

Knowledge and Technology Transfer
from NSF-supported Centers and Laboratories to Smaller Businesses:
Report to the U.S. Congress from the National Science Foundation

January, 1988

This report reviews the transfer of scientific and engineering knowledge from NSF Centers to small businesses and recommends actions to further such transfer in the future.

Although in the past there has been limited attention paid to small business connections by most NSF centers, a survey of center directors and NSF center monitors specifically on this topic has turned up a wide variety of small business involvements. Such activity varies enormously from center to center and from NSF program to program. The recently established Engineering Research Centers [ERC's] have the most active involvement with smaller businesses but significant connections are also reported by many other types of laboratories and centers including a majority of the nine Materials Research Laboratories [MRL's], and many of the 39 Industry-University Cooperative Centers [IUC's]. The potential for small business contacts was also noted by Supercomputer centers and by the newly formed Minority Research Centers of Excellence [MRCE]. Even basic research centers such as the three NSF-supported astronomy facilities were able to note some types of small business connections.

Center orientation to tech transfer and to small business involvement varies with type of program and the ground rules under which different centers were developed. Some centers such as the ERC's and IUC's are encouraged to attract industry support. Others are not. Some subjects also lend themselves to small business opportunities more readily than others. For example, the field of biotechnology currently appears to be attracting a very large number of small start-up enterprises. The further centers proceed toward the applied end of the research-development continuum, the more potential there will be for transfers especially to smaller firms.

Involvement of NSF centers with smaller businesses take place in five categories: [1] direct affiliations, [2] information sharing and educational activities, [3] joint projects, [4] involvement through third parties acting as mediators, and [5] special arrangements. Strengths and weaknesses of each approach as presently configured can be summarized as follows.

1. Formal center affiliations usually require annual fees in excess of \$25,000, which limits small business participation. Consortia arrangements and dual fee structures give some access to small business, but these arrangements are not yet widespread. IUC's in particular count on industrial affiliate fees as a major source of support and are therefore understandably reluctant to grant full participation to any firms at reduced rates.

2. Information sharing takes several forms including print, meetings and workshops, facilities access, and visits. All centers contribute substantially to the scientific and engineering literature which is ultimately available to all. However, some of this literature may be too technical and require considerable interpretation and reworking before industrial applications become evident. By being close to the research and knowing the researchers, industrial affiliates are better able to reach this level of understanding. Small working conferences and workshops where substantial transfers of technical knowledge can take place are also often reserved for affiliates. However, all ERC's and many other centers hold some open conferences or other events which are attended by small businesses. Some centers also have research facilities and costly equipment such as supercomputers whose use can be of significant value to small firms. Most centers also entertain a stream of visitors throughout the year and some give special consultative assistance to small businesses on an ad hoc basis.

3. Small businesses sometimes develop joint projects with center researchers, thus gaining informal or indirect access to the center's capacity. Patents and licensing arrangements may also emerge from such joint efforts. Every ERC has at least one joint project with a small business, and some have several in the works. The potential for this mechanism seems great.

4. Third parties often serve as catalysts or underwriters for small business linkages. Among these are state and local agencies, trade associations, larger firms, and other federal agencies. There has been a substantial increase in the activity of state and local economic development organizations in the last decade. NSF has been able to leverage a great deal of state and local government support especially for IUCs. Most ERCs also have such connections. Many of these agencies give special encouragement to small business development and thus represent a very promising conduit for their involvement. Large numbers of small businesses can also be provided access through trade association involvement with or affiliation in NSF centers. More than half the ERC's have such ties, but the type of transfer which results for small business members is likely to be of the "awareness" variety. Some small firms also may get to share technology from NSF centers through subcontractor relationships with larger firms or through special centers subsidized by larger firms with a particular interest. Various other federal agencies also may be available to encourage small business involvements with centers in areas of application relevant to those agencies.

5. Some NSF centers have units or officials designated to provide special knowledge or technology transfer services. A few are specifically oriented to small businesses. Another trend of the 1980's has been the growth of special organizations to assist entrepreneurs in the early stages of business development. Many of these "small business incubators" have a high tech orientation and many have university affiliations. Some foster the formation of new firms by researchers.

Recommendations

Mechanisms for technology transfer are continuing to expand nationwide at the federal, state, and local levels and within the private sector. Many NSF centers are taking advantage of these new developments, often to the specific benefit of small business. However, there are additional actions which can be taken to enhance small business involvement with the NSF-supported centers and laboratories. They are of three kinds.

Recommendation #1: Administrative Encouragement

NSF will encourage more activities through suggestions and administrative measures which do not require augmentation of center budgets, e.g.

- specific center reporting requirements on small business participation;
- encouraging inter-center information sharing on small business transfer strategies;
- encouraging more cooperative efforts within the local environment.

Recommendation #2. A Joint Project Incubation Program

If additional financial resources can be made available, NSF will consider providing special new incentives for specific joint projects between small businesses and centers.

Recommendation # 3. An Innovative Transfer Strategies Program

If additional financial resources can be made available, NSF will consider the initiation of a program to encourage new efforts by NSF-sponsored centers to interact with smaller businesses. Competitive proposals would be invited from existing centers to achieve such ends through a variety of mechanisms such as:

- special conferences for small business;
- new programs to support small business-oriented technical data base services, clearinghouses, and specialized publications;
- installation of small business-oriented tech transfer agents or offices;
- establishment of center-linked development units such as small business incubators.

Figure 1 [attached] summarizes current efforts and NSF recommendations in matrix form.

MECHANISMS OF KNOWLEDGE AND TECHNOLOGY TRANSFER

Figure 1: **SMALL BUSINESS INTERACTIONS WITH NSIP CENTERS**

	CURRENT STATUS	TREND WITH NO NEW NSF ACTION	NSF ADMINISTRATIVE ENCOURAGEMENT	ARRAY OF POTENTIAL NSF CENTER ACTIONS	NSF PROGRAM INITIATIVES
DIRECT AFFILIATIONS Full — Partial —	Very few small businesses or a full affiliates / high fees (avg. \$25,000) two tiered fee structure sometimes attracts a few small businesses	no change	↑ ↑ ↑	new creative arrangements for affiliating with small businesses	
INFORMATION SHARING Clearinghouse & database services	most are pub. dom./may be too technical for some small bus. not many yet; not usually small business-oriented	no change	↑	publications emphasizing applications potential of research findings new business-oriented data base services, clearinghouses, etc.	
Visits — Open meetings & conferences — Closed meetings — Workshops/Courses — Facilities access —	freq. use, 2-way, low cost, gateway to other types of linkage ERIC require 1/yr; sm. bus. participation avg. 10%* Usually reserved for affiliates; low small bus. enrollment (<10%*) Key ingredient of small business connections at some PRL's	no change	↑	special tech transfer conferences aimed at small business	
JOINT PROJECTS (between center or center projects and individual small businesses.)	many individual examples, e.g. one cited for each ERIC, some PRL's, probably more rare at IUCs and other center types	may increase as center projects reach maturity	↑	new joint projects involving center researchers and small or start-up businesses	JOINT PROJECT INCUBATION PROGRAM (competitive awards to initiate or subsidize small bus. joint projects)
MEDIATING MECHANISMS State / local economic development agencies	very widespread pattern of NSF center involvement with development org's but potential varies by state; many dev. org's target small bus. many centers (>50% ERICs) have ties to Trade Assoc's, can reach mltly s.d.'s this way but impact minor	increasing in coverage & impact as states get more sophisticated	↑	efforts to link centers to state/local development agencies, create inter-state networks	
Trade Associations — Large firms (e.g. support for subcontractors) —	not a common pattern but a sig. channel at a few centers	no change	↑	efforts to link centers to trade or professional associations to create small business linkages	
S.B.I.R. — Other Federal programs —	few now have any explicit ties to NSF centers; informal ties not known other fed R&D more applied than NSF; thus may be more sm. bus. linkage	no change	↑	inform centers on SBIR proj's in area/on topic; ask to give help	
SPECIAL ARRANGEMENTS Small business tech transfer office/agent — Small bus. consortia — Small bus. development units (e.g. incubators) —	many centers have tech transfer offices/officers//few of these are small bus.-oriented one example of this noted — not much evidence of NSF-center affiliation with these	number of TI offices may increase with implement. of Tech Tran Act but no special sm. bus. emphasis not known programs are expanding as a national trend (3 ERICs have plans)	↑	new small business-oriented transfer offices or agents affiliated with centers new consortia arrangements to link small businesses to NSF centers new NSF center-linked small business development units	INNOVATIVE SMALL BUSINESS TRANSFER STRATEGIES (Competitive supplemental awards to NSF Centers)

* There are two or three significant exceptions to this pattern, e.g. Bio-tech Center at MIT which attracts hundreds of small or start-up business contacts.

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Objectives and Scope

In recent years the National Science Foundation has given an increasing number of long-term awards to universities to establish interdisciplinary laboratories and centers. The primary purpose of these awards has been to strengthen our national capability to perform certain types of large-scale research that cannot be performed by single investigators or small teams with limited resources. Additional purposes have been to facilitate interdisciplinary research, to foster university-industry interactions, and to build a stronger knowledge base in certain areas critical to industrial competitiveness or clear national need. Many of these centers have also sought advice, participation and support from private industry since it is assumed that private industry in general benefits greatly from applications of the scientific knowledge which is being developed. It is less clear how these benefits are distributed, i.e., which industries benefit and in what ways. Such questions fall under the general heading of "knowledge or technology transfer."

The U.S. Congress has now asked the NSF to report specifically on how the various NSF-supported centers and laboratories transfer scientific and technical information to businesses, with emphasis on small and medium sized businesses. The Congress also want to know what can be done in the future to enhance such transfer activity. This report has been prepared in response to this request and has three purposes:

1. to indicate the context for NSF activity in this area;
2. to indicate the ways in which NSF and its centers now promote knowledge transfer or technology transfer to smaller businesses; and
3. to indicate what further efforts could be undertaken in this direction.

*Prepared by the NSF Task Force on Technology Transfer,
Lynn Preston, Chairperson, Ronald G. Havelock, Consultant/writer

It should be made clear at the outset that the charge to the Technology Transfer Task Force was limited to a summary review of current center activities. It does not represent a full accounting of the numbers of small businesses involved with NSF centers and the impact that such contacts have had on business success, employment, and technological advance, even though it appears that the impact may be quite substantial. Nor did the study extend to a systematic assessment of the most effective means to transfer knowledge from centers to small businesses. Rather, what is provided is a framework for such an assessment and an indication of areas of strength and weakness in current efforts. A more extensive and systematic effort to collect such information is prerequisite to the formulation of sound policy in this area and is recommended.

I: Context for NSF Activity in the Knowledge Transfer Arena

"Knowledge or technology transfer" refers to a rather broad area of concern which touches on the basic and applied sciences but is clearly distinct from them. It is necessary at the outset of this presentation to set down some definitions which limit the scope of this report.

A. Definition of Terms

Four key terms require definition. These are: [1] knowledge or technology, [2] transfer, [3] NSF-supported centers and laboratories, and [4] smaller businesses.

1. Knowledge or technology is defined as:

all knowledge products derived from scientific and engineering research.

Any outputs from basic science which have potential value for industry could fall within this definition. These might include technical knowledge pertaining to processes, methods, designs, and products.

2. Transfer is defined as:

transmittal to new users and transformation into new products or processes with different and/or more widespread applications.

NSF's prevailing mission is to support the generation of knowledge and experimentation with its use. This report seeks to determine an appro-

appropriate role for NSF in facilitating the transfer of knowledge to industrial users. Such facilitation involves a partnership among NSF, academic researchers, and industry. Responsibility for development of new processes and products derived from scientific knowledge rests with these other partners and lies outside the NSF purview.

Transfer may occur by any and all channels including publication, distribution, patent licensing, demonstration, teaching, training, consultation, collaboration, etc. A key aspect of transfer is level of impact. Low-impact transfer events create user awareness of or interest in the technology but little more. High-impact transfers lead to substantial changes in the user's situation including innovation, improved productivity or efficiency, and increased profitability. High-impact transfers are most likely to occur when researchers and users work closely together on mutual interests for long periods of time. Many special efforts to improve technology transfer are aimed at increasing such higher-impact transfers.

3. NSF-supported centers and laboratories are defined as:

organizations supported by NSF awards in which numbers of scientists and/or engineers work together on research programs of long duration.

For the purpose of this report we have included centers with a wide variety of program objectives from several different NSF divisions. In some instances, the award has been made primarily to support the acquisition of equipment and facilities which are then made available to individual researchers or research programs. As will be noted subsequently, these centers and laboratories differ widely in their orientation to industrial affiliation and to technology transfer either to small or large business.

4. Smaller business is defined as:

any technically-oriented business with fewer than 1,000 employees.

This definition includes the standard definition of "small" businesses as those firms employing fewer than 500 employees, and "medium-sized" businesses as those employing between 500 and 1,000 persons. The definition also assumes that the enterprises are independently owned and unaffiliated with any other company whose employees would bring the combined total employment to more than 1,000.

"Technically-oriented" signifies those businesses which might be expected to benefit directly from the application of advanced NSF center research. There are at least three distinct types of small business which

fit this category. One is the start-up business in which researchers take a leading entrepreneurial role. Often the founding members of such enterprises are university professors or former professors. They are fully imbued with a basic understanding of the technology and what it can do, but may not have a strong grasp of such issues as marketing and business management. A second type is represented by small businesses which have established markets and/or manufacturing capabilities but might benefit greatly from an infusion of new technology related to their product line or their manufacturing process. Such companies may be short on in-house technical expertise and may have a difficult time appreciating the significance of new scientific and engineering developments from which they could profit substantially. This is the group that stands to benefit the most from active transfer efforts by the research community. Yet a third group represents the suppliers to the scientific community of specialized materials and customized equipment in lots too small to interest larger companies. This class of businesses has a strong motivation to stay in close contact with laboratories and centers which is somewhat different from the other two.

B. The NSF Role in Knowledge/Technology Transfer

The primary function of the NSF is the support of fundamental scientific and engineering research. Traditionally, the NSF role in knowledge transfer has centered on the provision of support for undergraduate and graduate training so that U.S. industry is continuously supplied with a highly skilled and technically sophisticated work force. Where work of an applied nature is supported, NSF funding tends to be restricted to the generic aspects of that work, i.e. research which does not lead directly to marketable products and services without considerable additional applied R&D on prototyping, testing, and manufacturing processes well beyond the scope of NSF support. This does not mean that there has been no transfer from NSF programs. On the contrary, NSF research has led to major technological advances in many fields which have contributed in a significant way to economic growth and national security. Such high impact transfers usually do not occur because of any deliberate effort by NSF to manage the transfer process. Rather, they occur through through pre-existing channels and mechanisms and through private sector initiatives.

During the 1970's NSF did develop an approach to transfer through the program entitled "Research Applied to National Needs" (RANN). Many RANN projects were designed to bring universities and industry together in joint activities, and although almost all the RANN programs were phased out by the late 1970's and early 1980's, they provided experience on what can be done in this arena. The current program of Industry-University Cooperative Centers is based on that experience. The 39 IUC's currently in operation give ample proof that NSF can act as a catalyst to leverage substantial industry support for research in many fields.

NSF's Small Business Innovation Research Program [S.B.I.R] is an important example of a program designed to promote technology transfer. Under authority of the Small Business Innovation Development Act of 1982 [P.L. 97-219], NSF sets aside a fraction of its budget for competitive awards to small businesses to conduct research on new technologies with a defined market potential. This program requires applicants to structure their work in three phases, the first two of which are eligible for NSF support and the third requiring full funding from other sources. In 1987 there were 152 new Phase I awards and a smaller number of Phase II awards. There have been numerous cases of commercially successful innovations emerging as a result of this program.

The S.B.I.R. program serves as an example in at least two respects. First, it establishes the fact that there is considerable small business interest in exploiting research opportunities, often in some form of collaboration with university faculty [about half of all S.B.I.R. awardees make use of university faculty as consultants performing fundamental research in the same field as the application]. Second, it sets a firm precedent for the use of public funds to leverage substantially greater amounts of private funding for technology-based commercial ventures.

A third case where NSF support has a technological orientation is in the Engineering Research Centers Program [ERC's]. The intent of this program is to provide substantial support for fundamental engineering research and education in selected areas critical for the competitiveness of U.S. industry. The ERC's have been structured in such a way as to encourage substantial industry involvement in the direction of research and education programs of each center as well as providing substantial financial support to that center. The ERC's thus far established have been very successful in attracting such industry involvement and support. However, since the first centers established are now only in their third year, it is too early to tell how well these arrangements will work in providing substantial high impact transfers.

II: How NSF Centers Now Promote Transfer to Small Business

Although NSF centers have not been focused on encouraging small business involvement, a survey of center directors and NSF center monitors specifically on this topic has turned up a wide variety of mechanisms whereby such involvement is already taking place. These activities vary enormously from center to center and from NSF program to program. Inquiries were made of most center-laboratory programs including the following:

- Engineering Research Centers [ERC's] of which there are now 14; six were entering their third year of operations in the fall of 1987;
- Industry-University Cooperative Centers [IUC's] of which there were 39 as of November, 1987;
- Materials Research Laboratories [MRL's] of which there are now nine;
- National Center for Atmospheric Research [NCAR];
- Supercomputer centers;
- Three astronomy facilities including the National Astronomy and Ionosphere Center [NAIC], the National Radio Astronomy Observatory [NRAO], and the National Optical Astronomy Observatory [NOAO].

A. Types of Centers and General Level of Activity Re Small Business

Center orientation to knowledge/technology transfer and to small business involvement varies with type of program and the ground rules under which different programs were developed. These differences result in varied approaches to transfer, affect the level of transfer activities, and even determine which types of activities are feasible or appropriate. Five types of differences should be noted: [1] explicit industry affiliation, [2] subject, [3] placement on the basic-applied continuum, [4] purpose, and [5] age.

1. Explicit Industry Affiliation

A major distinction should be made between centers which are encouraged to attract industry support and those which are not. The IUC's are actually structured in such a way that industry and other non-federal support will predominate, with NSF funding completely phased out over a five year period. ERC's are also expected to attract industry affiliates who will contribute a substantial but not necessarily a majority share of financial support. In contrast, MRL's, astronomy laboratories, and the NCAR receive the great bulk of their funding from NSF, and there is no

particular expectation that they reach out to the private sector for additional support.

2. Subject

The NSF centers and laboratories obviously differ widely in subject matter. It is likely that some subjects lend themselves to more private sector interest than others. For example, materials research would appear to have more industrial applications than astronomy research. It also may be that some subjects lend themselves to small business opportunities more readily than others. For example, the field of biotechnology currently appears to be attracting a very large number of small start-up enterprises. Such patterns may reflect the state of the technology as well as the subject matter per se. They may also reflect the extent to which an industrial infrastructure has already developed in relation to the application opportunities. In established materials areas such as steel, polymers, and ceramics, there are large-scale fully developed industry users with a major and long-standing stake in new developments. This does not rule out small business participation but it changes the nature of the game for the smaller actors.

3. Placement on the Basic-Applied Continuum

The application-orientation of the research field is also a factor which is likely to affect industry interest and potential for technology transfer in major ways. It is customary to think of R&D as a continuum from very basic research to applied research and product-oriented development. The primary NSF mission is support of the basic end of this continuum. Nevertheless, many of its centers do conduct some applied research which includes the development of prototypes or proof-of-concept demonstrations of new processes and materials. For example, the ERC's are intended to perform generic research in areas that are important for technological advancement. The further centers proceed toward the applied end of the continuum, the more potential there will be for transfers to both large and small business.

Opportunities for small business participation may be greatest at the most applied end of the continuum where application possibilities are most obvious and where return on investment is likely to come quickly. On the other hand, some small businesses may be in a better position to take advantage of early-stage findings because of greater flexibility, a greater

willingness to take risks, and a higher interest in exploiting small markets.

4. Purpose

The purpose of the laboratory or center is also an important factor affecting the ways in which it is likely to interact with small business. Some centers are established to conduct specific types of research, but others are organized as facilities which are then made available to the research community as a whole. A major NSF mission is to make available certain kinds of facilities and equipment which cannot easily be acquired in other ways. This includes various kinds of expensive and elaborate scientific equipment, very high speed computers, and so forth. Usually facilities are placed on university campuses and are intended primarily for use by university researchers, but use by R&D personnel from the private sector is also allowed because these facilities are intended for the general benefit of the society as a whole. Thus, facilities use was considered as a major category of potential small business involvement with certain types of centers.

5. Age

Finally, it may be important to consider the age of centers and center programs in viewing their potential for involvement with business in general and small business in particular. The newest centers are likely to be preoccupied with getting organized and getting their core research program going. For some of these newest centers, outreach to small businesses which offer little in the way of resources may be seen as an unwanted distraction. On the other hand, some older established centers may have difficulty taking on a new transfer role to small business, especially where they have already developed strong and long standing relationships with a few major industrial sponsors. Thus, the most promising candidates for small business activity may be those centers which are in their early established years, when they have developed a certain self-confidence and stability but are still open to developing new ways of relating to different types and sizes of industrial organizations.

B. Overview of Smaller Business Involvements by Type of Center

1. Engineering Research Centers [ERC's]

All ERC's must strive to involve industry in their research and educational activities. Such involvement takes many forms. Industrial personnel sit on advisory boards and help to set research and education goals. They are sometimes involved in joint projects. Some also teach courses and help guide the research of students. Although NSF has made no stipulation regarding how industry affiliations are to be organized, all ERC's have evolved fee structures for industrial affiliation which provide a substantial amount of financial support. Some charge a flat fee of between \$30,000 and \$50,000, which entitles the firm to a seat on the industrial advisory board, involvement in the research, and early access to findings. Other ERC's have tiered membership structures in which annual dues of \$100,000 to \$200,000 entitle participants to board membership, placement of technical personnel in residence, and joint projects which lead to early access to findings. Affiliates who pay fees in the range of \$25,000 to \$50,000 get a lower level of access and have somewhat less direct influence on programs. Affiliates at the lowest level may pay from \$2,000 to \$10,000 annually for publications, attendance at various meetings and workshops, and access to special briefings.

Unfortunately, such fees are sometimes prohibitive for some small businesses. Even when provisions for tiered affiliations as described above, few small businesses feel they can justify such outlays. One major exception is the MIT Bioprocess Technology Center which has strong ties to many small business and start-up enterprises.

Despite the small number of formal ERC affiliations with firms in this category, ERC's have many and diverse linkages with small businesses, and all of them will eventually have a potential for strong impact in this area. Each ERC is currently required to hold at least one open industrial meeting annually. This event represents one obvious access opportunity for smaller enterprises. However, connections to the small business world are also formed through a wide variety of mechanisms which are detailed in the next section of this report. Prominent among these are connections through state economic development programs and through various types of ad hoc joint endeavors.

2. Industry-University Cooperative Centers [IUC's]

Even though there are 39 IUC's with a seemingly large potential for involvement with small business, it is very important to recognize that IUC's are largely dependent on dues-paying industrial affiliates which are mostly very large companies. IUC's are reluctant to allow any special access to small businesses which might undercut the special relationship with major sponsors although some have sliding scale membership fee structures. There are a few instances in which smaller businesses have been helped by IUC's. This help is most likely to come either through informal channels or through the encouragement of state development agencies which are major contributors to some IUC's [e.g. the New Jersey Institute of Technology's Hazardous and Toxic Waste Management Center].

3. Materials Research Laboratories [MRL's]

The MRL's were originally established by the Department of Defense in the early 1960's in response to what was then seen as a major national need for improved materials science capability. However, in part because their work was of a very fundamental nature, oversight responsibility was transferred to the NSF in the early 1970's. The primary concern over the years has been to develop interdisciplinary materials research programs of high quality without regard to specific applications. These facilities are entirely supported by the NSF, and there has been little emphasis on formal industrial participation or co-sponsorship, either large or small. Access to MRL research is provided through collaborative research with MRL faculty members and groups, open meetings, and the published literature. In response to an inquiry from the Task Force, MRL directors were able to cite many instances of small business involvement. Collectively they report 145 visits from small businesses over the last year and involvement by about 75 small firms in meetings. Five MRL's report joint projects involving smaller companies. Four have ongoing relations with state development agencies through which many kinds of small business linkages can be made.

4. Supercomputer Centers

Recently, facilities were established to provide supercomputer access to university-based researchers. Involvement with small business has not been an objective of this initiative. Nevertheless, some activity involving smaller businesses has been reported, much of it encouraged and

facilitated by state economic development agencies. This includes visits and workshop attendance and some participation in joint projects with universities in which the smaller firm has some limited access to super-computer usage. All these Centers also have technology transfer offices, but these are not particularly oriented to small business. On the whole, the balance of such activity is on the larger business side.

5. The National Center for Atmospheric Research

In accordance with provisions of the Stevenson-Weidler Act of 1980 and the Technology Transfer Act of 1986, NCAR has created a full time position for a technology transfer officer. It also has an ongoing project with one small business and purchases equipment and services from a number of other small businesses.

6. Astronomy and Other Basic Science Facilities.

Very little direct interaction with small business is reported by any of the centers surveyed. Although small businesses generally have little interest in the output of these centers, relationships often develop in which particular small businesses are important developers and suppliers of specialized equipment needed in such research. Smaller firms are often in a better position than large firms to provide customized items in low volume. For example, the National Radio Astronomical Observatory estimates that 40-50% of its purchase awards are to small businesses. They also note two instances of start-up company spin-offs from their research.

7. New Centers and New NSF Center Initiatives

NSF has still more center-type initiatives either launched or in the planning stage. Among these are the previously mentioned Minority Research Centers of Excellence, and a new program of Science and Technology Centers. When initiated, the S&T centers will incorporate some of the same features of linkage to the industrial community as were required of the ERC's including industrial fellows, visitor programs, and other mechanisms for knowledge transfer. It is clear that many of these institutions have considerable potential for small business linkages of one kind or another, and they should be considered in the evolution of an NSF policy regarding overall center involvements with small business.

C. Mechanisms of Smaller Business Involvement with NSF Centers

There are a wide variety of ways in which involvement of NSF centers with smaller businesses can take place. In our review of these activities, we tried to develop a comprehensive listing of these mechanisms, dividing them into five types: [1] direct affiliations, [2] information sharing and educational activities, [3] joint projects, [4] involvement through third parties acting as mediators, and [5] special arrangements. It should be emphasized that these mechanisms are not all available to every center. Furthermore, most mechanisms are not mutually exclusive; a single instance of transfer might have involved several mechanisms. For example, a small business membership might be arranged through a special consortium arrangement facilitated by a state economic development agency, allowing access to print material, attendance at advisory board meetings, and leading to joint projects.

Some discussion of each of these categories follows.

1. Direct Affiliations

The most obvious way in which private industry can take part in NSF center activities is through paid membership in affiliate programs. Such programs have become increasingly frequent in the 1980's and have become a very successful way to leverage substantial amounts of industry support for fundamental as well as applied research programs. For example, ERC's and IUC's invite industrial participation through affiliate arrangements in which each industrial member pays an annual fee. In return for this fee, the company is awarded a seat on a research advisory committee and is given special and early access to the center's knowledge output in a variety of ways including publications, workshops, visiting fellowships, etc. This level of access can cost up to \$100,000 or \$200,000. Affiliation fees are almost always set at a much higher level than small businesses are willing or able to pay. Thus, with a few notable exceptions, small businesses not have gained much access to centers via this route.

Some ERC's and a few IUC's have set up two tiered memberships in which smaller businesses can participate in a more limited set of activities for a lower fee, usually one half of the full affiliation. Such reduced fees are still too high to attract large numbers of small businesses. A very few centers have arranged for more substantial fee reductions for small business. For example, the Ohio State University ERC

offers a \$2,000 small business membership which gives access to programs and publications but no affiliate voting rights. The MIT ERC has developed a consortium relationship especially to encourage small business access on an equal footing with larger businesses. However, it should be recognized that the success of NSF centers in leveraging industry funding depends in part on the promise of special opportunities for commercial exploitation of the research. Free or reduced cost access by small firms is seen by many centers as potentially undermining this leveraging strategy.

What a company gets for its affiliate dues is a package of linkage opportunities. Full membership always includes a seat on an advisory board and a vote on the direction that the research program will take. This provides the opportunity to steer research programs into areas of highest interest to those particular member companies, even though the work supported is of a generic nature. Full affiliates also have the opportunity to closely monitor research progress to the proof-of-concept stage.

Another offering included in the affiliate package is the live-in industrial fellowship which allows industrial personnel to get seriously involved in the research program. This would seem to be a potent conduit for technology transfer, but this option is rarely taken because companies are reluctant to "lose" their most competent people for such a long period. Other offerings include license-free use of patented technology [few patents are generated from such generic research in any case], pre-publication access to research findings, and invitations to attend closed workshops and conferences.

Perhaps the most important benefit to industrial affiliates is having a window on the talent that is represented in the students and faculty in the centers. Simply by being there, reviewing research proposals, listening to results, industry people become aware not only of the leading edge research that is going on but the people who are doing it. These people may later be hired as consultants or full-time workers on company projects of a more applied and directly profitable nature. In any case, the evaluators of IUC's report that industrial board members express very high levels of satisfaction with the programs and full contentment that they remain at the generic level.* Small business entrepreneurs might not be quite as content supporting work with only long term pay-off.

*Gray, Denis O., Hetzner, William, Eveland, J.D., & Gidley, Teresa. "NSF's Industry-University Cooperative Research Centers Program and the innovation process," in D.O. Gray, T. Solomon, & W. Hetzner (editors) Technological Innovation-Strategies for a New Partnership. North-Holland: Elsevier Science Publishers B.V., 1986

2. Information sharing

There are a number of ways in which small and medium-sized businesses can receive information from NSF centers. While the numbers of smaller firms served in this way may look fairly impressive, it should be pointed out that information sharing usually leads to low-impact transfers such as awareness, interest, and some technical understanding. On the other hand, such information sharing is often the first step towards more serious forms of collaboration.

About one third of the ERC's are already able to report considerable information sharing with small and medium sized businesses through a variety of channels. Such involvement varies depending on the field of research and on length of time the center has been in existence. The ERC's which report the most information sharing to industry in general are those that have been in existence the longest. Since even these centers are very new, we would expect the rates of industrial participation to increase still further in the ensuing years.

Regarding the focus area of the research program, some topics seem to be more attractive to small business than others. It is clear, for example, that biotechnology is seen as a major opportunity area for small start-up enterprises, and high participation rates at the MIT Bioprocess ERC reflect this. Centers focussed on fundamental technologies in a number of other areas may be of most initial interest to larger firms which have the capacity to do their own parallel application-oriented research. Opportunities for smaller firms may only become apparent when the research programs have led to full proof-of-concept demonstrations and prototypes. University-based research does not usually extend as far as prototype development.

a. Publications and other print distribution

All NSF-supported centers make most of their publications available to any interested parties as part of the general body of publicly accessible scientific literature. Many centers also have newsletters which are distributed to affiliates and others. For newsletter mailing lists, the MIT ERC reports about 50% small business, for the Ohio State ERC, 40%, and for the Maryland ERC, 25%. Other ERC's report small business representation on their mailing lists between 5 and 10%. Two MRL's also report significant distribution of their newsletters to small businesses.

Access to technical publications may be very important for some types of small firms but not be very helpful for others. Some small start-up

enterprises are founded and staffed by highly skilled researchers with an entrepreneurial bent and with a view to a market niche which is highly technical and highly specialized. Such entrepreneurs really have a colleague status with the university researchers and many are former or part time academics. In some cases they will value the research being developed in a center to such an extent that they will pay for full affiliate status. For another and probably much larger group of small businesses, having access to the published research will not be enough for intelligent and profitable utilization. Many small businesses which might have relevant production capabilities and entrée to markets may lack the scientifically-oriented technical personnel who can read and interpret the findings in ways which will benefit the firm. This is a general problem with publications oriented to the scientific community, but it falls most heavily on many small firms with limited internal resources to absorb and interpret the knowledge as given. .

b. Clearinghouse and special information service functions

To overcome some of the problems inherent in the practical utilization of knowledge from scientific publication, it is possible to create various kinds of information services to select and interpret such information in user-relevant categories. Providing such services can be expensive and time-consuming; few examples of this kind of activity can be cited.

Two ERC's specifically mentioned clearinghouse activities as an area which could give special advantage to small businesses. The UC-Santa Barbara ERC Director noted that small businesses need adequate access to information sources more than do large companies. For that reason the UCSB ERC provides information services for a nominal fee. The Maryland Center Director reported that his ERC is also developing a special clearinghouse function which should help small businesses. The IUC's provide special information access to their major industrial sponsors and are very reluctant to develop arrangements for more general information access as early access is one of the incentives for membership.

c. Visits

Visits represent the most frequent type of direct contact between centers and smaller businesses. For the most part, visits are informal events involving one or two persons. We should also include in this category the reverse phenomenon of center researchers or staff visiting small business sites.

Three ERC's report a substantial volume of small business visitors, led by Purdue with about 500 individuals from 200 companies. MIT's Bioprocess ERC reports 150 visitors from about 60 companies, representing 60% of total visits. Two other ERC's report that about 30% of their visitors are from small businesses.

MRL's also report a stream of visitations from small businesses, estimated at 145 over the last year for eight MRL's. No estimate was provided of what percentage this represents of total visits.

Five ERC's also report a significant number of visits by faculty and students to small businesses in their region. Lehigh leads in this category with visits to 45 firms. The Purdue ERC reports visits to 20 and the Maryland Center to 15. The MIT and Ohio State ERC's each report about 10 such field visits.

d. Open meetings and conferences

Each ERC holds one open informational meeting for industry each year. All ERC's report some small and medium sized business participation in such meetings. At MIT's Biotechnology Center a majority of participants are in this category, some 500 individuals representing 150 companies. The Maryland ERC estimates small business attendance at about 100 persons from 40 companies, 25% of their total. The Lehigh ERC indicates that 90% of their industrial meeting attendees are small businesses. Two other centers report small business attendance rates between 30 and 35% and the remainder indicate rates of 5 to 10%. Five MRL's also reported a significant presence of small firms at industrial meetings with an estimated total of 75 companies represented or an average of 15 per meeting.

e. Workshops and courses

For those with industry affiliation programs, participation in workshops or courses may be one of the members-only privileges. The most small business activity in this category is reported by the same three ERC's which lead in other categories of information sharing. The MIT Bioprocess ERC's workshops draw roughly half their attendance from small or medium sized businesses, about 80 persons from 20 firms. Likewise about 35% of that Center's courses have small-business enrollees, about 200 persons from 60 companies. The Maryland Center reports 40% of course enrollees in this category, estimated at about 100 persons from 30 different firms. Purdue reports about 10% small business participation in

both course and workshops. The UCLA Center estimates that as many as 100 small businesses are served through their educational extension program.

f. Facilities access

Being able to make use of expensive testing, computing, or analytic tools and facilities can be a very important resource for the small technically-oriented firm. In principle all such equipment and facilities funded by NSF are available to any legitimate users in the private sector although access is controlled by the university centers in which they are located. This may be problematic for many small firms since universities reserve primary access to university research and are more likely to provide private sector access to larger firms, especially those with which they have affiliate status. Several small businesses are reported to have time allocations at one or another NSF supercomputer center and others can gain access through procedures established by each center. In general, however, centers such as the MRL's which do have well established facilities are understandably reluctant to open their gates to all and sundry users because they have neither the time nor the space to accommodate large numbers.

3. Joint projects with small and medium-sized businesses

The most likely way in which small businesses will receive sustained and substantial transfers from NSF centers is through joint projects. At least 10 centers within the ERC group already have such joint projects under way with one or more firms in the small business category, and all ERC's are actively considering such possibilities. While the actual numbers are small so far, it is clear that all centers have this capability. We would also expect that small business joint project opportunities will mushroom as technologies mature and as some students and professors who have worked on successful projects begin to perceive market opportunities related to their discoveries.

Among other types of centers, joint projects are less commonly cited as typical forms of interaction. Three MRL directors reported such activity as ongoing and two others indicated that some such projects were being initiated. Some MRL research has also led to patents which have been licensed to small businesses.

4. Involvement through mediating agencies

NSF center-small business interactions take place in a larger social environment which has become markedly more complex in the last decade. Many new organizations have come into being with the explicit purpose of aiding or promoting economic growth or productivity in one sphere or another. Some are governmental, some private, and some represent a mix of private and public cooperative efforts. There are a number of ways in which these new organizational forms can facilitate small business development. Many NSF centers have made use of more than one of these facilitating mechanisms to increase small business participation, and ERC's have been particularly active in this category of involvement. There are at least four important types of third party facilitation organizations. These are [a] state and local economic development organizations, [b] trade associations, [c] large businesses acting as umbrella organizations, and [d] other federal programs.

a. State, county or other local economic development organizations

The 1980's has seen a tremendous growth in regional, state and local development agencies, many with an R&D emphasis, and many with a mandate to concentrate some of their efforts on the creation and support of small businesses. Because of their high technology emphasis, many state programs gravitate to NSF centers and are sometimes instrumental in the founding of such centers. State and local government funding has been particularly important for the continuance and growth of the Industry-University Cooperative Centers which now receive three times as much of their support from these sources as they receive from the NSF. Although ERC's do not depend on state funding, nine have already established some relationship with a state or local government development agency and four more are actively considering developing such ties. Four MRL's report such ties and three others have them under active discussion. The states of Illinois, California, and Pennsylvania actively promote and coordinate visits to their supercomputer centers, but the total of such visits is estimated at under five per year per center. Thus, state and local development agencies are important partners in NSF center activity and a significant potential avenue for technology transfer.

The fact that such ties are common does not mean that they are important as far as the intensity of small business involvement is concerned. In spite of heavy state involvement, the IUC's have had relatively few small business interactions in a direct sense. Thus, IUC

staff often interact with small businesses but do so through state or university-state programs not directly connected with the IUC. The availability of such organizations as well as their emphasis also varies from state to state so that their potential in relation to small business involvement will sometimes be great, sometimes only marginal. Some states such as Indiana and Pennsylvania have development organizations with a strong small business orientation. The ERC's in those states tend to see a high potential for using this mechanism to enhance small business participation. For example, the Purdue ERC estimates that some 200 small firms have become involved through Indiana's small business-oriented Technical Assistance Program (TAP). Overall, MRL and ERC directors rate the potential of these state-local relationships for the enhancement of small business contacts as moderate to high.

b. Trade or industry associations

Trade or industry associations which have a large small business membership should in theory be a good vehicle for widespread sharing of new technologies, but most NSF centers have minimal contacts in this direction. IUC's do not encourage trade association affiliations for fear that they would minimize the incentive of larger companies to have separate memberships. Only one of the nine MRL's has considered trade association affiliation, and the astronomy centers have no such ties. The ERC's present a distinctly different picture. Six centers reported that they have established ties to one or more trade associations, and three more have discussed the possibility of ties. Four others have not yet considered this option.

For those ERC's which have developed such relations, the numbers of small businesses reached thereby seem rather impressive: in one case more than 500, in another more than 150, and in another about 50. On the other hand, the types of involvement engendered may not be very intense. In some cases the association tie provides companies with "awareness" of what the ERC is doing. In other cases it leads to workshop attendance, distribution of ERC reports, the donation of company equipment to the center, and at one or two centers it has also led to joint projects. Future potential of this mechanism was rated by four directors as "high," by four others as "medium," and by one as "low."

c. Large businesses as facilitators of small business involvement

Another potential avenue for small business involvement is through connections to larger businesses who are members and who may want to pass on the technology through subcontracts, joint ventures, and other means. Some centers in each category noted such relationships but few ascribed any importance to them. For example, five ERC directors affirmed that such connections do exist, but five others reported that they were not aware of any such indirect ties involving small businesses. The Purdue Center reports several such connections, and the Ohio State University Center notes that two of its major affiliates now encourage their subcontractors to join the ERC. Nevertheless, none of the center directors was ready to rate this path to small business involvement as having high future potential. Four rated it "medium," three, "low;" two were not sure and four gave no rating at all. MRL's gave this mechanism similar marks. Two were aware of such connections, four were not. One rated the potential as "high", three "medium" and one "low."

d. The Small Business Innovation Research Program [S.B.I.R.]

Grant awards under the Small Business Innovation Research Program represent yet another potential avenue for indirectly supporting small business involvement with NSF centers. There is nothing to prevent either SBIR awardees from affiliating with centers or center scientists from allying themselves with small businesses to pursue such awards.

e. Other federal programs

There are a large number of R&D programs sponsored by other agencies of the federal government which to some extent overlap NSF center programs. In sum total, such programs actually dwarf NSF in total dollar funding. Because most of these other initiatives are more applied in nature, they may represent an additional bridge for industrial involvement and technology transfer. Although such interactions are rarely mentioned by NSF center directors or monitors, it seems very likely that they are ubiquitous and that they offer special opportunities for small business. This is an uncharted region.

5. Special Transfer Arrangements Targeting Small Businesses

Because knowledge and technology transfer is a complex process both in a social and a technical sense, it is supported in many fields by a complex infrastructure of special roles arrangements. U.S. agriculture probably has the most elaborated transfer system in the Cooperative Extension Service but transfer structures have also been established for aerospace technology [the NASA TU Program], for education, and for some other special areas. In the early 1970's NSF also experimented with new facilitative arrangements and mechanisms oriented to various public needs and a few of these continue to exist long after NSF support has been withdrawn. The Technology Transfer Act of 1986 endorses much of this infrastructure development and specifically sanctions the Federal Laboratory Consortium to take a lead role in furthering the dissemination and use of R&D emanating from federally-funded programs.

Without taking a position on the pros and cons of any particular mechanism, we have attempted to lay out some alternatives within this realm which might have some relevance to facilitating transfer of technology from NSF-supported centers to small business.

a. Special technology transfer role

The major innovation in this arena has been the special technology transfer office or officer for whom the archetype is the agricultural "county agent." Some of the NSF centers have taken the step to appoint an individual to carry forward the transfer mission. NCAR, as a national laboratory, is required to have a tech transfer agent on staff. The supercomputing centers also have technology transfer agents and one of the three astronomy facilities has one. However, none of these is designated to pay special attention to small business. Among the MRL's, one has a full time transfer agent and two others have part time agents. The remaining six have not considered the possibility of having one. Similarly, most IUC's have incorporated no such role because their member companies have not asked for it.

Nine of the 14 ERC's now have a staff member assigned specifically to tech transfer duties. At four ERC's this is a full time position. For the five others it is a significant part of someone's duties. Two additional centers have such a role under active consideration, and two have not yet considered having one. Of those eight who have a tech transfer officer, three have thus far put special emphasis on small and medium-sized business involvement.

Two ERC's indicated that the tech transfer officer was engaged in setting up arrangements with state development organizations, trade associations, and special programs within the region which would involve a number of small businesses. Others indicated that the tech transfer officer developed innovative educational and communication mechanisms, set up meetings, and performed miscellaneous other tasks designed to stimulate more active dialog with affiliates and others generally.

Having a tech transfer officer was seen as a mechanism with "high" future potential for advancing transfer to small and medium-sized businesses by four ERC directors, whereas five thought it had "medium" potential and two others were uncertain. Among MRL's only one gave this option a "high" rating and four others a "medium."

b. Small business consortia and consortia-center affiliations

If smallness as such is a problem, an obvious solution might be to combine forces to make a larger entity. Simple as that concept seems, it has not been a common path to small business involvement in NSF-supported centers. However, there are a few examples of small business consortia such as one developed by MIT's Bioprocess Technology ERC. The consortium arrangement provides a group of small businesses the same level of access usually accorded large firms which are assessed large membership fees. The MIT case suggests that models of collaboration in this form will work if given the right situation and a modicum of encouragement. Acceptance of these special arrangements may also hinge on the type of knowledge/technology being developed, the competitive structure of the field, etc. Some such collaborations are facilitated by state development programs, some by trade associations, and some by larger companies.

c. Small business development organizations

Another phenomenon of the 1980's has been the growth of new organizations specifically designed to assist the start-up and early nurturing of new businesses. These include consulting services, small business incubators, venture capital locating services, and so forth. Many of these are located on or adjacent to university campuses or established as special university units. Many are supported directly or indirectly by the state development agencies already discussed above. NSF asked center directors if they had ties to such organizations, and found that both formal and informal connections were widespread. Among MRL's, five reported

formal ties, another had informal ties, and two more were considering ties. Five ERC's also reported formal ties to at least one such entity. Two others reported informal ties while three more have been discussing the possibility of developing such ties. The potential of such mechanisms was rated "high" by two ERC's and one MRL. Three other ERC's and three MRL's rated such mechanisms of only "medium" potential.

This list does not exhaust the possibilities for special arrangements to help small businesses benefit from NSF-supported laboratories and centers. What should be emphasized is the variety of efforts that have already emerged and the clear willingness of many centers to experiment with innovative modes of industry and small business involvement to maximize the impact of their programs.

III: Recommendations

The preceding limited review serves to point out two facts. First, there is already a considerable amount of ongoing activity linking NSF centers and laboratories to small and medium sized businesses. Second, the ways in which such linkages take place are extremely varied. In proceeding to make recommendations, it will be important to keep both of these facts in the foreground. It is desirable to build on what has come before and to take advantage of trends which are already apparent.

In making recommendations, we should also note the fact that not all centers have equal potential for transferring knowledge to small business. Some are better positioned by subject matter, size, and program maturity to play an important role in this area. The ERC's are the most actively involved with small business users for a variety of reasons: they have an engineering rather than a basic science focus; their substantial NSF and state funding base frees them from heavy dependence on large industry contributions [in contrast to IUC's which have a smaller funding base and are clearly dependent on industrial contributions]; their status as a young program brings a certain amount of flexibility and willingness to experiment with organizational forms and arrangements. Other types of centers share some of these attributes and a few may have some special advantages in regard to relating to small businesses which ERC's do not have. Nevertheless, there is a roughly definable scale of applicability of any new measures that might be developed to encourage small business interactions.

A. Current trends

It is useful to start the recommendation process with consideration of what would happen without any additional initiatives from NSF. It is clear that the nation as a whole is mobilizing in various ways to meet the challenge from other industrialized countries. More and more businesses, large and small, are coming to realize that more effective ways must be found to utilize basic knowledge for industrial innovation. Many firms have banded together in new R&D consortia, and many states have begun to invest substantial sums in economic development efforts. State efforts are often implemented through universities which are also the recipients of NSF center support. Various branches of the federal government other than NSF are also actively involved in supporting new mechanisms, some of which are advantageous to the development of smaller businesses. The Congress has also passed legislation which explicitly encourages transfer activities including those of the Federal Laboratory Consortium.

In short, there is an emerging technology transfer infrastructure which will continue to expand with or without active NSF participation. Many of the existing centers are taking rather creative advantage of these developments to enhance their transfer capabilities and a significant fraction of these benefit small business directly. Even without specific NSF encouragement, these trends will continue for the next few years at least. Nevertheless there are specific steps that can and should be taken to strengthen the connection to smaller businesses.

The following proposal for increased NSF encouragement of knowledge/technology transfer from centers to smaller businesses rests on three observations. First, such firms have a strong role to play in innovation and technical employment. Second, effective transfer to a broad spectrum of firms will require special measures on the part of NSF and its centers. Third, such initiatives were not envisaged when current center funding levels were set. Thus, only modest enhancements of linkage to small business can be made within existing budget limits. A significant extension of the center role into this realm would require augmented support. It should also be re-emphasized that any NSF initiatives on transfer must be of a catalytic nature, designed to enhance the partnership among centers, state and local governments, and the small business community.

B. Additional Administrative Encouragement [Recommendation # 1]

NSF will encourage many kinds of activities through suggestions to centers or through other administrative measures which do not require augmentation of center budgets by NSF and do not in any way subvert the basic scientific and engineering missions of the centers.

- reporting requirements

NSF center programs will now put knowledge and/or technology transfer requirements in proposal guidelines and request more extensive and detailed routine reporting on activities in relation to transfer to small business. At present the ERC program has these requirements for technology transfer in general. A number of small business contacts have evolved out of these activities and as a natural consequence of centers' evolution. More such activities will be encouraged by adding a regular reporting requirement on small business transfer activity per se.

- inter-center information sharing

Because many centers have experimented in one way or another with different mechanisms of involvement of smaller businesses, it is now time to start sharing these experiences, heightening cross-center awareness of alternatives, and developing a support network among centers for further initiatives, as the ERC program now has started to do through its annual center directors' management meeting.

- encourage cooperative efforts within the local environment

Most NSF-supported centers are located on university campuses where there is a great deal of activity going on in support of large and small business interactions. Some NSF centers are much more active in linking to these activities than others. NSF will encourage more active linkage by requesting annual reporting on what specific activities have been undertaken. Such encouragements will also be made informally by NSF center monitors.

- encourage linkage to other local/state/national networks and resources

There is an evolving national infrastructure for supporting technology transfer generally and within specific fields. Every trade association in a

technology area represents such a network as does the Federal Laboratory Consortium, the IEEE and its many affiliated interest groups, and numerous state and regional entities. Many of these actively encourage small business involvement and others represent low-cost channels of access to technical information which are compatible with small business capabilities. Centers will be encouraged to become more aware of opportunities of this type and to establish links to those networks that are especially relevant to their own fields.

C. Special Financial Incentives [Recommendation #2]

NSF will consider providing special financial incentives to promote smaller business involvement with NSF centers or to promote their use of research output. Such action might include support for: [a] full or limited industrial affiliate memberships, [b] small business participation in workshops or courses, [c] trade associations, large businesses or other third party entities to encourage consortia-type small business affiliations with centers or [d] joint projects.

Direct support for industrial affiliate memberships is not recommended because of the potential high costs and difficulties involved in determining eligibility requirements. It is also difficult to determine a priori what small businesses would truly benefit from affiliate status or from attendance at what sorts of workshops and conferences. Supporting larger entities like trade associations or major companies is probably inappropriate for NSF, especially since some of these entities have shown that they are capable of supporting their own initiatives. This is also an area in which state programs are active, and there is no reason for NSF to duplicate state efforts. On the other hand, NSF can provide encouragement and applaud the efforts of centers which make the most of such opportunities [as indicated in Part 'B' above].

The one type of support which seems to have high potential is for specific small business cooperative projects. It is therefore desirable to establish a special fund for joint projects with small and start-up businesses which want to exploit the commercial possibilities emanating from NSF center research. Such projects would be funded by NSF on a competitive basis and would have to meet with the approval of the industry advisory boards of each center. However, no such program of incentives can be provided unless NSF has additional financial resources made available for this purpose.

**D. A New NSF Center Program for Innovative Linkages to Small Business
[Recommendation #3]**

It is clear that there have been a number of creative efforts undertaken by particular centers to enhance small business involvement. In order to encourage more such efforts and to take full advantage of this diversity, NSF will consider a new program of supplemental awards to centers which propose special arrangements or mechanisms for this purpose. Within fairly broad guidelines this program will be field-initiated. The nature of each proposal will be the responsibility of the proposing center, reflecting their diversity and the diversity of opportunities available to them by reason of geography, topic, etc. Proposals can cover any of the areas reviewed previously in this report under "mechanisms" and might include:

- special types of publications, technical data base services or information clearinghouse activities targetted to small business,
- special conferences or workshop series for small business
- special forms of program participation for small businesses,
- installation of small business-oriented technology transfer agents or offices,
- programs for center-linked small business development units such as business incubators or consulting services.

The awards program would be competitive across all center programs. Individual projects and the program as a whole would be cast in an experimental mold with built-in evaluations at specified intervals. Projects would also be required to build in graduated cost sharing with other sources to the point where self-renewal without NSF funds is projected. This recommendation, like recommendation #2, cannot be implemented unless additional financial resources are made available.

In summary, we envisage a three-pronged initiative to enhance small business involvement with NSF-supported centers and laboratories. First, with no significant budget increase, we will encourage increased collection and sharing of information on small business interactions among centers. Second, with a significant budget increase, NSF will consider initiating a program for center-oriented small business collaborative projects. Third, with the same proviso, NSF will consider initiating a new program of competitive supplemental awards to centers for innovative mechanisms to enhance their interactions with small business in order to facilitate knowledge and technology transfer and use.