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Inter-Institutional Decision Making in the Technology Transfer Process: Some Preliminary Issues in the Evaluation of ORNL's High-Temperature Superconductivity Pilot Center

D. L. Feldman

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ORNL/TM-11139

Energy Division

INTER-INSTITUTIONAL DECISION MAKING IN THE TECHNOLOGY TRANSFER PROCESS: SOME PRELIMINARY ISSUES IN THE EVALUATION OF ORNL'S HIGH-TEMPERATURE SUPERCONDUCTIVITY PILOT CENTER

David L. Feldman

Date Published: September 1989

Prepared for
the Oak Ridge National Laboratory
Technology Policy Center

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
Operated by
Martin Marietta Energy Systems, Inc.
for the
U. S. Department of Energy
under Contract No. DE-AC05-840R21400

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ABSTRACT

Many activities are taking place at Oak Ridge National Laboratory (ORNL) to expedite the transfer of commercially viable technologies to the private sector. Moreover, the technology transfer process has various mechanisms for achieving its goals. Some of the means by which technology may be transferred from the laboratory include technical publications and research reports, workshops, licensing of inventions by the U.S. Department of Energy (DOE) operating contractor for the laboratory, Martin Marietta Energy Systems, Inc., (MMES) and personnel exchanges and cooperative agreements between the laboratory, industry and universities. While each of these mechanisms has its advantages and drawbacks in achieving the transfer of valuable technologies to the marketplace, this report will focus upon the transfer of patentable technologies for which DOE has waived its rights to MMES for the licensing of inventions. This particular mechanism is expected to play a significant role in the operation of the High Temperature Superconductivity (HTSC) Pilot Center. The HTSC Pilot Center is a recently chartered effort designed to encourage rapid incubation and commercialization of HTSC technologies. The success of this venture will hinge upon (1) assuring compatibility of objectives between the center and likely industrial participants and (2) directing center efforts toward the aspirations of potential collaborators and the ultimate consumers of HTSC technologies and processes.

The purpose of this study was to identify factors at DOE headquarters, Oak Ridge Operations, MMES, and ORNL likely to influence technology development efforts in HTSC. This information can be used in conjunction with other studies to eventually establish a multiobjective evaluation protocol for assessing the Pilot Center's effectiveness. Lessons for general multiprogram laboratory technology transfer efforts are also elucidated.

We conclude that technology transfer and development efforts taking place within the HTSC Pilot Center can be optimized by an "open" model of collaboration that emphasizes informality, facilitates the streamlining of information vital to the cross-fertilization of ideas, and reduces bureaucratic barriers to industrial/academic collaboration with ORNL scientists. Many of these characteristics of openness are already taking place in other technology transfer activities at the laboratory.

Major considerations in the evaluation of this process should include (1) realistic commercialization expectations, (2) appropriate reforms of licensing and royalty-sharing processes, (3) facilitating research staff collaboration with external constituencies, and (4) viewing the HTSC Pilot Center as a catalyst that blends intellectual talent by simplifying the process of scientific collaboration.

ACKNOWLEDGMENTS

I would like to extend my appreciation to the following individuals for their reviews of an earlier draft of this report and for their comments, criticisms, and suggestions. From the Energy Division, Oak Ridge National Laboratory, I wish to thank Martin Katzman and Rajeev K. Goel. From the Office of Technology Applications at Martin Marietta Energy Systems, I wish to thank E. Jonathan Soderstrom. From the High Temperature Superconductivity Pilot Center, I am grateful for the comments of Anthony Schaffhauser and Louise Dunlap. And, finally I appreciate the suggestions of Robert Poteat from the Office of Patent Counsel, U. S. Department of Energy, Oak Ridge Operations.

All errors of fact and interpretation are borne by the author alone. Moreover, nothing in this report should be construed as being officially endorsed by either Martin Marietta Energy Systems, Inc., or the U. S. Department of Energy.

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1. INTRODUCTION

This report illuminates the decision-making processes affecting technology transfer at ORNL as they potentially impact upon development of high-temperature superconductors. The methodology of this report consists of an analysis of Oak Ridge National Laboratory (ORNL) documents laws, and regulations; a review of relevant literature on licensing, patents, and user center decision making; and interviews with persons directly involved in technology development and transfer at the laboratory. The process of technology development at ORNL encompasses, among other things, activities aimed at research and development (R & D), technology transfer, and technology utilization. Each of these activities has officially become part of an overall laboratory mission referred to as technology development.

The purpose of this report is to identify factors at the U.S. Department of Energy headquarters (DOE), Oak Ridge Operations (ORO), Martin Marietta Energy Systems, Inc. (MMES), and ORNL likely to influence the technology development and transfer efforts of the recently chartered High Temperature Superconductivity (HTSC) Pilot Center. This center was established to "collaborate with industry in advancing high-temperature superconducting technologies" to encourage their rapid incubation and commercialization (Draft Implementation Plan—HTSC Pilot Center 1988).

This information will be used in conjunction with other studies to establish an evaluation protocol and to proceed with an in-depth study of the Pilot Center to assess its effectiveness in this collaborative process. After examining the varied commercialization expectations of different laboratory-related sectors, this report analyzes the probable impact of current technology development policies on HTSC activities.

1.1 TECHNOLOGY TRANSFER AT ORNL: COMMERCIALIZATION EXPECTATIONS OF RELEVANT SECTORS

Many activities are currently taking place at ORNL to expedite the transfer of commercially viable technologies in the area of high-temperature superconductors to the private sector. While animated by several concerns, they all hinge upon an effort to increase American competitiveness in an increasingly interdependent global economy (Kash 1987; Soderstrom 1988; Soderstrom et al. 1985; Charles 1988).

Despite ambitious strides in the physics, chemistry, and engineering of high-temperature superconductivity, institutional progress in and applications of high-temperature superconductivity have been slower to implement than basic R & D. Contrary to assumptions held in some quarters, technology transfer is not a mechanical process that automatically follows scientific invention or discovery. It is an "organic" process of decision making that must be consciously nurtured through interaction of all the parts of an R & D organization (Chanaron and Perrin 1987). Moreover, because of constantly changing market structures, business cycles, adoption costs, and user expectations, public sector and private sector cooperation in this decision making process must occur to ensure its success (Curlee and Goel 1988). Suggested in the conclusions of this report, it may also be necessary to provide incentives to some parts of an R & D organization to encourage this process.

Technologies rely upon both invention and innovation. While the former encompasses basic research leading to product development, the latter entails a complex process of combining research discoveries with unique, new, or previously unused ideas or methods. It also involves the testing

of prototypes. The goal of invention and innovation is to produce a commercially viable invention that is lower in cost and higher in quality, and which exhibits performance superior to its competition (Kash 1987).

1.1.1 The Technology Transfer Process at ORNL: Some Possible Impacts upon High-Temperature Superconductivity Developments

As is characteristic of any complex organization, the various components of the greater ORNL community bring different expectations to the task of technology development. For the success of the HTSC Pilot Center, it is essential that these different expectations (1) be compatible with each other and with the aspirations of likely industrial participants; (2) reflect predictable, long-term commitments that each participant is prepared to contribute to the process of technology transfer; and (3) be directed toward meeting the needs of potential users, both pilot center collaborators and the ultimate consumers of superconductive materials and processes.

Each part of the ORNL community professes explicit standards, goals, and aspirations. Collectively, these standards, goals, and aspirations constitute a "statement of purpose" that serves as a means of evaluating the organizational outcomes of the pilot center (Babbie 1989). This "statement of purpose" constitutes the basis for suggesting possible evaluation parameters in the conclusion of this report.

DOE, ORO, MMES, and the research and supervisory staff of ORNL are strongly committed to the commercial success of high-temperature superconductors. Although these commitments are compatible, it has been found that expectations and other evaluative concerns vary in important ways.

1.1.2 DOE Expectations: Patents, Licenses, and Likely Evaluation Concerns

DOE is a mission-oriented agency. The development of technologies by its national laboratories is viewed, in part, as means of achieving this mission. Technology development cannot be left totally to the private sector because government may want to focus the direction of the research toward public goals not fulfilled by the marketplace. The principal reason that DOE has established technology transfer programs at each of its major national laboratories is to determine the most effective routes for commercialization of energy-related technologies. To assure that public goals are fulfilled by these programs, DOE exercises audit and oversight control to evaluate the success of technology transfer. In turn, national laboratories have agreed to bear the primary responsibility for technology transfer and have subsequently established licensing activities designed, for the most part, to achieve this objective. For example, the HTSC Pilot Center is designed to facilitate the development of a complex technology thought to be of considerable value to the attainment of several nationally important objectives, including strategic defense (magnetic shielding); energy conservation; electric power generation and transmission; and computational technologies (e.g., high-speed signal processors). At the same time, however, DOE and others readily concede that high-temperature superconductivity is a complex, continually evolving phenomenon—for which commercialization cannot be expected soon because of barriers to the chemical stability, current carrying-capacity, and brittleness of superconductive materials, as well as other engineering problems (Vreeland 1988; Hazen 1988; "Initiative for Research" 1989).

As a consequence of this mission and the complexity of high-temperature superconductivity, evaluation of Pilot Center effectiveness by DOE will at some point be gauged by criteria extrinsic to the science itself. That is, justification for continued support and nurturance of the Pilot Center

will likely lie in what Alvin Weinberg (1988) terms "external criteria" the utility of scientific activity in this field to other social and technological sectors. DOE will evaluate the center partly in terms of how readily commercial devices are patented, licensed, and commercialized. On the other hand, it appears likely that DOE will also evaluate the center in terms of how effectively users perceive the benefits of their interactions with it—whether commercial devices emerge soon or not. This is because even patented technologies often take extraordinary effort on the part of licensees to bring them to the point of commercial application (U.S. GAO 1986). In other words, patenting alone does not assure technological diffusion because the task of developing a technology may entail significant costs to acquire information and to achieve adoption. Also, many products can be commercialized without patents or licensing. This can occur by relying upon unique processing capabilities and trade secrets.

I would contend that the HTSC Pilot Center will derive greater benefit from stressing the latter set of factors (user benefits leading toward ultimate commercialization) rather than commercialization itself, because expectations of patents leading to licenses and subsequent commercialization cannot, now, be set too high. If a technology proves to be useful, it will likely be commercialized on its own, subject to information constraints about its potential. On the other hand, a hard and fast timetable cannot be made for this process. One of the best ways to encourage technology transfer through the Pilot Center is simply to encourage the interaction between research staff from ORNL and industrial sponsors. In essence, the Pilot Center should be viewed as a catalyst that blends intellectual talents through simplifying the collaborative process.

No general agreement between program managers and legal staff exists within DOE headquarters, or within operations offices, over the best method of transferring technology from national laboratories to the commercial marketplace. Also, significant differences in philosophy concerning how this process should work exist among different national laboratories. Currently, two broad systems for transferring technology are in place at DOE laboratories. The first approach encompasses national laboratories managed by for-profit contractors, and the second approach applies to those managed by nonprofit contractors such as universities. In the management of technology transfer from both types of laboratories, there is concern that these technologies not be transferred to the private sector in a way that would compromise DOE's perception of the public interest in preserving government-developed intellectual property. In no area are these differing philosophies greater than in possible inventions emanating from the HTSC Pilot Center. DOE wants to hasten the waiver of patents to the operating contractor and, ultimately, to the industrial user—a process permitted as a result of recent reforms in patent law (Cheston 1987; U. S. DOE 1987). However, there is a reluctance among some within DOE (and especially ORO) to be bound entirely to an assessment of commercial success that relates commercialization to the granting of patents from high-temperature superconductivity R & D. This is due in part to the concerns about the likelihood of commercialization and the recognition that the pilot centers cannot succeed if bound too closely to rigorous quantitative assessment (U.S. GAO 1986).

1.2 PATENT POLICY CHANGES AFFECTING THE TECHNOLOGY TRANSFER PROCESS

Legislative changes initiated by Congress, as well as suggested modifications by the Office of Management and Budget and the GAO, have led to reforms designed to accelerate the transfer of technology from DOE and other federal R & D agencies to the private sector. These changes are depicted in Table 1. In principle, DOE favors reforms that allow sharing of patent rights with government-owned, contractor-operated installations (GOCOs) and sharing of royalties with collaborating inventors. This policy benefits facilities like the HTSC Pilot Center by encouraging

greater industrial collaboration. In practice, however, DOE has expressed concern over the impact of such changes upon national laboratory R & D missions. Two issues especially relevant for the Pilot Center are (1) DOE's view of how this technology transfer process should be implemented and, (2) obligations DOE imposes upon private sector beneficiaries from these transfers. These issues are important because past DOE patent transfer policies that were seen by some as too rigid may have had the effect of making some industrial collaborators reluctant to work with national laboratories. Some potential collaborators might have chosen to preserve their "human capital" (scientific development skills) for R & D efforts elsewhere.

In the assessment of commercialization from waived national laboratory patents, DOE and the U.S. General Accounting Office (GAO) use somewhat different criteria. The GAO, an arm of Congress, wants to see commercialization success measured partly in terms of licenses granted for new inventions as a percentage of total patent applications. This view comes from a GAO report summarizing its assessment of how best to implement patent policy changes. DOE, on the other hand, wants the number of licenses to compare to the number of patents obtained (Cheston 1987). Not only will this produce a proportionally higher figure but, DOE contends, applications not patented are unlikely to be commercially viable. DOE and ORO are in agreement that increasing patents merely to increase aggregate data on "inventions" is not a good strategy. In my view, it would be better to adopt both criteria of evaluation with the following caveat. The DOE standard will be favored in ascertaining user center effectiveness whereas the more patent application-oriented GAO standard would be used for reports to Congress on the scope and breadth of potential technology transfer activity at laboratories.

An example of my position is currently afforded by ORO's view of federal government retention of "march-in" rights over patents. "March-in rights" are rights that all government agencies, including DOE, retain to force an industry to commercialize an invention for which patent rights have been waived. This could be done, in theory, by placing a deadline on actual manufacturing and marketing of a product, or threatening to transfer the waived patent to another manufacturer. There is no interest in forcing licensees to manufacture inventions unlikely to be commercially viable for the mere sake of complying with this authority (Poteat et al. 1988). Likewise, it appears that DOE recognizes that royalty charges for inventions should be gauged by the effort expended to bring an invention to the point of practical, commercial application (U.S. GAO 1986). For inventions stemming from HTSC pilot center collaboration, this suggests that (1) collaborators need not fear that the federal government will compete with them over superconductivity inventions; (2) the need for sufficient time for technology incubation will be acknowledged; and (3) some "discoveries" which are not immediately patented will still be seen as valuable products of the center if, in the opinion of center users, they prove useful for American industrial competitiveness in other ways (e. g., they contribute to enhanced industrial efficiency or new sources of employment, or create new enterprises).

Table 1. Major Patent Laws Relevant to HTSC Pilot Center: Evolution and Current Status

- **Atomic Energy Act of 1954 (Section 152)**
  - — Inventions or discoveries in field of atomic energy at ORNL belong to government—may waive at discretion of agency. (Inventions never waived)
  - — Full cost recovery of industrial R&D at ORNL is expected.
- **Nonnuclear Act (Sect. 9)**
  - — Specific guidance regarding waivers include hastening commercialization, encouraging private sector participation, fostering competition.
  - — Waivers based on willingness of industry to participate in DOE programs, ability to share costs, intended use of contract results, effects on public health and welfare, small business status of industrial participants, likelihood of antitrust conflicts.
- **Pub.L. 96-517 Patents and Trademarks Act of '80/"Bayh-Dole Act"**
  - — Small businesses and nonprofits have first option to obtain title to inventions under government R & D contracts—takes precedence over prior acts.
  - — Does not apply to GOCOs like MMES.
  - — Government retains royalty-free, nonexclusive, irrevocable worldwide license for, or on behalf of, the U.S.—a "minimum rights" criterion. (Also called a "nonexclusive license.")
  - — DOE retains "march-in rights"—If contractor fails to commercialize technology or violates anti-trust laws, government may require the contractor to grant a nonexclusive, potentially exclusive, or exclusive license to others in the field of use.
  - — Contractor cannot grant exclusive rights unless product is manufactured substantially in the United States.
  - — Nonprofits cannot be assigned patent rights for more than "reasonable periods" of time.
- **June, 1982 DOE "Class Waiver"—Proprietary Use of National Laboratories by Private Sponsors**
  - — Waiver extends to inventors, sponsor of work, and GOCOs.

Table 1. (continued)

— No limitations on background patents (patents after contract expires), or on U.S. manufacturing requirements.

— Third party (sponsor) may treat data as proprietary.

— Applied automatically by local doe patent counsel if determined that work is not of sufficient interest to DOE, nor part of another contract with DOE, and is under an approved work-for-others (WFO) program.

— Some negotiation between DOE, sponsor, and contractor is required.

o **February 18, 1983 Memo on Patent Policy to Heads of Government Departments**

— Disposition of all inventions under federal R&D contracts substantially same as for nonprofits, small businesses, and large businesses under Pub.L. 96-517.

— Little agency discretion permitted.

— Prior legislation does not permit waiver without reversing nonnuclear patent policy—except as provided for by Pub.L. 96-517 (GOCOs, national security, etc.). If discretion applied, DOE can only acquire rights in limited instances.

— DOE felt that application to contractors other than nonprofits inappropriate.

— DOE believes memo allows government to waive even nonexclusive license and march-in rights, if desired.

— Discretion permits such waivers if interests of U.S. better served (e. g., to obtain a unique or highly qualified contractor) or if R & D requires substantial cosponsored, cost shared or joint ventured activities.

— Any sole source justification could be enough to determine that contractor is "unique" and government must relinquish rights.

— Availability of research facilities to public for privately sponsored research fall outside of funding agreement—not covered by Pub.L. 96-517 and, thus, falls within traditional DOE title-taking policy.

o **March 1983 DOE "Class Waiver"—User Facilities**

— When private organization is permitted to use facility, class waiver may apply.

Table 1. (continued)

— Full reimbursement is not made for utilization of facility or for time of facility operator's personnel.

— Government retains only license and march-in rights.

o **Federal District Court Organization Act of 1984 (Pub.L. 98-620)**

— GOCOs may directly obtain patent rights if they meet Bayh-Dole criteria that is, that they are nonprofit or small businesses; MMES and ORNL were not covered by this exception.

— However, act urged federal agencies to develop rules for "arms length" negotiations between contractors and developers of commercial products as a compromise to hasten incentives for technology transfer.

o **February 5, 1985 DOE Patent Policy (Donald Hodel)**

— All GOCO may retain ownership of inventions consistent with memo of February 18, 1983. This includes "for profit" GOCOs.

— Removed 5-year licensing period restriction.

— Required outside parties to pay royalties for right to use patents.

— Royalties earned by contractors are to be used to cover incidental expenses relating to patenting and licensing.

— After these criteria are met, balance of royalties go to MMES in form of a discretionary fund (for ORNL director to use for R & D, education, etc. All aimed at further incentives for technology transfer)—if balance of fund exceeds 5% of operating budget of facility, 75% of balance reverts to U. S. Treasury.

— Has encouraged ORNL to move aggressively in technology transfer.

o **H. R. 4505 National Superconductivity and Competitiveness Act of 1988**

— Allows National Laboratory directors to negotiate collaborative research agreements that protect intellectual property rights associated with joint ventures.

— Prescribes commercialization of computer software stemming from any collaborative effort.

— Patent ownership supposedly clarified by provisions that allow invention disposal to private sector similar to those which apply to nonprofits, universities, and small businesses.

Table 1. (continued)

— Costs of patenting are shared by laboratory and collaborator.

— Government may waive "nonexclusive rights" to attract a uniquely qualified sponsor and to optimize commercialization.

1.2.1 Statutory Invention Registrations: A Potential Controversy for Technology Transfer

If rapid registration of inventions is a goal, the use of "Statutory Invention Registrations" (SIRs) is a simpler, quicker way of permitting registration of inventions and discoveries. SIRs provide a means of protecting government-funded ideas (especially in sensitive or other classified areas) while they avoiding clogging the patent system with defensive government patents. The inventor can gain some advantage on a competitor by publishing information about a discovery (Winchell 1988). Unfortunately, they also lessen inventor morale because the holder of an SIR is not permitted to exclude others from making, using, or selling the invention. Also, SIRs save DOE relatively little in patent registration costs (Cheston 1987). Finally, SIRs may entail some compromise in trade secrets by enterprises that collaborate with DOE laboratories because they are made public. SIRs will not be filed on behalf of the HTSC Pilot Center because licensing authority has already been waived to MMES. Moreover, even had this authority not been waived, the importance of superconductivity technology to DOE serves as an inducement for pursuing regular patent applications as patentable inventions are developed. Nevertheless, this discussion is provided because it illustrates the need to place all potential incentives and counterincentives to national laboratory technology transfer in perspective. If SIRs were to be used for the HTSC Pilot Center, they could have been counter incentives to larger companies likely to collaborate in superconductivity research. Because they are public, they could require compromise with proprietary secrets (Winchell 1988). On balance, DOE does not prefer the use of SIRs rather than exclusive patents. Moreover, SIRs do not really hasten technology transfer.

Some idea of the impact of SIRs on DOE facilities' patenting process generally is indicated by Table 2, which depicts formal DOE patent applications in comparison with SIR applications for FY 1986. As can be seen, SIRs not only constituted a small fraction of total invention applications in FY 1986, but half of the SIRs originally applied for were converted from regular patent applications. The significance of Table 2 is to indicate the relative lack of interest in SIRs as compared with patents.

1.2.2 Cost Recovery and Auditing of Patents

DOE has expressed concern over the recovery of costs of patent waivers (U. S. DOE 1987). DOE wants GOCOs to consistently and carefully track the costs of patents, as well as the rate of royalty return when patents are waived to contractors. This approach has been applied to "class waivers" (a type of waiver granted to the Pilot Center) as well as "identified invention waivers" (specific waivers for a unique discovery) (U. S. DOE 1987). It should be noted that the former are not always automatically applied.

Table 2. U.S. Department of Energy Patent and Statutory Invention Registrations Applications—FY 1986*

Patent applications	Original SIRs	Conversions	Total SIRs
294	11	11	22

**Source*: R. Cheston, *Patent Policy, Recent Changes in Federal Law Considered Beneficial*, Report to Chair, Subcommittee on Courts, Civil Liberties, and Administration of Justice, Judiciary Committee, U. S. Congress, House of Representatives, p. 31 in GAO/RCED-87-44, Washington, D.C. General Accounting Office, 1987.

The significance of this cost-recovery issue for the HTSC Pilot Center is that DOE's "model agreements" for patent collaboration with industrial users of national laboratories are designed to promote a high ratio of licenses and royalties relative to DOE expenditures on patents. Unfortunately, because patenting and licensing are likely to remain slow, sometimes tedious processes, the number of patents will probably remain small (Winchell 1988). As a consequence, if royalties were to become the gauge of success in technology transfer, then Pilot Center effectiveness is likely to be modest. Royalties as a measure of success depend upon the nature of the invention. A 1% return on investment for a capital good, for example, is not the same as a 1% rate of return on a consumer item. Fortunately, as shall be seen, there are ways of overcoming reliance upon this measure.

There is a related problem, however, that is more complex. In theory, rights to the invention are shared between a particular laboratory and the inventor. There are really three possible configurations the process of invention through the HTSC Pilot Center might take. An invention may be made primarily by the collaborator at his facilities, by laboratory personnel at ORNL, or by true joint collaboration. In the latter case, joint ownership, with each party owning an "undivided interest" would occur. However, the patent would be controlled by one organization. For most large corporations, ownership of a patent on an invention stemming from Pilot Center collaboration is less important than exclusivity of right through waivers. Waivers split royalties and lead to the cross-licensing of an invention with the industrial collaborator.

1.3 ORO AND OTHER DOE OPERATIONS OFFICES: IMPACT UPON THE SUPERCONDUCTIVITY PILOT CENTER

ORO is anxious to see the Pilot Center succeed. Legal staff insist they are eager to "get out of the way" and allow the collaborative process between ORNL and industrial participants evolve into a stable, working relationship (Poteat et al. 1988). However, it is important to bear in mind that what works for ORNL may not work for other national laboratories. Each laboratory operates within its own cultural milieu (Soderstrom 1988). Thus, each pilot center must develop a working relationship with its respective DOE operations office appropriate to its mission and contractor-setting. This was one reason DOE selected ORNL, Argonne National Laboratory (ANL), and Los Alamos National Laboratory (LANL) to establish high-temperature

superconductivity pilot centers. These laboratories represent the full range of possible national laboratory missions and GOCO installation relationships: a university-managed weapons laboratory (LANL); a university-sponsored multiprogram laboratory (ANL); and an industrial-sponsored multiprogram laboratory (ORNL).

Fortunately for ORNL, the relationship with ORO has matured with a considerable amount of effort. The understanding on the part of ORO of the need for timely contractual approval for collaboration between industry and ORNL has advanced to the point where it is possible for a collaborative agreement between the Pilot Center and an industrial participant to receive approval in 24 h.

ORO appears anxious to gauge the degree of industry eagerness to gain laboratory access through the HTSC Pilot Center (Poteat et al. 1988). At the same time, however, uncertainty surrounds ORO expectations about this industry eagerness. This uncertainty is manifested by three divergent approaches to evaluation discernible in discussions with patent staff.

- **The "'Clean Slate" approach.** All pilot centers have been given everything they need from DOE to foster technology development; thus, evaluation should focus upon what has been produced over X amount of time. It is exemplified by the following measures: (1) increased numbers of inventions compared to the time before the granting of class waivers; (2) increased publication of technical reports by research staff; (3) filing every disclosure and comparing them with every commercial invention; and (4) pursuing more aggressive licensing of waived patents. In essence, evaluation criteria should be broader than inventions and/or patents. They should include numbers of cooperative agreements entered into by pilot centers, money leveraged for technology development, and licenses executed.

- **The "Exceptionalism" approach.** The HTSC Pilot Center is not the best place to test hypotheses about commercialization of government inventions; there is too much risk, little technological track record, and what may eventually become patentable is not even known yet. Essentially, this approach contends that no rigid evaluation method is useful. However, it is politically unlikely that DOE and ORO will accept this conclusion without some qualification.

- **The "Compromise" method of evaluation.** What can be evaluated in terms of commercialization effectiveness depends upon the points within the patent process one chooses to put into the database. ORO appears to be most sympathetic to this approach. This view contends that DOE is mostly concerned with waived, electable inventions (those transferred to the private sector and actually commercialized). The likely questions raised by this type of evaluation include the following: 1. Are waived patents pursued aggressively by industrial participants? If not, why not? 2. What obstacles to commercialization were discovered after collaboration with the pilot center ended? 3. How many inventions filed (reported) ended up as production licenses? 4. Were unelected inventions not commercialized because likely royalties were foreseen to be less than R & D costs?

Significantly, these approaches should not be seen as mutually exclusive. They may instead be viewed as different but complementary. Moreover, as noted previously, ownership of patents alone is not as important a concern for technology transfer as exclusivity of rights (to use the

patent). Many larger companies merely want to be granted a patent waiver to split royalties and cross-license inventions.

Finally, ORO contends that the retention by DOE of "nonexclusive rights" should not be a barrier to commercialization or to cooperation with industry. DOE has no intention of competing with private industrial collaborators over superconductivity research (Poteat R. et al. 1988). Moreover, if inventions do not prove commercially viable, "march-in rights" are unlikely to be exercised.

1.4 MARTIN MARIETTA ENERGY SYSTEMS: VIEWS TOWARD COMMERCIALIZATION

Some suggest that a profit-earning GOCO installation is in an ideal position to gauge industrial needs, to "speak the language" of industrial users, and to possess the traits of flexibility and innovation necessary to boost the technology transfer process (Soderstrom 1988). MMES is committed to erasing whatever barriers might hinder pilot center-industry collaboration. However, informal barriers to collaboration may persist. From the MMES perspective, "fortuitousness"—being in the right place at the right time—may ultimately determine successful pilot center-industry interaction.

1.4.1 Change in Contractors and Changes in Political Climate

MMES believes that ORNL has certain advantages in the process of technology development through pilot centers. This is so for two reasons. First, the current contractor is relatively new (in comparison with operators of other DOE laboratories) (Soderstrom 1988). The transfer of ORNL to MMES from Union Carbide Nuclear Division in 1984 occurred only four years after the advent of the Reagan Administration and the rise of a national commitment to use laboratory expertise to further industrial competitiveness (Packard 1983; Soderstrom 1988). Changes in the political climate that are beyond the laboratory's control may influence technology development in ways difficult to foresee.

Second, ORNL benefits from having had a slightly different mission from other multiprogram laboratories in the field of technology transfer. Considerable technology transfer has taken place at ORNL for several years, independent of any direct encouragement from outside the laboratory. When this activity was discovered to be successful, management encouraged it.

The relevance of this point for the HTSC Pilot Center is seen in Nickel-Aluminide research. Many of the current developments in applications of this technology lie outside the field of energy. What is important, however, is that the technology is getting into the marketplace in near-term applications to build industry capacity for long-range energy applications. It is clearly DOE's vision that long-range R & D in this technology serve energy goals. On the surface, it is not clear why ORNL should have pursued such ventures. However, since an informal and unregimented pattern of collaboration with industry has been encouraged, it has built up an industrial infrastructure to support DOE's needs. Thus, when this technology "took off," a number of commercial "cross licensings" came about as a result (Soderstrom 1988).

1.5 ORNL STAFF AND INDUSTRIAL COLLABORATORS: COMPLEMENTARY RELATIONSHIPS

Two barriers to collaboration between ORNL research staff and industrial collaborators have been hypothesized (1) scientists and industrial collaborators have divergent interests—the

former want to publish the results of their research while the latter want nondisclosures of proprietary information and (2) laboratory research is slow, methodical, and halting in contrast to the goal-oriented, utilitarian, and scientifically "uninteresting" character of industrial R & D. Both hypotheses greatly oversimplify the dynamics of industrial collaboration at ORNL (Soderstrom 1988).

Interviews with research staff from the Physics and the Metals and Ceramics divisions who have experience with industrial collaboration, in both user and nonuser centers, suggest a more optimistic prognosis for pilot center-industry interaction. First, the divergence of interest between scientists and industrial collaborators is less profound than generally hypothesized. The experience of Metals and Ceramics collaboration suggests that research staff need little motivation to collaborate with industry as long as a particular project: (a) falls within a division's work, (b) is scientifically interesting, and (c) conforms to an ongoing research agenda. While industries looking for a "job shop" are discouraged from collaboration, this problem has arisen infrequently (Bessman 1988).

Second, the Pilot Center cannot reveal proprietary information given under a nondisclosure agreement. The center only wants proprietary information on a "need to know" basis to expedite collaboration. If such a "need to know" exists, signing the model collaborative agreement with the sponsor legally protects the information from disclosure. This is different in structure—but not in principle—from the way "nondisclosure" is handled laboratory-wide. If experience in other divisions of the laboratory is any guide, nondisclosure can been handled deftly and, at times, informally. For example, Metals and Ceramics tells potential collaborators that they should not reveal purely proprietary information to researchers at the laboratory if they do not want it reported in academic publications (Weir 1988). This helps avoid possible misunderstandings later on. On the other hand, some industrial collaborators are anxious to see the results of collaborative research published and reported in trade publications. Reporting the results of collaborative research serves as a means of enticing business clients, generating favorable corporate publicity, and gaining competitive advantage (Weir 1988; Besmann 1988).

Third, temporary nondisclosure of patentable information by research staff has not been shown to inhibit collaboration. Nondisclosures last for only a short period of time (Soderstrom 1988). Moreover, staff appreciate that the protection of patentable information advances opportunities for further industrial collaboration (Besmann 1988). Results of collaborative R & D can be fully protected if funded by a full-cost recovery scheme, and if performed under a work-for-others (WFO) agreement that requires the collaborator to pay the entire cost of the research.

One potential problem that is more difficult to resolve is the varying "sociology" of science at different user facilities (Ball 1988). The experience of the Physics Division and the Holifield Heavy Ion Research Facility illustrates this problem. Holifield, unlike the HTSC Pilot Center, is characterized by a "nonmission" orientation in its collaborative research. There are few industrial interactions, frequent foreign participants, and a radically different mode of operation from that of a technology-oriented user center. Unlike the engineering centers, Holifield offers its facilities to nonproprietary users who compete for access under extremely rigorous conditions. This is significant for the HTSC Pilot Center, inasmuch as those engineers and scientists more acclimated to a highly fluid working environment such as the Holifield Center may find it difficult to move in a different direction to collaborate with industry (Ball 1988).

Finally, while scientific confidence in high-temperature superconductivity is great, and while expectations of various "breakthroughs" in the field are infectious, there is an atmosphere of caution matched by a sense of challenge (Hazen 1988). Many believe that movement from the

"laboratory" or glove box stage of R & D to up-scale commercialization is unlikely to come about quickly. Again, this is one reason to emphasize the benefits of user collaboration from the standpoint of process development rather than short-term commercialization prospects.

1.5.1 Communication and Industrial Contact: Informality as Key

Initial collaboration with industries and entrepreneurs at most user centers tends to occur through personal and informal mechanisms. Contacts are generally established through conferences and scientific meetings where individuals in an area of scientific specialization meet other individuals with similar interests with whom they feel comfortable working. Personal rapport, essential for effective collaboration, is developed "nonsystematically" (Soderstrom 1988; Bessman 1988).

From the standpoint of an evaluation instrument, one lesson for the HTSC Pilot Center is the need to exploit the value of this informal process (Kash 1987). The Center's mission includes clear demarcations on how it leverages funds, coordinates with the laboratory and industry, makes decisions, and allows industry to evaluate its activities (Draft Implementation Plan High-Temperature Superconductivity Pilot Center 1988). I suggest that the Industry Advisory Board, a part of the Pilot Center, be used to provide industries with a mechanism for feedback on pilot center effectiveness.

At this time, special incentives to induce further collaboration by research staff are not believed to be necessary. Publications and industrial connections coming out of Pilot Center activity constitute sufficient reward for staff. Likewise, nondisclosures (discussed in more detail in Sect. 4.2) on classified information have not proven to be a problem for collaboration. Even though many superconductivity pilot center projects are, or are expected to become, defense-related, this has not yet inhibited cooperation with industry.

A few potential issues in this area remain to be addressed. It has been suggested that technology transfer needs to be made an explicit mission of the laboratory (Kash 1987), even though it is part of the laboratory's institutional plan. Recently proposed legislation has attempted to further this goal—but the extent remains uncertain (U.S. Congress Senate 1988). In addition, simple, logistical problems may inhibit collaboration. Timing, as much as substance of collaboration, may make a considerable difference in success. If the pilot center can eventually concentrate all licensing processes in one central office providing "one-stop shopping," and if it can provide rapid turn-around time on demonstration or feasibility projects, many industrial concerns will be satisfied. However, resistance to this concentration of authority in a pilot center, among some elements of laboratory management, is likely to continue (Soderstrom 1988).

Finally, it must be appreciated that the pilot center will continue to operate within a complex environment with numerous and sometimes divergent priorities, Thus, changes in GOCO installation policy, to be discussed in Sect. 2, will continue to affect prospects for technology innovation (Soderstrom and Winchell 1986).

2. CURRENT TECHNOLOGY DEVELOPMENT POLICIES: IMPACT UPON THE PILOT CENTER

Technology transfer is a process—it builds upon experience. National laboratory participants in the process of technology transfer tend to want an adoption of an "open" process that among other things would (1) streamline exchanges of information vital for scientific cross-fertilization while simultaneously protecting national security concerns; (2) eliminate added cost factors required of industrial sponsors; (3) establish a basis for high laboratory-industry trust through reduction of "red tape," WFO limits, and the aggregation of similar work at fewer laboratories; and (4) retain exploratory flexibility through speeded-up patent transfers from government to industry (U.S. Congress—Senate 1987).

2.1 "MICRO-MANAGEMENT" AND TECHNOLOGY TRANSFER

There is no dearth of studies about the need for various internal reforms in national laboratories to enhance their contribution to American industrial competitiveness. A few years ago, one of these studies (Packard 1983) pointed to the need to reduce micro-management, encourage awareness of national needs, seek excellence in all phases of research, and establish technology transfer as an explicit laboratory mission. How well has ORNL met these criteria from the standpoint of HTAC Pilot Center effectiveness in industrial collaboration?

There is anecdotal evidence to suggest that the most productive laboratory research units in the area of technology transfer succeed by (1) placing scientists and engineers in close contact with one another; (2) encouraging "cross-fertilization" of disciplines by not concentrating a single scientific discipline in a section or division; and (3) fostering an entrepreneurial, "get it done" climate (Soderstrom 1988). Reduced mobility of research scientists, as well as political pressures to redefine technology transfer so as to include efforts to evaluate proposed public policies to manage social problems (Berry 1984) are likely to place contradictiory pressures upon the laboratory to consistently meet these criteria. Continuing debates over patent policy reflect these cross-purposes.

2.2 INTELLECTUAL PROPERTY RIGHTS: RESTRICTIONS, REFORMS, AND DEBATES

The impact of patents and intellectual property rights upon technology development are well documented and firmly established. In the area of energy-related inventions, federal investments in patent R & D have been shown to induce significant changes in private sector investments (Mansfield 1984). Moreover, there is compelling evidence that nations which successfully embark upon high-technology development diligently attempt to simplify the process of patenting and licensing.

2.2.1 An Alternative Model of Technological Collaboration: Significance for American Superconductivity Efforts

The impact of patent policy upon technology transfer in high-temperature superconductivity can be partly gauged by examining the contrasting efforts of the Japanese. In Japan, technology development and patent reform were undertaken simultaneously at the inception of that country's

industrial revolution. These efforts were even linked to government-financed "national industrial laboratories" as early as the turn of the century (Watanabe 1985).

The patent system is a major incentive to industrial invention (Watanabe 1985). It serves to spur the application of new technologies. The total number of annual patent applications in Japan is 74% greater than in the United States. In addition, patent laws were modeled after those of Western European countries, which underwent relatively rapid industrialization. The prevailing pattern sought by initial Japanese patent laws, and by later reforms, was a system of inventor protection which would (1) hasten registration of minor improvements in processes or devices through short-term intellectual property rights protections (to generate applications of technologies as well as new ideas); (2) provide simple procedures to permit creation and use of new devices and inventions among small; and, (3) promote the development of government-sponsored "industrial laboratories" that would cosponsor research and development projects designed to improve industrial processes in the private sector (Watanabe 1985).

A special International Superconductivity Technology Center, designed to promote government-private sector R & D collaboration, has recently been formed in Japan. It is partly modeled after these older industrial laboratories. Significantly, its goal is to accelerate basic as well as applied research by allowing international participation (Cassidy 1988).

In context, it appears that these patent traditions partly explain Japanese aggressiveness in high-temperature superconductivity R & D. While dramatic changes in the U. S. system of patents along Japanese lines is unlikely to come about, elucidating the contrasts between the two countries may illuminate constraints upon American high-temperature superconductivity commercial efforts that are likely to remain as indefinite barriers. It is also important that, when making comparisons, the basic goal of collaboration in the United States be borne in mind—not merely obtaining "more" patents, but hastening industry-laboratory collaboration.

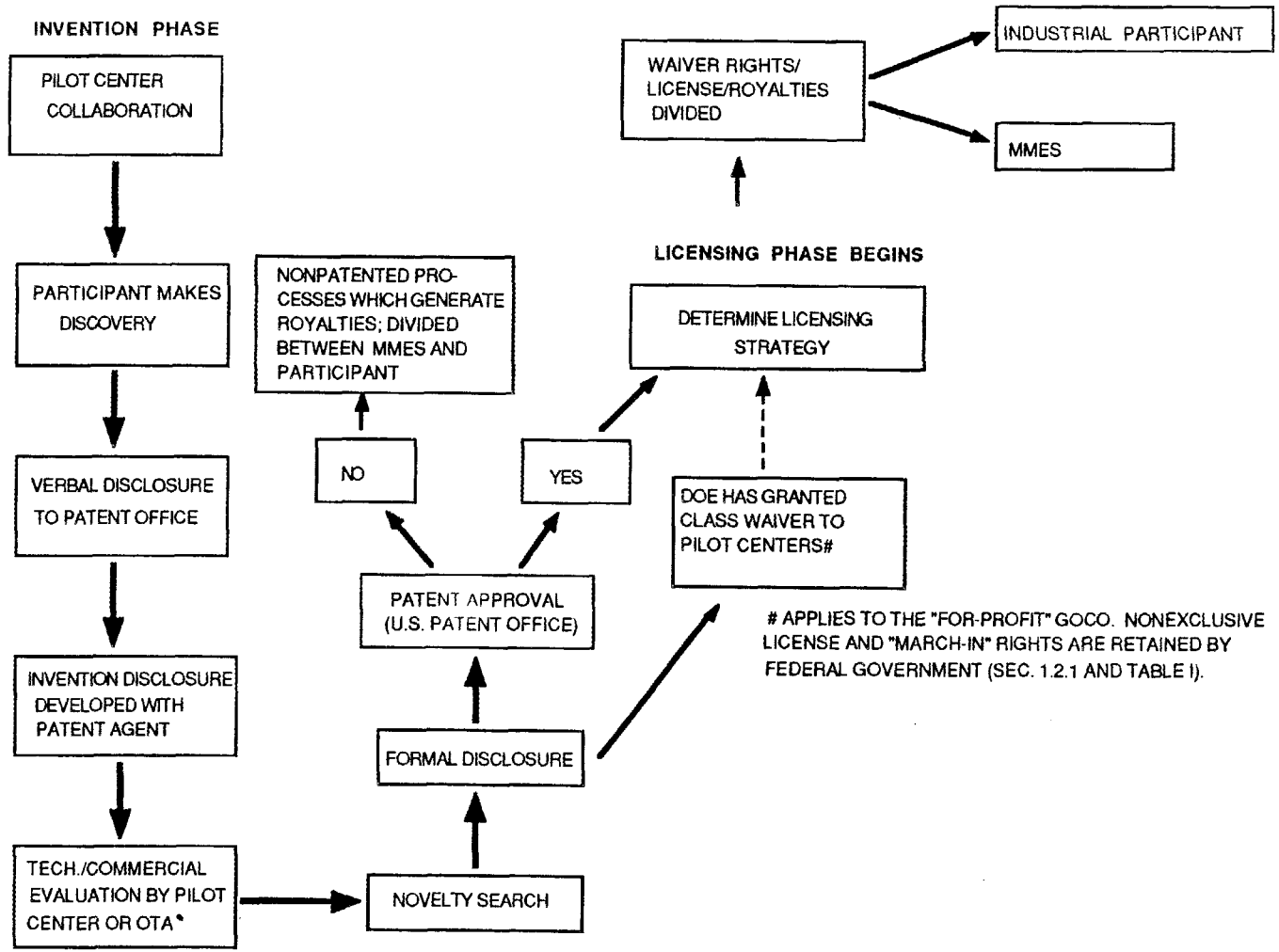
2.2.2 Changes in U.S. Patent Law

The effect of recent changes in federal patent policies affecting DOE's technology transfer efforts is a source of considerable contention within and outside of the government (U.S. GAO 1986; Winchell 1988). While a class waiver has been granted to the HTSC Pilot Center, the long-term impact of other recent patent changes upon both the center and national laboratory technology transfer generally remain uncertain. Figure 1 depicts the current patenting process affecting HTSC Pilot Center efforts. Articulated goals of this process include (1) lessening constraints upon contractors and industrial collaborators to commercialize inventions stemming from national laboratory research, (2) encouraging "one-stop shopping" for patents and licensing, and (3) ensuring that "nondisclosure" rules designed to protect industrial collaborators, not to inhibit laboratory-industry collaboration.

It is easy to place too much emphasis upon patents and licenses as a means of technology transfer through pilot centers. Another issue that may be as important for the transfer of technologies such as high-temperature superconductivity are rights to technical data pertaining to the use of certain processes. Such information is likely to appear in technical reports emanating from ORNL and other laboratories.

Finally, some concern has been expressed over the likelihood that national security considerations could eventually hinder technology transfer in a field such as high-temperature superconductivity. Anecdotal evidence from a survey of DOE contractors, conducted by the U.S. GAO (1986), indicates the relative status of this concern. As shown by Table 3, respondents were asked to rate various obstacles to availability of laboratory products, processes, and services.

Figure 1. Schematic of the patent and licensing process for the high-temperature superconductivity pilot center.



Sources: R. Cheston, Patent Policy, Recent Changes in Federal Law Considered Beneficial, GAO/RCED-87-44, Report to Chair Subcommittee on Courts, Civil Liberties, and Administration of Justice, Judiciary Committees, U.S. Congress, House of Representatives, Washington, D.C., April 1987.

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Relatively speaking, it would appear that the nature of the product or service stemming from research is more likely to affect commercialization potential than are security considerations. Moreover, Defense Advanced Research Projects Agency (DARPA)-funded research on high-temperature superconductivity at ORNL is not currently classified.

Table 3. DOE contractor opinions on the number of inventions affected by various barriers*

Reasons why laboratory products are unavailable	All	Most	About one-half	Some	Few
National Security	3	0	0	4	15
Limited Application of product or process	5	4	2	8	3
Early stage of development	2	3	2	8	7
Prohibitive engineering costs	0	0	2	7	13
Patent/license restrictions	1	0	1	8	12

**Source*: U.S. GAO, Energy Management: Effects of Recent Changes in DOE Patent Policies, p. 28 in GAO/RCED-87-5, Washington, D.C., December 1986).

3. DEVELOPMENTS LIKELY TO IMPACT UPON THE PILOT CENTER: WHAT THE FUTURE HOLDS

3.1 CURRENT DEVELOPMENTS IN LABORATORY TECHNOLOGY DEVELOPMENT POLICY

In October 1988, the House of Representatives passed H. R. 4505, The National Superconductivity and Competitiveness Act of 1988. Because of differences in the House and Senate versions, the bill was not signed into law. Nevertheless, political momentum for the ideas contained in it have been built up, and it is likely that some version of it will eventually become law. The purpose of this bill was to hasten cooperation between DOE laboratories, universities, and the private sector in technology transfer in areas critical to national economic competitiveness. A central portion of H.R. 4505 concerned high-temperature superconductivity. The major points of the Act were the following:

- It officially stated the importance of superconductivity to the economic health of the nation. Thus, superconductivity R & D would have become a formal DOE laboratory mission.

- Pilot centers would be transformed into broad-based research centers that could possibly develop reciprocal sabbaticals between laboratories and universities or private enterprises.

- DOE would have established a secretary-level policy council for oversight, evaluation, and review of laboratory R & D efforts—pinpointing weaknesses and recommending policy changes.

- DOE could have established specific line-item budgeting for high-temperature superconductivity R & D.

- Sponsor cost-sharing would have been required when pilot center work included "work for others"—up to 10% of a laboratory's entire budget.

- It would have allowed laboratory directors to negotiate collaborative research agreements that are designed to protect intellectual property rights associated with joint ventures, encourage better pilot center publicity concerning facility availability, prescribe commercialization of computer software stemming from collaboration, and allowed streamlining of contract negotiation. (To some degree, ORO would have been removed from the R & D aspects of collaboration, and MMES's role would have been clarified as facilitating licensing, not undertaking collaborative decisions.)

3.2 MORE PATENT REFORM

In line with recent past efforts, H. R. 4505 would have strengthened provisions of patent law which allow disposal of intellectual property to the private sector similar to those already granted to nonprofit organizations and small businesses. This was favored by DOE. The

government can waive, at its discretion, rights to retention of intellectual property if such action is necessary to attract a uniquely qualified sponsor. While it waives the patent, it retains the right to use the invention. This permits transfers of intellectual property rights to many types of organizations not just nonprofit enterprises or small businesses. Other reforms, as have been noted in Sect. 1.2 and 2.1, have attempted to encourage similar rapid transfers of technology to the private sector, but without major short-term impact. As a restatement of congressional intent, the consideration of H.R. 4505 may accelerate this process. Only time will tell.

Finally, amendments to this act would have provided "safeguards" against transmission of defense-related secrets by giving DOE a final veto over "data rights" pertaining to processes and information similar to those which have already existed. If nothing else, this may have had the effect of making security considerations clearly and predictably a potential barrier to collaboration.

4. CONCLUSIONS: TOWARD CRITERIA FOR AN EVALUATION INSTRUMENT SENSITIVE TO PROCESS AS WELL AS "OUTPUT"

As one recent study has noted, policies designed to hasten public sector involvement in technology transfer will continue to be motivated by the need to develop good data on technology transfer, as well as by the need to correct perceived deficiencies in the technology transfer process (Curlee and Goel 1988). To gauge the effectiveness of these policies, monitoring and evaluation will be necessary.

I recommend that part of the Pilot Center's evaluation instrument encompass four issues. These are (1) the relationship between commercialization expectations of components of the greater ORNL community and the realities of Pilot Center-industry collaboration; (2) the effect of intellectual property rights and policies (i. e., data and patent considerations) upon Pilot Center-industry collaboration; (3) the potential divergence of interests of research staff and industries; and (4) the adaptability of the pilot center in a climate of potential political and economic change. Sections 4.1—4.4 contain a list of questions that I believe need to be raised and addressed in a cogent discussion of industry-laboratory collaboration.

4.1 REALISTIC COMMERCIALIZATION EXPECTATIONS

- Is the federal government's view of commercialization—often held as a set of informal expectations—realistic in the view of participants?

- Is the HTSC Pilot Center able to speedily process the logistics of cooperation (e.g., facilitation of the admission of visitors, permission for WFOs, and the ability to make collaborative agreements in a decentralized manner)?

- Have processes of approval formerly located at DOE or ORO been relocated to the Pilot Center?

- Does the Pilot Center respond in a timely manner to requests for collaboration, or for demonstrations of the feasibility of collaboration?

- Does the Pilot Center lessen the layers of approval for cooperation necessary to gain access to scientific facilities? Is turn around time rapid from industrial request to pilot center response? Is higher authority needed to process requests?

4.2 INTELLECTUAL PROPERTY RIGHTS

- Is the process of patenting and licensing expedient, fair and equitable in terms of royalties? Is the process cohesive enough to be managed by the Pilot Center alone?

- What has been the staff response to publications under patent discretion practices? Have publications significantly increased, decreased, or stayed about the same?

- Have patent waivers quickened the pace of licensing, or are there other obstructions in the view of participants? What is the impact, if any, of cost-recovery issues on patent activities?

- Is the retention of "nonexclusive rights" by the government and its contractors a problem for certain industries? Is this ever a stated reason for declining collaboration with a Pilot Center?

- What is the effect of classified information on collaboration? Could it eventually inhibit the technology transfer process given the fact that many projects may be funded by U.S. Department of Defense or other agencies concerned with strategic applications of high-temperature superconductors? Are defense-related developments less likely to lead to commercialization?[1]

4.3 DIVERGENCE OF RESEARCH STAFF INTERESTS AND INDUSTRIAL INTERESTS

- Have greater trust and closer collaboration emerged between scientists and industrial participants? Are industrial-scientific collaborations increasing, decreasing, or staying about the same?

- How have the potential barriers of visitor facilitation, WFOs, collaborative agreement rules been reduced by the HTSC Pilot Center?

- Have there been delays in peer review and/or release of data for publications? How has nondisclosure affected the quality of publications in the opinion of research staff?

- What is the relationship between the structure of research divisions and technology transfer? Have pilot centers with closer working relationships between scientists and engineers done a better job of technology transfer than others? Has commercialization through pilot centers worked better with "cross-fertilized" divisions than single-discipline dominated divisions?

- How are outputs evaluated? Is evaluation based upon every invention filed; upon waived, electable patents; upon licenses?

- What do external agents—MMES, ORO, DOE—get out of this process? What stakes do they have in it? Are they satisfied with the rewards they receive from the process?

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[1]To cite one example, high-temperature superconductivity research funded by DARPA is not currently classified. However, it is possible this status may change once high-temperature superconductor materials reach the application stage in the Strategic Defense Initiative.

4.4 ANTICIPATING CHANGE AND ENCOURAGING FLEXIBILITY

- Are there any occupational health and safety problems involved in the development or manufacture of high-temperature superconductors which serve as potential barriers to commercialization?

- What commercial barriers remain in getting beyond the "glove box?" Are industrial interchanges overcoming these barriers?

- Are user center access decisions and other technology development decisions made in conformance with stated policy aspirations? How has industry been included into the process of assessment? What policy changes are likely to affect current user center access and technology development decisions?

While by no means exhaustive, these questions encompass some of the major concerns contained in the expectations of laboratory-related constituencies. They provide one point of departure for evaluation focused upon the improvement of intra-institutional decision making.

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