/Technology

	Almost Certain	Pretty Likely	Somewhat Likely	Scarcely Likely
University Researchers	7	18	34	42
Industry Researchers	4	10	27	59

Table 13
Likelihood of Commercialized Products/Technology

	Almost Certain	Pretty Likely	Somewhat Likely	Scarcely Likely
University Researchers	11	15	36	37
Industry Researchers	6	13	27	55

According to Table 13, there were also limited expectations about the likelihood of commercialized products resulting from IUCR. University scientists were somewhat more optimistic than their counterparts in industry about commercial products emanating from the research (e.g., 26 percent and 19 percent rate the probability as "pretty likely" or "almost certain"), and the difference between university and industry respondent scores, by project, was statistically significant ($t = 3.58$, $p \leqslant .001$), with the university respondents again expecting more positive tangible outcomes. Both group had indicated in Table 7 that this was also an "extremely" or "considerably" important goal of the research.

Both the university and industry scientists saw improvements in instrumentation/methods as the most likely tangible benefit (Table 14). University respondents (44 percent) and industry respondents (41 percent) saw improvements in this area as either "pretty likely" or "almost certain."

Neither group was optimistic regarding the likelihood of tangible benefits in manufacturing processes resulting from the IUCR projects; 72 percent of the university researchers and 81 percent of the industry researchers, believed improvements were only "somewhat" or "scarcely likely." This difference between co-investigator perceptions was also statistically significant ($t = 3.44$, $p \leqslant .001$), again favoring the university respondents.

Table 14
Likelihood of Improved Instrumentation/Methods

	Almost Certain	Pretty Likely	Somewhat Likely	Scarcely Likely
University Researchers	26	18	26	30
Industry Researchers	15	26	22	37

Table 15
Likelihood of Improvements in Manufacturing Processes

	Almost Certain	Pretty Likely	Somewhat Likely	Scarcely Likely
University Researchers	14	15	21	51
Industry Researchers	4	15	17	64

In summary, although all four areas were viewed as important research goals by both groups, they were most hopeful about tangible benefits through improved instrumentation and methods. The university respondents were more optimistic than their industry counterparts regarding these various outcomes.

Personal Outcomes. Both groups of scientists agreed that participation in IUCR would probably have minimal impact on their future promotions, salary, job assignments or visibility within the organization. However, as seen in Tables 16 and 17 the majority did feel that the project would have moderate impact on their *prestige* among their peers within their respective organizations and in the larger scientific community. According to Table 16, participation in a successful IUCR project was seen as having an appreciable impact on investigator prestige among their organizational colleagues for 27 percent of the university scientists and 34 percent of the industry scientists. (This difference was not statistically significant.)

Table 17 indicates that the investigators perceived that their prestige among their peers in the larger scientific community would be positively affected (41 percent for university scientists; 51 percent for industry scientists.) Although the industry scientists were slightly more optimistic in this regard, the difference was not statistically significant.

In terms of student placement, 56 percent of the university scientists and 46 percent of the industry scientists thought participation in the project would result in better personnel recruitment. At the time of

Table 16
Potential Effect of IUCR Project Success on Researcher Prestige Among Organizational Colleagues

	Completely	Considerably	Some	Not at All
University Researchers	6	21	56	18
Industry Researchers	7	27	50	17

Table 17
Potential Effect of IUCR Project on Researcher Prestige Among Peers in Scientific Community

	Completely	Considerably	Some	Not at All
University Researchers	9	32	49	11
Industry Researchers	8	43	41	7

this assessment a total of 87 students, involved in 45 projects, had been interviewed by participating firms, and 29 had been hired.

General Satisfaction with Research Activities. There was general agreement between university and company scientists regarding their satisfaction with various aspects of the research project. According to Table 18, 97 percent of the university investigators and 92 percent of the company researchers were either "completely" or a "great deal" satisfied with the technical quality of the research. In addition, approximately 76 percent of both groups of researchers were "completely" or "a great deal satisfied" with the communication between participants. Eighty-three percent of both groups were "completely" or "a great deal" satisfied with the administration of the research project. These data represent a strong endorsement of the IUCR projects in which these scientists participated.

There was a significant difference in the perceived responsiveness of the project to organizational priorities. While 96 percent of the university scientists were "completely" or a "great deal" satisfied with the project's responsiveness to academic priorities, only about 75 percent of the company scientists were equally convinced of the project's relevance to industry priorities. This difference was statistically significant ($chi^2 = 47.494$, $p \leqslant .001$) and may reflect fundamental differences in the research perspectives of the two sectors,

Table 18
Satisfaction with Project

Project Feature	*Respondent Group*	*Satisfaction Rating**				
		Com- pletely	*A Great Deal*	*Some*	*Not at All*	
Technical quality of the research	University	61	36	4	0	100%
	Industry	56	36	8	0	100%
Communications between university and industrial participants	University	41	36	18	4	100%
	Industry	48	28	21	4	100%
Administration of the research project	University	43	40	15	2	100%
	Industry	31	52	13	4	100%
Responsiveness of project to organizational priorities and interests[1]	University	75	21	3	1	100%
	Industry	31	44	23	2	100%

[1] $p \leqslant .001$.

such as time horizons, the relative importance of basic versus applied science, etc. Overall satisfaction with project activities was high for both groups. That is, 88 percent of the university scientists and 80 percent of the industry scientists were "considerably" or "completely" satisfied.

Summary of Descriptive Results

- There had been extensive contacts between university and industry scientists prior to the IUCR projects, with consulting relationships being the most common form of interaction.

- University scientists played a leading role in initiating the IUCR projects, and NSF staff played a crucial brokering function.

- Both university and industrial participants expressed a high degree of general satisfaction with IUCR participation, and with the technical quality, communication patterns, administration, and responsiveness of the project.

- University and industry researchers involved in IUCR projects are senior, well-established scientists, with considerable prestige and authority in their institutions.

- The majority of university and industry scientists felt that the cooperative research project would not have been undertaken in the absence of the IUCR program.

- Project management and decision-making was not a team effort in the majority of projects; these responsibilities tended to reside with the university and industry principal investigators.

- University scientists tended to be more personally involved in all research tasks than their industrial co-investigators.

- Coordination and communication between the university and industry teams was frequent and generally informal (by phone or meeting).

- There was a high degree of consensus between university and industry co-investigators on the goals of the IUCR projects.

- A large majority of both university and industry researchers felt that improved research projects, in general, would result from IUCR participation.

- University participants strongly felt that changes in their research topics and issues resulted from IUCR involvement, more so than their industrial colleagues.

- Both university and industry scientists felt that a significant result of participation in IUCR was generally improved ability to cooperate with the other sector.

• Improvements in instrumentation and methods were seen by both university and industry participants as a highly likely result of participation in IUCR.

• University respondents were generally more optimistic than their industrial colleagues concerning the likelihood of tangible benefits accruing to the firm.

CORRELATIONAL ANALYSIS

This chapter will present the results of further analyses performed on the data categories described in Chapter Two. The intent was to explore the relationships between researcher descriptors, project structure, project activities, and project outcomes. Results have been organized by data category. Differences and similarities between the results for university and industry respondents will be highlighted.

The first section of the chapter briefly describes how the original data set was reduced into a more manageable number of *predictor* variables. The methodology utilized is somewhat peripheral to the central question of what is related to successful university-industry cooperative science and is detailed in Appendix C. The second section of the chapter describes how the measures of project *outcomes* were developed from the original raw data, and how these outcome variables relate to one another. In the last section the correlational analysis of project processes as predictors of project outcome is presented.

Data Reduction and Variable Aggregation Procedures

As previously mentioned, 141 discrete variables were coded from the university questionnaire and 162 discrete variables were coded from the industry questionnaire. This number of variables precluded a succinct consideration of the project success question, and argued strongly for data reduction and aggregation. Since there were significant differences between university and industry respondents (described in Chapter 2), and because there was interest in extending side-by-side comparisons, these data aggregation analyses were performed separately for the two sets of respondents.

In the first stage of analysis several steps were taken to reduce the size of the data set. Variables were eliminated from further analyses based on minimum variance in responses, low response rates, or overlap with other items. Some recoding was performed to combine items into rational mini-scales. Items of background information were also eliminated. Factor analysis and empirical scaling techniques were then employed to create aggregate variables.

These procedures served quite well to winnow down the size and complexity of the data set for subsequent analyses. As seen in Table 19, the procedures reduced 141 discrete variables to 25 scores for the university respondents, and 162 discrete variables to 34 scores for the industry respondents. The aggregate variables and scales created by these data reduction methods, and their interrelationships, for researcher descriptors, project structure and project activity variables are described in detail in Appendix C.

Outcome Variables and Their Interrelationships

Particular attention was focused on developing "success" criteria for the cooperative projects. The factoring and scaling procedures yielded a set of composite outcome measures (see Figure 1) which tapped four general areas: 1) satisfaction with the project; 2) commercial outcomes which translated into actual or expected product/process improvements; 3) written scholarly output; and 4) changes in the science (research topics, methods, or procedures).

The *Satisfaction* measure was an amalgam of perceptions about several aspects of project operations: administration; communication; research quality; and responsiveness. As such, it was a global measure of good feeling about the project.

Two types of questions related to *Product/Process Improvements*. One focused on gains already achieved; another type of question asked for future expectations. The results of the factor analysis grouped both these

Table 19
Results of Data Reduction

Data Category	*No. of Questionnaire Items*	*No. of Variables After Data Reduction*
University Respondents		
Researcher Descriptors	9	5
Prior Relationships/Initiation of the Collaboration	17	5
Project Management	42	7
Coordination of Project Activities	14	4
Benefits/Outcomes	59	4
Total	141	25
Industry Respondents		
Researcher Descriptors	12	7
Prior Relationships/Initiation of the Collaboration	19	6
Project Management	45	6
Coordination of Project Activities	22	10
Benefits/Outcomes	64	5
Total	162	34

items together, although there was a greater emphasis in the composite variable on gains already realized. In this sense, the resultant indices represent a much more conservative test of IUCR success in this area. It will be noted (see Figure 1) that the university respondents tended to lump product and process improvements together while the industry respondents made discriminations between improvements in these two areas. As a result, two separate measures for each dimension were constructed for the industry group, while the university variable was a composite of both.

The *Written Products* measure is the clearest index of traditional scholarly activity. It is a composite of various kinds of written products: papers, articles, reports, etc. Resources did not permit construction of a measure that reflected quality of written output; this was strictly a quantity index.

Perhaps the most interesting outcome or dependent variable was the one which has been labeled *Changes in the Science*. The index itself was an amalgam of perceived changes in research topics and methods resulting from IUCR participation. This is an admittedly crude measure of one of the more exciting aspects of cooperative research: how the nature of the inquiry is altered.

There were some noteworthy differences between university and industry respondents in terms of the interrelationships among the outcome variables (Table 20).[9] Generally speaking, the university outcome variables tended to be less inter-correlated than industry outcome variables. In particular, Changes in the Science were not related to the other outcome variables for university respondents. In contrast, for industry respondents Changes in the Science were associatetd with all of the other outcomes, i.e, satisfaction, product/process improvements and written products. These data suggest that Changes in the Science may have a pivotal relationship to other outcomes in the industrial setting. One hypothesis might be that changes in nature of scientific inquiry have to precede changes of a more tangible or commercial nature (or vice versa).

Figure 1
Outcome Variables

Variable Name	*Description*
	University Respondents
1. Satisfaction	The degree of participant satisfaction with project administration, communication, research quality and project compatibility with organizational priorities.
2. Product/Process Improvements	The extent to which improvements/changes in products or the production process were mentioned.
3. Written Products	Summative index of written products from project including books, articles, etc.
4. Changes in the Science	Extent to which participation in the project had changed research topics and methods in the university setting.
	Industry Respondents
1. Satisfaction	The degree of participant satisfaction with project administration, communication, research quality and project compatibility with organizational priorities.
2. Product Improvements	The extent to which improvements/changes in products, costs, and designs had occurred.
3. Process Improvements	The extent to which improvements/changes in production methods, costs, product uniformity were mentioned.
4. Written Products	Summative index of written products from the project including books, articles, etc.
5. Changes in the Science	Extent to which participation in the project had changed research topics and methods in the industry setting.

Table 20
Correlations Among Outcome Variables

	1.	*2.*	*3.*	*4.*
University Respondents				
1. Changes in the Science				
2. Satisfaction	.07			
3. Written Products	.02	.20		
4. Product/Process Improvements	.02	.23*	.17	
Industry Respondents				
1. Changes in the Science				
2. Satisfaction	.25*			
3. Written Products	.37**	.29**		
4. Product Improvements	.42**	.13	.01	
5. Process Improvements	.35**	.24*	.22*	.35**

* p ≤ .01.
** p ≤ .001.

Project Process and Project Outcome: The Definers of Success

In this section an attempt will be made to unravel the ingredients of successful cooperative research projects (see Tables 21 and 22). The data that will be reported will consist of simple zero-order correlations between aspects of project structure and processes and the various outcome indicators. As noted above, we have defined success in terms of several dimen-

[9] In this chapter all reported interrelationships are Pearson's product-moment correlations.

sions and the correlational data will be described in these categories.[10]

Changes in the Science. For university respondents (Table 21) one variable significantly correlated with changes in research topics and methods: the amount of exchanges and interaction among participants during the project. These activities would tend to facilitate intellectual exchange and networking, which are important precursors to changing the research agenda and methods in universities.

In a like manner, the intensity of industry respondents' contacts with university team members *before* the project began was also related to changes in the firm's research agenda and methods. (Table 22) However, the major factor relating to Changes in the Science was the greater involvement in the project of top R&D planning and management staff. Whether this indicated that the more methodologically important projects attracted the interest of R&D planning and/or management staff, or that their interest produced the Changes in the Science, is unclear.

[10] Only those correlations which were statistically significantly different from 0 at $p \leq .01$ will be discussed. The magnitudes of the correlations are generally in the range of .25 to .5, indicating that between 5% and 25% of the variance in the dependent variable is accounted for by the independent variable. These are quite substantial percentages for zero-order relationships in data of this type.

Satisfaction. The higher ranking university scientists and those with administrative experience tended to be more satisfied with the project. Again, the range of contact between groups during the project was important to university scientists' satisfaction.

Similarly for industry scientists, the frequency of interaction during the project, supported by the placement of university team members at the firm site, contributed to satisfaction.

Written Output. University scientists indicated that frequent and varied contacts during the project with industry collaborators were important in producing written documents. Reinforcing these findings, an idea broker role for the university PI was also related to the amount of scholarly output.

Correlations for industry scientists followed the same general pattern. Having industry team members working at the university during the project correlated positively with the amount of written output, as did an idea broker role for the industry participant. Bench level industry scientists tended to produce more written documents. The fact that reporting requirements were more stringent for industry scientists may partially explain this finding.

Product/Process Improvements. For university respondents, commercial outcomes for the firm were correlated with the university's role in initiating the project, and the researcher's level of involvement in bureaucratic activities.

Table 21
Correlations Between Research Process and Outcome Variables

University Respondents

	Changes in the Science	*Satisfaction*	*Written Output*	*Product/Process Improvements*
Researcher Descriptors		Seniority .36** Administrative Experience .23*		
Project Initiation				University Project Impetus .28**
Project Coordination	Amount of Exchange and Interaction .23*	Range of Project Interaction .27*	Range of Project Interaction .25* Amount of Exchange and Interaction .25*	
PI Roles			PI as Idea Broker .20*	PI as Bureaucrat .23*

* $p \leq .01$.
** $p \leq .001$.

Table 22
Correlations Between Research Process and Outcome Variables
Industry Respondents

	Changes in the Science	*Satisfaction*	*Written Output*	*Product Improvements*	*Process Improvements*
Researcher Descriptors				Studied at Collaborating University .21* Rank in Organization -.20*	
Project Initiation	Range of Prior Contacts .25*			University Project Impetus .26*	
Project Coordination	Top R&D Planning/ Management Involvement .41**	Frequency of Project Interaction .33** University Personnel Exchange .21*	Industry Personnel Exchange .28**	Top R&D Planning/ Management Involvement .37** Industry Personnel Exchange .23*	Production Staff Involvement .27*
PI Roles			PI as Idea Broker .24* PI as Bench Scientist .21	PI as Project Conceptualizer -.23*	

* $p \leqslant .01$.
** $p \leqslant .001$.

Industry participants separated product and process improvements and there was no overlap among factors related to these categories of outcomes. Product improvements were noted most by junior scientists who functioned less as conceptualizers, had an academic tie to the university, and who were in a role subordinate to the university in project initiation. However, the most important correlate of product/ process improvements was the involvement of other company officials, including planning, management, and production staff.

Summary of Correlational Analysis

Four major outcome measures were identified: 1) Changes in the Science; 2) Satisfaction with the Project; 3) Written Output and; 4) Product/Process Improvements. The correlations among these measures and between outcomes and research process variables are summarized below:

- For industry respondents outcomes in one area tended to be correlated with successful outcomes in the other three areas; this was less true for university respondents.

- The amount of interaction between participants correlated with Changes in the Science for both groups of respondents. However the period of interaction differed. Prior interaction was important for firm scientists, while interaction during the project was more important for the university scientists.

- The major factor relating to Changes in the Science for industry PIs' was the involvement of top R&D planning and management staff.

- For both university and industry participants, satisfaction with the project tended to be a function of intraproject "networking," such as the amount of interaction and actual personnel exchange.

- The higher ranking and senior university scientists tended to be more satisfied with the project.

- Major factors correlating with written output follow the same general pattern for both groups, with the degree of contact and intellectual exchange being crucial.

- Industry participants separated product and process improvements; university respondents did not.

- University impetus in project initiation seemed to be an important correlate of commercial outcomes for both university and industry respondents.

• For industry scientists, the most important correlate of product/process improvements was the involvement in the project of staff from elsewhere in the company (e.g., R&D planning and management, production).

• Those projects with more product improvements involved industry scientists who were junior in their organization, and who had a prior personal link with the particular university (such as former students). These projects also tended to have industry staff operating on site at the university.

APPENDICES

Appendix A

UNIVERSITY RESPONDENT QUESTIONNAIRE

OMB No. 3145-0076

Expires: 3/83

ID CODE NUMBER ________

UNIVERSITY PARTICIPANT QUESTIONNAIRE

This questionnaire is designed to provide the NSF with information to understand better the effects of the Industry University Cooperative Research Projects Program and to indicate to us how that program or others like it might be more effectively monitored. We are asking the same questions of all university Principal Investigators who participated in the program during 1978-1980. Your individual responses will be held confidential and will not be discussed. If a question is inapplicable, proceed to the next question.

> In order to understand the relationship between university and industrial participants in the Industry/University Cooperative Research Program, it would be useful to have some background about university researchers such as yourself. Questions 1 to 7 are designed to provide us with some data about your experience, and your position within the university.

1. How many years have you spent with this university? ____

2. How many years have you spent working in academic settings since receiving your highest degree? ____

3. How many years, if any, have you spent working full-time in industry since receiving your highest degree? ____

4. Have your ever been a chairman of your department, or held an administrative position in your university?

   ___Yes ___No

5. What is your current academic rank?

   ____

6. How long have you held this position?

   ____

7. Have you been with this Industry/University Cooperative Research project since its inception?

   ___Yes ___No

> We are also concerned with the decision making and logistics associated with your university's involvement with this Industry/University Cooperative Research project. We know that in general the scope of discussion in universities about project participation has varied widely; so has the amount of prior contact with industry personnel. Items 8 to 18 are intended to help us understand the early formation of Industry/University Cooperative Research teams.

8. How many faculty participate actively in this project at any one time? ____

ID CODE NUMBER________

9. Considering all the faculty now involved with this project, approximately what percentage of them have had the following types of prior contacts with industry?

   Individual consulting relationships ___%

   Contract research projects ___%

   Faculty exchange ___%

   Student placement ___%

   Other (please specify)

   ________________ ___%

10. Prior to the beginning of this Industry/University Cooperative Research project, how frequently did you personally have contact with industry personnel now associated with it?

   ___ Several times per week

   ___ Several times per month

   ___ Several times per year

   ___ Rarely or never

11. How did you hear about the Industry/University Cooperative Research Program? (Check all that apply)

   ___ NSF personnel

   ___ A colleague at your university

   ___ A colleague in industry

   ___ Other, specify ________________________

   ____

12. From where did the initial impetus for this project come?

   ___ Your university

   ___ The firm

   ___ Evolved from mutual discussion

13. Do you think your university would have undertaken this type of collaborative research with a firm in the absence of a specific NSF program?

   ___Yes ___No

14. Other than this Industry/University Cooperative Research project, how many NSF grants have you been involved with in the last five years (i.e., '78-'82)? ____

15. Of these, on how many were you the Principal Investigator? ____

16. How many grants have your received from other government agencies in the last five years (i.e., '78-'82)? ____

17. How many organizational levels in your unversity above your own had to give explicit approval for participation in this Industry/University Cooperative Research project? ____

18. Was this approval process substantially different from that used with projects not involving industrial participation?

   ___Yes ___No

ID CODE NUMBER________

Each University/Industry Cooperative Research project represents a unique research effort. In order to better understand the overall program, we would like to know about some of the structures and decision processes which operate in this project.
Questions 19 to 27 deal with these dimensions of structure and decision processes.

19. To whom in the university are you obliged to send formal reports concerning the activities of this project?

20. In general, which of the following alternatives best describes the way in which decisions are made about work priorities on this project (i.e., what needs to be done)?

____The Principal Investigators decide alone;

____The Principal Investigators decide after consulting with senior members of the project team;

____The Principal Investigators decide after consulting with the team as a whole;

____The Principal Investigators and senior members of the project team jointly make the decision;

____The project team as a whole decides;

____Each individual project team member determines his or her own work priorities.

____Other, specify ________________________________

21. In general, how are specific task assignments made on this project (i.e., who does a specific job)?

____By the Prinicpal Investigators;

____By either the Principal Investigators or a senior member of the project team;

____By collective team decision;

____By self-assignment.

22. Each of the following paragraphs describes a working arrangement typically found in research teams. Please consider each paragraph carefully and then circle the letter corresponding to the paragraph that comes closest to describing the working arrangement in this project.

A. "In this project each team member executes some aspect of a coordinated research plan which has been formulated primarily by the principal investigators. Coordination between specific sub-tasks performed by team members is pre-planned and supervised by the principal investigators."

B. "In this project each team member executes some aspect of a coordinated research plan which has been formulated through team discussions. Coordination between specific sub-tasks performed by team members is by mutual agreement and responsibility is shared by various team members except when the principal investigators are needed to resolve disputes."

C. "In this project each team member designs and executes his research plan which is relevant to a common problem. Coordination between these specific research products occurs at the end of the project when the principal investigators combine the individual outputs into a coherent whole."

D. "In this project each team member executes some aspect of a coordinated research plan formulated by the principal investigators after ideas from various disciplines have been solicited. Coordination between specific sub-tasks performed by team members is pre-planned and supervised by the principal investigators."

ID CODE NUMBER________

23. Outside of seeking funds, which of the following managerial functions do you consider most important in your role as a Principal Investigator on this project? (Check all that apply)

A)____Supervise the work of team members;

B)____Evaluate the work of team members;

C)____Assign work to team members;

D)____Coordinate the work of team members;

E)____Make decisions about priorities in team objectives;

F)____Make decisions about priorities in the utilization of resources;

G)____Serve as interface between the team and a parent organization;

H)____Locate new team members;

I)____Disseminate the team's product/results.

J)____Other, specify ________________________________

24. Of those functions you have just checked, please specify the letter (A - J) of the three most important, in order of importance.

___ Most important

___ Second most important

___ Third most important

25. The Principal Investigator in any research effort may be called upon to perform a variety of intellectual duties. Besides contributing new ideas yourself, which of the following do you consider to be the most important intellectual activities in your role as a Principal Investigator of this project? (Check all that apply)

A)____Encourage team members to contribute new ideas;

B)____Consult people outside the team for new ideas;

C)____Evaluate ideas of team members;

D)____Encourage team members to evaluate your ideas;

E)____Encourage team members to evaluate each other's ideas;

F)____Encourage team members to consult outside the team for new ideas;

G)____Translate ideas from the language of one scientific discipline to the language of another;

H)____Encourage team members to translate their ideas into the language of other scientific disciplines;

I)____Seek outside evaluation of the team's ideas;

J)____Help promote the ideas of peripheral team members.

K)____Other, specify ________________________________

26. Of those functions you have just checked please specify the letter (A - K) of the three you consider most important, in order of importance.

___ Most important

___ Second most important

___ Third most important

ID CODE NUMBER________

27. Below is a list of main areas of R&D activities usually performed by a research unit. In the space provided please write the number corresponding to your PERSONAL INVOLVEMENT in each area on this project, using the following scale:

1 = very high; 2 = high; 3 = medium; 4 = low; 5 = very low.

My personal involvement in the following areas is:

a. Perception and identification of an area of interest.............____
b. Literature review..____
c. Problem definition: conceptualization, formulation, analysis.....____
d. Orientation and perception of methods, techniques, and apparatus..____
e. Formulation and statement of hypotheses..........................____
f. Research design: planning, strategies and experimental approach..____
g. Collection and production of data, including experimental work....____
h. Results: detailed analysis, interpretation and conclusions.......____
i. Report writing, e.g., for publication, dissertation, etc.........____
j. Time-table, administration, organization and budget considerations...____
k. Allocation of work within the unit...............................____
l. Coordination and/or cooperation with other units.................____
m. Personnel decisions..____
n. Selection of equipment/instruments...............................____

> We are particularly interested in the types of relationships formed between university and firm personnel in the execution of this research project. Questions 28 to 34 are designed to give us some idea of how the two organizations work together.

28. How many industrial scientists affiliated with this research have spent time working on-site at your university on this project? ____

29. How many scientists from the university have spent time working at the collaborating firm on this project? ____

30. During the course of this project how frequently do you interact with industry personnel associated with it? (Check one)

____ Several times per week
____ Several times per month
____ Several times per year
____ Rarely or never

31. What methods of interaction do you typically use to interact with industry personnel? (Check all that apply)

____ Face-to-face/informal meetings
____ By phone
____ By letter or memo
____ Formal scheduled meetings

32. What percentage of the face-to-face meetings took place at the following sites?

The university ___%

The firm ___%

Other sites, specify ________________________ ___%

ID CODE NUMBER________

33. Who initiates most of the contacts between university and industry scientists working on this project? (Check one)

____ University scientists initiate most of the interaction
____ Industrial scientists initiate most of the interaction
____ There is no clear patterns.

34. What is the percentage of this project's research activities which involves sharing of the work and/or joint management between university and industry personnel? ____%

> A primary concern of this assessment are the various results and benefits that have accrued to universities from participation in this Industry/University Cooperate Research project. Please be as objective and candid as possible, since in the long run it will be to the program's advantage to understand project strengths and limitations fully. Questions 35 to 50 focus on outcomes, results, and potential benefits.

35. Approximately, how many people at your university have requested information from you concerning specific activities of this Industry/University Cooperative Research project? ____

36. Approximately, how many people outside your university have requested information from you concerning specific activities of this Industry/University Cooperative Research project? ____

37. Approximately what percentage of these information requests can be classified as technical in nature? ____

38. Approximately what percentage of these information requests concern administrative or operational issues of this Industry/University Cooperative Research project? ____%

39. How would you rate this research project compared to similar research projects in other U.S. universities?

___ Top 2%
___ Top 10%
___ Above average
___ Below average
___ Not comparable, because...

Please indicate the NUMBER of written products and/or prototypes produced in conjunction with this project, by yourself or other faculty members at your university.

	No. of Products produced by the project
40a. Written Products	
a. Books (including editorship)	____
b. Scientific or technical articles published in the open literature	____
c. Patents or patent applications	____
d. Algorithms, blueprints, flowcharts, drawings, etc	____
e. Reviews and bibliographies published in the open literature	____
f. Internal reports on work pertaining to this project	____
g. Other written products (specify)	
________________________________	____
________________________________	____

ID CODE NUMBER_________

40b. Prototypes and other Undocumented Products

	No. of Products produced by the project
a. Experimental prototypes of devices, instruments and apparatus, components of devices, etc.	____
b. Experimental materials such as fibres, plastics, glass, metals, alloys, substrates, chemicals, drugs, plants, etc.	____
c. Prototype computer programs	____
d. Audio-visual materials/productions	____
e. Other undocumented products (specify)	
____________________	____
____________________	____

41. How satisfied are you with the following features of this Industry/University Cooperative Research project?

	Completely	A Great Deal	Some	Not at all
Technical quality of the research	___	___	___	___
Communications between university and industrial participants	___	___	___	___
Administration of the research project	___	___	___	___
Compatability of project with academic priorities and interests	___	___	___	___

42. Are there any particular features of project operations and results with which you are expecially satisfied?

43. Are there any particular features of project operations and results with which you are dissatisfied?

ID CODE NUMBER_________

44. Please rate the importance of the following goals and potential outcomes of this project?

	Extremely Important	Considerably Important	Somewhat Important	Not at all Important
General expansion of knowledge in this technical area.	___	___	___	___
Enhancement of graduate students' technical training.	___	___	___	___
Enhancement of graduate students' understanding of industry.	___	___	___	___
Redirection of university research toward industrial problems.	___	___	___	___
Enhancement of quality of industrial research.	___	___	___	___
Enhancement of quality of university research.	___	___	___	___
Instrumentation development.	___	___	___	___
Development of new research projects in your university.	___	___	___	___
Improvements in manufacturing processes.	___	___	___	___
Development of patentable products.	___	___	___	___
Development of commercialized products.	___	___	___	___

45. In your opinion, how likely is it that the collaborating industrial company will realize tangible benefits, now or in the future, in the following areas as a result of participation in this project?

	Almost Certain	Pretty Likely	Somewhat Likely	Scarcely Likely
Better personnel recruitment	___	___	___	___
Improved research projects	___	___	___	___
Patentable products/ technology	___	___	___	___
Commercialized products/ technology	___	___	___	___
Improved instrumentation/ methods	___	___	___	___
Improvements in manufacturing processes	___	___	___	___

46. To what extent has participation in this Industry/University Cooperative Research project caused changes in the research projects conducted in your university?

	A Lot	Some	A Little	Hardly Any
Changes in research topics and issues	___	___	___	___
Changes in research methods and procedures used	___	___	___	___

47. If this Industry/University Cooperative Research project has caused changes in the kinds of research projects conducted in your university, what specifically are these changes?

ID CODE NUMBER________

48. In your opinion, has participation in the Industry/University Research project had any effect on the following specific outcomes in the collaborating industrial company?

	Yes	No	Maybe	Not Applicable
Improvements in products and services	___	___	___	___
Changes in warranty and complaints in view of improvements in products	___	___	___	___
New products developed due to related efforts	___	___	___	___
Changes in cost of products to users (price changes or decreased product maintenance)	___	___	___	___
Reduction of production costs	___	___	___	___
Improvement in processes and methods of production	___	___	___	___
Increased uniformity of products	___	___	___	___
Improved product or process design	___	___	___	___
Improved capability to deal with government regulations	___	___	___	___
Improved capability to cooperate with university scientists	___	___	___	___

ID CODE NUMBER________

49. To what extent is each of the following likely to be positively affected by the relative success of your work in this project?	Completely	Considerably	Some	Not at all
A. Your promotion to a higher position in the university.	___	___	___	___
B. Salary increases.	___	___	___	___
C. Your prestige among your colleagues in the university	___	___	___	___
D. Your prestige among your peers in the larger scientific community.	___	___	___	___
E. Your receipt of financial rewards which are independent of salary.	___	___	___	___
F. The amount of control you might have over future job assignments.	___	___	___	___
G. Your "visibility" to upper level university administration.	___	___	___	___

50. To what extent are you generally satisfied with the operations and activities of this Industry/University Cooperative Research project?

___ Completely

___ Considerably

___ Some

___ Not at all

51. In the future we intend to site visit a sample of universities who have responded to this survey. Would you be willing to participate in this follow-on study?

Yes ____ No ____

THANK YOU FOR YOUR COOPERATION!

Results in an aggregated form will be made available to all respondents to this questionnaire.

APPENDIX B

INDUSTRY RESPONDENT QUESTIONNAIRE

OMB No. 3145-0076

Expires: 3/83

ID CODE #________

INDUSTRIAL PARTICIPANT QUESTIONNAIRE

This questionnaire is designed to provide the NSF with information to understand better the effects of the Industry University Cooperative Research Projects Program and to indicate to us how that program or others like it might be more effectively monitored. We are asking the same questions of all firms which participated in the program during 1978-1980. Your individual responses will be held confidential and will not be discussed. If a question is inapplicable, proceed to the next question.

> In order to understand the relationship between university and industrial participants in the Industry/University Cooperative Research program, it would be useful to have some background about industry researchers such as yourself. Questions 1 to 15 are designed to provide us with some data about your firm, your experience, and your position within the firm.

1. Is your firm an affiliate or subsidiary of another company?

    ___ No

    ___ Yes; If yes, specify the nature of the relationship.

    ____

2. What is the main product line or service offered by your firm?

    ____

3. How many years have you spent with your company?

    ____

4. How many years have you spent in research and development with your company? ___

5. How many years have you spent in industry in general? ___

6. How many years have you spent in research and development in industry? ___

7. How many organizational levels are there between you and the chief executive officer in the company? ___

8. How many organizational levels are there between you and the senior technical executive in the company? ___

9. How many people report directly to you? ___

10. How many people report to you through your subordinates? ___

11. What is your current position/title?

    ____

12. How long have you held this position?

    ____

13. What is the highest degree you have received? ______

    In what field? ______________________________

ID CODE #________

14. Do you have a degree from or have you taken course work at the collaborating university?

    ___Yes ___No

15. Have you been with this Industry/University Cooperative Research project since its inception?

    ___Yes ___No

> We are also concerned with the decision making and logistics associated with your company's involvement with this Industry/University Cooperative Research project. We know that in general the scope of discussion in companies about project participation has varied widely; so has the amount of prior contact with university personnel. Items 16 to 25 are intended to help us understand the early formation of Industry/University Cooperative Research teams.

16. Prior to the beginning of this Industry/University Cooperative Research project, was your company involved in any of the following activities with university personnel now associated with the project? (Check all that apply)

    ___ Individual consulting relationships

    ___ Contract research projects

    ___ General support of faculty research

    ___ Support of student thesis research

    ___ Faculty exchange

    ___ Student placement

    ___ Other (please specify)

    ____

17. Prior to the beginning of this Industry/University Cooperative Research project, how frequently did you personally have contact with university personnel now associated with it?

    ___ Several times per week

    ___ Several times per month

    ___ Several times per year

    ___ Rarely or never

18. How did you hear about the Industry/University Cooperative Research Program? (Check all that apply)

    ___ NSF personnel

    ___ A colleague at your company

    ___ A colleague at the university

    ___ Other, specify ______________________________

    ____

19. From where did the initial impetus for this project come?

    ___ Your firm

    ___ The university

    ___ Evolved from mutual discussion

20. Do you think your firm would have undertaken this type of collaborative research with a university in the absence of a specific NSF program?

    ___Yes ___No

21. Other than this Industry/University Cooperative Research project, how many NSF grants have you been involved with in the last five years (i.e., '78-'82)? ___

ID CODE #______

22. How many organizational levels in your firm above your own had to give explicit approval for participation in this Industry/University Cooperative Research project? ____

23. How many groups at your level in your company had to concur with the decision to participate in this Industry/University Cooperative Research project? ____

24. Was this approval process substantially different from that used with projects not involving university participation?

___Yes ___No

25. What is the approximate total cost per year of your company's participation in this project, including cash and in-kind contributions? $________

> Each University/Industry Cooperative Research project represents a unique research effort. In order to better understand the overall program, we would like to know about some of the structures and decision processes which operate in this project.
>
> Questions 26 to 37 deal with these dimensions of structure and decision processes.

26. How many people in your firm participate actively in this project at any one time? ____

27. In general, which of the following alternatives best describes the way in which decisions are made about work priorities on this project (i.e., what needs to be done)?

___The Principal Investigators decide alone;

___The Principal Investigators decide after consulting with senior members of the project team;

___The Principal Investigators decide after consulting with the team as a whole;

___The Principal Investigators and senior members of the project team jointly make the decision;

___The project team as a whole decides;

___Each individual project team member determines his or her own work priorities.

___Other, specify ________________________

28. In general, how are specific task assignments made on this project (i.e., who does a specific job)?

___By the Prinicpal Investigators;

___By either the Principal Investigators or a senior member of the project team;

___By collective team decision;

___By self-assignment.

29. What functional groups in your company work directly with the Industry/University Cooperative Research project? (Check all that apply)

	Regularly	Occasionally
Central R&D staff	___	___
Divisional R&D staffs	___	___
Production staff	___	___
Marketing staff	___	___
Engineering/technical staff	___	___
Corporate planning staff	___	___
Other, specify________	___	___

ID CODE #______

30. To what what extent is your company's top R&D management involved with the activities of this Industry/University Cooperative Research project?

___ Follows the project closely

___ Is aware of general progress of the project

___ Knows it exists, but not much more

___ Is not aware of the project

31. To whom in your firm are you obliged to send formal reports concerning the activities of this project?

32. Each of the following paragraphs describes a working arrangement typically found in research teams. Please consider each paragraph carefully and then circle the letter corresponding to the paragraph that comes closest to describing the working arrangement in this project.

A. "In this project each team member executes some aspect of a coordinated research plan which has been formulated primarily by the principal investigators. Coordination between specific sub-tasks performed by team members is pre-planned and supervised by the principal investigators."

B. "In this project each team member executes some aspect of a coordinated research plan which has been formulated through team discussions. Coordination between specific sub-tasks performed by team members is by mutual agreement and responsibility is shared by various team members except when the principal investigators are needed to resolve disputes."

C. "In this project each team member designs and executes his research plan which is relevant to a common problem. Coordination between these specific research products occurs at the end of the project when the principal investigators combine the individual outputs into a coherent whole."

D. "In this project each team member executes some aspect of a coordinated research plan formulated by the principal investigators after ideas from various disciplines have been solicited. Coordination between specific sub-tasks performed by team members is pre-planned and supervised by the principal investigators."

33. Outside of seeking funds, which of the following managerial functions do you consider most important in your role as a Principal Investigator on this project? (Check all that apply)

A)___Supervise the work of team members;

B)___Evaluate the work of team members;

C)___Assign work to team members;

D)___Coordinate the work of team members;

E)___Make decisions about priorities in team objectives;

F)___Make decisions about priorities in the utilization of resources;

G)___Serve as interface between the team and a parent organization;

H)___Locate new team members;

I)___Disseminate the team's product/results.

J)___Other, specify ________________________

34. Of those functions you have just checked, please specify the letter (A - J) of the three most important, in order of importance.

___ Most important

___ Second most important

___ Third most important

ID CODE #______

35. The Principal Investigator in any research effort may be called upon to perform a variety of intellectual duties. Besides contributing new ideas yourself, which of the following do you consider to be the most important intellectual activities in your role as a Principal Investigator of this project? (Check all that apply)

A)____Encourage team members to contribute new ideas;

B)____Consult people outside the team for new ideas;

C)____Evaluate ideas of team members;

D)____Encourage team members to evaluate your ideas;

E)____Encourage team members to evaluate each other's ideas;

F)____Encourage team members to consult outside the team for new ideas;

G)____Translate ideas from the language of one scientific discipline to the language of another;

H)____Encourage team members to translate their ideas into the language of other scientific disciplines;

I)____Seek outside evaluation of the team's ideas;

J)____Help promote the ideas of peripheral team members.

K)____Other, specify ______________________________

36. Of those functions you have just checked please specify the letter (A - K) of the three you consider most important, in order of importance.

___ Most important

___ Second most important

___ Third most important

37. Below is a list of main areas of R&D activities usually performed by a research unit. In the space provided please write the number corresponding to your PERSONAL INVOLVEMENT in each area on this project, using the following scale:

1 = very high; 2 = high; 3 = medium; 4 = low; 5 = very low.

My personal involvement in the following areas is:

a. Perception and identification of an area of interest.............____

b. Literature review..____

c. Problem definition: conceptualization, formulation, analysis.....____

d. Orientation and perception of methods, techniques, and apparatus ____

e. Formulation and statement of hypotheses..........................____

f. Research design: planning, strategies and experimental approach..____

g. Collection and production of data, including experimental work....____

h. Results: detailed analysis, interpretation and conclusions.......____

i. Report writing, e.g., for publication, dissertation, etc..........____

j. Time-table, administration, organization and budget considerations..____

k. Allocation of work within the unit...............................____

l. Coordination and/or cooperation with other units.................____

m. Personnel decisions..____

n. Selection of equipment/instruments...............................____

We are particularly interested in the types of relationships formed between university and firm personnel in the execution of this research project. Questions 38 to 44 are designed to give us some idea of how the two organizations work together.

38. How many university scientists affiliated with this research have spent time working on-site in your company on this project? ____

ID CODE #______

39. How many scientists from your company have spent time working at the university on this project? ____

40. During the course of this project how frequently do you interact with university personnel associated with it? (Check one)

___ Several times per week

___ Several times per month

___ Several times per year

___ Rarely or never

41. What methods of interaction do you typically use to interact with university personnel? (Check all that apply)

___ Face-to-face/informal meetings

___ By phone

___ By letter or memo

___ Formal scheduled meetings

42. What percentage of the face-to-face meetings took place at the following sites?

The university ___%

The firm ___%

Other sites, specify ______________ ___%

43. Who initiates most of the contacts between university and industry scientists working on this project? (Check one)

___ University scientists initiate most of the interaction

___ Industrial scientists initiate most of the interaction

___ There is no clear pattern

44. What is the percentage of this project's research activities which involves sharing of the work and/or joint management between university and industry personnel? ____%

A primary concern of this assessment are the various results and benefits that have accrued to companies from participation in this Industry/University Cooperate Research project. Please be as objective and candid as possible, since in the long run it will be to the program's advantage to understand project strengths and limitations fully. Questions 45 to 60 focus on outcomes, results, and potential benefits.

Please indicate the NUMBER of written products and/or prototypes produced in conjunction with this project, by yourself or other employees of your company.

		No. of Products produced by the project
45a. Written Products		
a.	Books (including editorship)	____
b.	Scientific or technical articles published in the open literature	____
c.	Patents or patent applications	____
d.	Algorithms, blueprints, flowcharts, drawings, etc.	____
e.	Reviews and bibliographies published in the open literature	____
f.	Internal reports on work pertaining to this project	____
g.	Other written products (specify)	
	______________________	____
	______________________	____

ID CODE #________

45b. Prototypes and other Undocumented Products

	No. of Products produced by the project
a. Experimental prototypes of devices, instruments and apparatus, components of devices, etc.	____
b. Experimental materials such as fibres, plastics, glass, metals, alloys, substrates, chemicals, drugs, plants, etc.	____
c. Prototype computer programs	____
d. Audio-visual materials/productions	____
e. Other undocumented products (specify)	
______________________	____
______________________	____

46. Approximately, how many people in your company have requested information from you concerning specific activities of this Industry/University Cooperative Research project? ____

47. Approximately, how many people outside your company have requested information from you concerning specific activities of this Industry/University Cooperative Research project? ____

48. Approximately what percentage of these information requests can be classified as technical in nature? ____%

49. Approximately what percentage of these information requests concern administrative or operational issues of this Industry/University Cooperative Research project? ____%

50. How satisfied are you with the following features of this Industry/University Cooperative Research project?

	Completely	A Great Deal	Some	Not at All
Technical quality of the research	___	___	___	___
Communications between university and industrial participants	___	___	___	___
Administration of the research project	___	___	___	___
Responsiveness of project to industry priorities and interests	___	___	___	___

51. Are there any particular features of project operations and results with which you are especially satisfied?

ID CODE #________

51. Are there any particular features of project operations and results with which you are dissatisfied?

52. Please rate the importance of the following goals and potential outcomes of this project?

	Extremely Important	Considerably Important	Somewhat Important	Not at all Important
General expansion of knowledge in this technical area.	___	___	___	___
Enhancement of graduate students' technical training.	___	___	___	___
Enhancement of graduate students' understanding of industry.	___	___	___	___
Redirection of university research toward industrial problems.	___	___	___	___
Enhancement of quality of industrial research.	___	___	___	___
Enhancement of quality of university research.	___	___	___	___
Instrumentation development.	___	___	___	___
Development of new research projects in your firm.	___	___	___	___
Improvements in manufacturing processes.	___	___	___	___
Development of patentable products in your firm.	___	___	___	___
Development of commercialized products in your firm.	___	___	___	___

ID CODE #______

53. In your opinion, how likely is it that your company will realize tangible benefits in the following areas, now or in the future, as a result of participation in this project?

	Almost Certain	Pretty Likely	Somewhat Likely	Scarcely Likely
Better personnel recruitment	___	___	___	___
Improved research projects	___	___	___	___
Patentable products/ technology	___	___	___	___
Commercialized products/ technology	___	___	___	___
Improved instrumentation/ methods	___	___	___	___
Improvements in manufacturing processes	___	___	___	___

54. Approximately how many new research projects have been stimulated in your research laboratories by this project's activities? ____

How much is this in terms of research dollars? ______

55. To what extent has participation in this Industry/University Cooperative Research research project caused changes in the R&D projects conducted in your company?

	A Lot	Some	A Little	Hardly Any
Changes in research topics and issues	___	___	___	___
Changes in research methods and procedures used	___	___	___	___

56. If this Industry/University Cooperative Research project has caused changes in the kinds of R&D projects conducted in your company, what specifically are these changes?

57. In your opinion, has participation in the Industry/University Research project had any effect on the following specific outcomes in your company?

	Yes	No	Maybe	Not Applicable
Improvements in products and services	___	___	___	___
Changes in warranty and complaints in view of improvements in products	___	___	___	___
New products developed due to related efforts	___	___	___	___
Changes in cost of products to users (price changes or decreased product maintenance)	___	___	___	___
Reduction of production costs	___	___	___	___
Improvement in processes and methods of production	___	___	___	___
Increased uniformity of products	___	___	___	___
Improved product or process design	___	___	___	___
Improved capability to deal with government regulations	___	___	___	___
Improved capability to cooperate with university scientists	___	___	___	___

ID CODE #______

58. How many students affiliated with this research project have been interviewed for possible employment in your company? ____

How many have actually been hired? ____

59. To what extent is each of the following likely to be positively affected by the relative success of your work in this project?

	Completely	Considerably	Some	Not at all
A. Your promotion to a higher position in the organization.	___	___	___	___
B. Salary increases.	___	___	___	___
C. Your prestige among your R&D colleagues in the organization.	___	___	___	___
D. Your prestige among your peers in the larger scientific community.	___	___	___	___
E. Your receipt of financial rewards which are independent of salary.	___	___	___	___
F. The amount of control you might have over future job assignments.	___	___	___	___
G. Your "visibility" to upper level R&D management.	___	___	___	___
H. Your "visibility" to upper level management outside of R&D.	___	___	___	___
I. The likelihood that you will be allowed to do more stimulating or interesting work in the future.	___	___	___	___

60. To what extent are you generally satisfied with the operations and activities of this Industry/University Cooperative Research project?

___ Completely

___ Considerably

___ Some

___ Not at all

61. In the future we intend to site visit a sample of firms who have responded to this survey. Would you be willing to participate in this follow-on study?

Yes ____ No ____

THANK YOU FOR YOUR COOPERATION!

Results in an aggregated form will be made available to all respondents to this questionnaire.

DATA REDUCTION PROCEDURES AND RESULTS

The basic procedure was to conduct factor analysis in each of five variable domains: 1) researcher descriptors; 2) prior relationships/initation of the collaboration; 3) project management/decision-making; 4) coordination of project activities; and 5) benefits and outcomes. (Data reduction for outcome measures is described in Chapter 3.) These analyses were conducted separately for university and industry data sets. The resultant factors were inspected for conceptual coherence, and in terms of statistical criteria. The SPSS Factor Analysis program, principal components with iterations (oblique rotation) was used. Factors with an eigenvalue of less than 1.0 were eliminated along with variables with factor loading of less than .40. When a factor was retained, respondent scores on each item in a factor were converted to standardized z scores and these scores were summed across items to create a new composite variable. This section describes how the measures were developed from the original data and how the variables relate to one another within variable domains.*

Researcher Descriptors

A total of nine university variables and twelve industry variables were originally in this category. As described in Figure C-1, university items grouped themselves after factoring and scaling into two composite variables relating to seniority and NSF grant experience. Three other experience-related individual variables were retained for subsequent analyses.

Factor analyses of the industry variables resulted in a similar composite seniority variable and one relating to organizational rank. Also retained for subsequent correlational analysis were five discrete variables reflecting organizational status and experience.

The retained and constructed variables were for the most part independent of one another (see Table C-1). For university respondents there were significant positive correlations between administrative experience and seniority, NSF grant experience and administrative experience, and general grantsmanship and industry experience. This is a logical but unremarkable set of relationships. For industry respondents there were three significant correlations which reflected fairly obvious relationships between supervisory responsibilites, educational attainment, and NSF grant experience.

* Note: Only these correlations which were statistically significant at $p \leqslant .01$ will be discussed.

Prior Relationships/Project Initiation

Seventeen university and nineteen industry items in this variable domain were subjected to data reduction. Figure C-2 presents the results of scaling and factor analytic procedures. Analysis of university items resulted in one composite variable describing the range of prior contacts and a scale indicating the university's role in project initiation. Three individual variables relating to the frequency of prior contacts, the grant approval process, and the role of the IUCR program

Figure C-1
Researcher Descriptor Variables

Variable Name	*Description*
	University Respondents
1. Seniority	A composite of academic rank, the number of years in academia, years at the university and years in current job.
2. NSF Grant Experience	The number of NSF grants received within the last five years and the number on which the researcher was principal investigator.
3. Industry Work Experience	Number of years of full-time work experience in industry since terminal degree.
4. Administrative Experience	Indicates whether researcher had been a department administrator or chairperson.
5. Grantsmanship	Number of non-NSF federal grants.
	Industry Respondents
1. Seniority	A composite of number of years with firm, number of years in industry, number of years in R&D in general, number of years in R&D at firm, and number of years in current position.
2. Organizational Rank	A composite of the number of organizational levels between the researcher and CEO, and between the researcher and senior technical officer.
3. Direct Supervisory Responsibilities	Number of people reporting directly to researcher.
4. Indirect Supervisory Responsibilities	Number of people reporting to researcher through subordinates.
5. Educational Attainment	Highest degree obtained.
6. Studied at Collaborating University	Course work on degree from collaborating university.
7. NSF Grant Experience	Number of NSF grants in last five years.

Table C-1
Correlations Among Researcher Descriptor Variables

	1.	2.	3.	4.	5.	6.
University Respondents						
1. Seniority						
2. NSF Grant Experience	.12					
3. Industry Work Experience	-.03	-.01				
4. Administrative Experience	.33**	.27*	-.02			
5. Grantsmanship	.06	.14	.26*	£.06		
Industry Respondents						
1. Seniority						
2. Organizational Rank	-.05					
3. Direct Supervisory Responsibilities	-.06	-.09				
4. Indirect Supervisory Responsibilities	-.09	-.19	.30**			
5. Educational Attainment	-.20	.08	-.08	-.25*		
6. Studied at Collaborating University	-.12	-.13	-.09	-.11	.11	
7. NSF Grant Experience	.11	-.12	-.04	-.05	-.22*	.01

* $p \leq .01$.
** $p \leq .001$.

Figure C-2
Prior Relationships/Project Initiation Variables

Variable/Scale Name	*Description*
University Respondents	
1. Range of Prior Industry Contacts	A composite of the percent of team members involved in prior student placement, in consulting, and in contract research activities in Industry.
2. University Project Impetus	The extent to which the idea for the project came from the university.
3. Frequency of Prior Industry Contacts	Frequency of prior contacts with industry.
4. Upper Management Involvement in Grant Approval	Number of organizational levels which approved grant.
5. NSF as Project Broker	Whether project would have been initiated without IUCR program.
Industry Respondents	
1. Range of Prior University Contacts	A composite of prior company involvement with university project personnel including student placement activities, support of faculty research, faculty exchange activities, student research activities, contract research and consulting relationships.
2. University Project Impetus	The extent to which the idea for the project came from the university.
3. Frequency of Prior University Contacts	Frequency of prior contacts with the university.
4. Upper Management Involved in Project Approval	Number of organizational levels which approved grant.
5. Parallel Groups Involved	Number of groups at researcher level to approve grant.
6. NSF as Project Broker	Whether project would have been initiated without IUCR program.

were retained for further analysis. The analysis of industry items resulted in a parallel set of composite and single variables.

There were two significant correlations (see Table C-2) among university respondent variables: 1) when the university researcher had more previous contact with the industry team, upper management of the university was more involved in project approval; 2) in cases where the project would not have been initiated without the IUCR program, the university researcher played a major role in project initiation (possibly because they were more familiar with NSF).

For industry respondents, there was one significant correlation; the range of prior contacts by the firm with the university tended to lead to more groups being involved in project approval.

Project Management and Decision-Making

This data category initially included 42 university and 45 industry items. The factor analysis of these items resulted in several composite variables (Figure C-3) which tended to capture different research roles (i.e., administrative, liaison, bureaucratic). One discrete variable, team involvement in the development of the research plan, was included in the final array of indices. Overall, seven university and six industry variables in the project were retained for further analysis.

There were two significant correlations (Table C-3) among the university variables which described researcher roles. For example, when the PI functioned as a research administrator, there tended not to be significant team input into the development and the research plan; also the liaison role incorporated some idea broker functions. There were five significant correlations among industry variables indicating some overlap among the various roles.

Coordination of Project Activities

Scaling and factor analytic techniques were used to aggregate the fourteen university and twenty-two indus-

Table C-2
Correlations Among Prior Relationships/Project Initiation Variables

	1.	2.	3.	4.	5.
University Respondents					
1. Range of Prior Contacts					
2. University Project Impetus	.13				
3. Frequency of Prior Contacts	.07	.20			
4. Upper Management Involved in Project Approval	.21*	-.15	-.04		
5. NSF as Project Broker	-.06	-.22*	.15	.10	
Industry Respondents					
1. Range of Prior Contacts					
2. University Project Impetus	-.05				
3. Frequency Prior Contacts	.19	-.17			
4. Upper Management Involved in Project Approval	-.02	.02	-.17		
5. NSF as Project Broker	-.11	-.01	.05	.04	
6. Parallel Groups Involved in Project Approval	.33**	.06	-.10	.14	-.04

* p ≤ .01.
** p ≤ .001.

Table C-3
Correlations Among Project Management Variables

	1.	2.	3.	4.	5.	6.
University Respondents						
1. PI as Bench Scientist						
2. PI as Research Administrator	.02					
3. PI as Bureaucrat	.17	.16				
4. PI as Project Conceptualizer	.18	-.05	.14			
5. PI as Idea Broker	0	-.01	-.03	.08		
6. PI as Liaison	-.13	-.08	-.13	.11	.22*	
7. Team Development of Research Plan	-.04	-.47**	.09	.10	.11	.16
Industry Respondents						
1. PI as Bench Scientist						
2. PI as Research Administrator	-.02					
3. PI as Bureaucrat	.36**	.12				
4. PI as Idea Broker	.19	.09	.32**			
5. PI as Project Conceptualizer	.50**	.14	.32**	.16		
6. Team Development of Research Plan	.10	-.35**	.07	.04	.10	

* p ≤ .01.
** p ≤ .001.

Figure C-3
Project Management/Decision-Making Variables

Variable Name	*Description*
University Respondents	
1. Researcher as Bureaucrat	Describes a researcher whose primary activities consist of personnel decisions, coordination activities, work allocation, administrative/budget duties, and equipment selection.
2. Researcher as Liaison	Describes a researcher on a large team who, as liaison with other university groups, encourages team to translate ideas, and promotes team ideas.
3. Research as Research Administrator	Describes a researcher who determines work priorities and formulates the research plans without team input.
4. Research as Bench Scientist	Portrays a researcher who is involved in literature review, collecting and producing data, result analysis, and report writing.
5. Research as Project Conceptualizer	Describes a researcher who is involved in problem definition and the formulation of hypothesis.
6. Researcher as Idea Broker	Portrays a researcher who consults others for new ideas and seeks outside evaluation of team ideas.
7. Team Development of Research Plan	Indicates team input in the formulation of the research plan.
Industry Respondents	
1. Researcher as Bureaucrat	Describes a researcher whose primary activities consist of personnel decisions, work allocation, the coordination with other company units, administrative/budgetary activities and the selection of equipment.
2. Researcher as Research Administrator	Describes a researcher who determines task assignments, formulates the research plan without team input, determines work priorities, and supervises team members.
3. Researcher as Bench Scientist	Portrays a researcher who is involved in report writing, data collection and production, orientation of methods, literature review, results analysis and research design.
4. Researcher as Project Conceptualizer	Indicates a researcher who is involved in problem definition and hypothesis formulation.
5. Researcher as Idea Broker	Describes a researcher who encourages new ideas as well as the evaluation of ideas by team members and others.
6. Team Development of Research Plan	Indicates team input in the formulation of the research plan.

try items included under the domain of project coordination. For the university respondents this resulted in the creation of one factor and two scales (Figure C-4). The factor describes the type and frequency of contacts between teams, the two scales group those items covering the amount of interaction, and the university's initiation of contacts. A single variable pertaining to the percent of meetings at the university was retained.

The analysis of industry respondent variables also resulted in one factor and two scales. The factor indicates the degree of project involvement by top company officials. The two scales were parallel in form and content to the university scales. Single variables pertaining to personnel exchanges, frequency and site of interaction, and groups within the firm working with the IUCR project were retained.

As seen in Table C-4, university scientists' interaction and exchange variables correlated positively while the university's initiating role in project initiation tended not to be related with its use as a meeting site. The five significant correlations among industry variables tended to highlight the individual elements which contribute to the level and type of exchange between participants.

Figure C-4
Coordination of Project Activity Variables

Variable Name	*Description*
	University Respondents
1. Amount of Exchange and Interaction	A composite of the number of university researchers working at the firm site and vice-versa, and the frequency of interaction between teams.
2. University Initiation of Contacts (Scale)	The extent to which contacts are initiated by the university.
3. Range of Project Interaction (Scale)	The total number of communication methods employed (i.e., phone, letter, face-to-face meetings).
4. University as Meeting Site	Percent of project meetings held at the university.
	Industry Respondents
1. Top R&D Planning/ Management Involvement	The extent to which corporate officials/ planning staff are knowledgeable about or involved in the project.
2. University Initiation of Contacts (Scale)	The extent to which contacts are initiated by the university.
3. Range of Project Interaction (Scale)	The total number of communication methods employed (i.e., phone, letter, face-to-face, meetings).
4. University Personnel Exchange	Number of university scientists working at industry site.
5. Industry Personnel Exchange	Number of industry scientists working at university site.
6. Frequency of Project Interaction	Frequency of contacts.
7. University as Meeting Site	Percent of project meetings at the university.
8. Production Staff Involvement	Extent to which the product staff in involved in project.
9. Marketing Staff Involvement	Extent to which the marketing staff is involved in project.
10. Divisional R&D Staff Involvement	Extent to which the divisional R&D staff is involved in project.

Table C-4
Correlations Among Project Coordination Variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.
			University Respondents						
1. Range of Project Interaction									
2. University Initiates Contacts	-.05								
3. Amount of Exchange and Interaction	.22*	-.05							
4. University as Meeting Site	-.03	-.26*	.05						
			Industry Respondents						
1. Range of Project Interaction									
2. University Initiates Contacts	-.02								
3. University Personnel Exchange	-.09	.14							
4. Industry Personnel Exchange	.04	.01	.29**						
5. Frequency of Project Interaction	.05	-.20	.10	.23*					
6. University as Meeting Site	.09	-.22*	-.29**	.26*	.18				
7. Top R&D/Planning Involvement in Project	.19	.01	.12	.09	.18	-.04			
8. Divisional R&D Involvement in Project	.03	.12	.06	.12	-.12	.04	.18		
9. Production Staff Involvement in Project	.16	.04	-.04	.03	.03	.11	.02	.04	
10. Marketing Staff Involvement in Project	.16	.05	-.05	.03	-.04	-.01	.05	.14	.03

* = $p \leq .01$.
** = $p \leq .001$.

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