Chapter 6

Comparison of Industrial Superconductivity R&D Efforts in the United States and Japan: An OTA Survey

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Chapter 6

Comparison of Industrial Superconductivity R&D Efforts in the United States and Japan: An OTA Survey

INTRODUCTION

In late 1988 and early 1989, the Office of Technology Assessment (OTA) conducted a survey of U.S. industrial superconductivity R&D in cooperation with the National Science Foundation (NSF). A parallel survey of Japanese industrial superconductivity R&D was conducted jointly with the International Superconductivity Technology Center (ISTEC), a consortium of Japanese firms organized under the auspices of the Ministry of International Trade and Industry.

In the United States, OTA/NSF attempted to capture all companies involved in superconductivity R&D. Surveys were received from 360 U.S. companies, of which 217 reported either in-house or collaborative superconductivity R&D.[1,2] OTA estimates that the research at these companies represents about 90 percent of the U.S. industrial effort.[3] In Japan, OTA/ISTEC attempted to capture only the major superconductivity R&D-performing companies.[4] Surveys were received from 92 Japanese companies, of which 71 reported either in-house or collaborative superconductivity R&D. OTA and ISTEC estimate that about 80 percent of Japanese industrial research was captured by the survey. Unless specifically indicated, the data reported in this chapter are not adjusted for these different capture rates. For a more accurate comparison of funding levels and numbers of researchers, it is necessary to increase the U.S. data by about 11 percent and the Japanese data by about 25 percent.

R&D spending figures quoted throughout this chapter represent only the companies' own funds unless otherwise specified. Government funding for research performed by industry is considered separately, This highlights what in OTA's view is the best measure of a company's commitment to superconductivity —the investment of its own cash.

For simplicity, this chapter focuses primarily on HTS survey results. Additional survey data relating to LTS are provided in appendix 6-A. The OTA survey form used in the United States is included as appendix 6-B (a Japanese translation with slight modifications was sent to the Japanese companies).

OVERALL TOTALS: UNITED STATES AND JAPAN

Figure 6-1 shows OTA's estimate of the total industry effort in the United States and Japan, measured in both millions of dollars[5] and numbers of full-time researchers.[6] These data *are adjusted* according to OTA's estimate of the efforts not captured in each country. In 1988, Japanese industrial spending on in-house HTS R&D is estimated to be about $107 million—some 50 percent greater than the estimated total of $74 million in the United States.[7,8] Japanese firms also spent about $44

[1]Nine of the 217 U.S.-based companies are 50 percent or more foreign-owned, but the research they reported took place in U.S. facilities.

[2]Some companies chose to answer only selected questions. The response rate on the data presented here was over 90 percent unless otherwise indicated.

[3]This estimate is based on those companies known by OTA to have superconductivity R&D efforts that did not return a survey.

[4]Because the survey coverage in the United States was more comprehensive, the U.S. sample contains a long "tail" of small efforts that were not captured in the truncated Japanese sample (see figure 6-5). Thus, some caution is appropriate in comparing U.S. and Japanese survey results.

[5]Internal funding only; Japanese companies were asked for funding totals in yen; conversions used were: 144.6 yen per dollar for 1987 and 128.2 for 1988.

[6]Researchers spending more than 50 percent of their time on superconductivity. No distinction is made here between industry researchers paid with government funds and those paid with internal funds. Thus, the number of researchers reflects the total R&D performed in industry, regardless of funding source.

[7]Some Japanese companies reported low ratios of funding to research staff (less than $50,000 per researcher). This may mean that actual Japanese spending totals are even higher.

[8]In 1988, Japanese firms reported spending an additional $29 million for HTS collaborative research outside their own firms, e.g., to establish the ISTEC research center, which will conduct research primarily on HTS. By comparison, U.S. firms surveyed spent an additional $8 million on HTS collaborative R&D performed outside their own firms.

million on in-house LTS R&D compared with $16 million by U.S. firms.[9]

These differences are also reflected in the R&D staff totals in the two countries. As of October 1988, OTA estimates that some 440 U.S. industry researchers were spending greater than 50 percent of their time on HTS, compared with some 710 in Japan.[10]

Figure 6-2 shows the increase in industry R&D efforts (as captured in the survey) over time. When corrected for changes in yen/dollar exchange rates,[11] HTS funding grew by about 40 percent and LTS funding by about 20 percent in both countries from 1987 to 1988. The corresponding R&D staff data, taken at three points in time, suggest that the industrial effort began to level off in both countries during 1988. This impression was confirmed by spokesmen for several key companies interviewed by OTA.

Figure 6-3 gives a breakdown of funding sources for HTS research performed by industry in the United States and Japan. In the aggregate, companies in both countries spend more of their own internal funds than they receive from outside sources, by at least 4 to 1.[12] Compared with Japan, the U.S. Government is funding about twice as much of the I-ITS R&D performed by industry .13

Comparable data for LTS are shown in figure 6-4. In the United States, 56 percent of the LTS industrial research was funded by the Federal Government, while in Japan, only 9 percent was funded by the Japanese Government. This demonstrates the far greater commitment of Japanese companies to LTS.

CHARACTERIZING THE SURVEYED COMPANIES

In both countries, HTS R&D is heavily concentrated in a few firms. As shown in figure 6-5, the top five U.S. firms put up 55 percent of the R&D dollars, while in Japan the top five firms paid for 42 percent. The major Japanese companies tended to have more HTS researched; 9 companies had 20 or more full-time researchers (comprising 60 percent of all full-time Japanese researchers captured), compared with just 3 companies with 20 or more in the United States. In the United States, one-quarter of all full-time researchers work in companies employing three or fewer I-ITS research staff.

Company Size

With few exceptions, the big HTS spenders are large companies, but not all large companies in the survey have big HTS programs. In the United States, 73 percent of all internal HTS funding came from 61 companies with sales of over $1 billion. But 36 out of 61 were investing less than $300,000 in HTS; i.e., less than the cost of 2 full-time researchers.[14]

Small companies are sometimes viewed as the ''secret weapon' of U.S. competitiveness. Of the 217 U.S. companies captured in the OTA survey, 121 are small companies;[15] of these, 53 are startups in the last 5 years. Two of these startups have internal HTS R&D programs of over $1 million per year. Small companies as a group put up only 9 percent of total industry funding for HTS, but receive 44 percent of all Federal funding. (In Japan, just 10 large firms receive 100 percent of government funding.) Interestingly, small companies in the United States account for a much larger fraction of LTS R&D—57 percent—a reflection of the reluctance of most large U.S. companies to spend their own money on LTS R&D. No small Japanese

9The U.S. Government provides far more funding to U.S. companies for LTS R&D than the Japanese Government provides to its companies. Total industrial LTS R&D *performed* is estimated to be $48 million in Japan and about $40 million in the United States in 1988.

10Interestingly, the number of researchers spending at least a *part* of their time on HTS (when adjusted for efforts not captured in the survey) was larger in the United States (about 1,170) than in Japan (about 1,070). This suggests that a large number of firms in the United States continue to monitor developments, but are reluctant to make full-time staff commitments.

11The stronger yen in 1988 exaggerates the R&D growth in Japan, measured in dollars, cf. footnote 5.

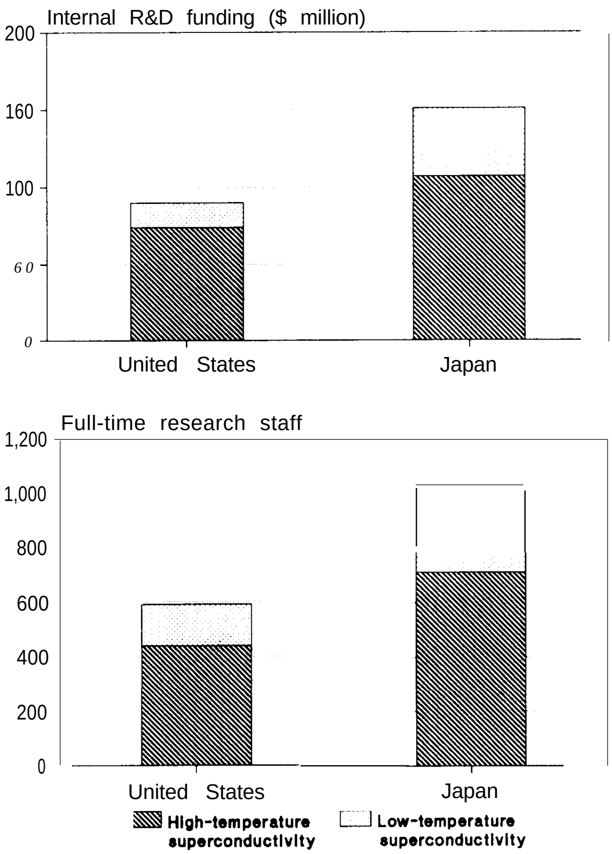
12In the United States, Federal agencies reported budgeting about $24 million for industry HTS R&D in 1988, whereas the companies captured in the survey reported receiving only about $12 million. This discrepancy may have been due to a problem of timing; funding may have been obligated by the agencies in 1988 that had not yet been spent at the time of the survey.

13The U.S. sample included 17 companies classified as ''dependent'' efforts; that is, they spend none of their own funds, but receive R&D funding from outside sources. These dependent efforts account for 7 percent of the captured government funds. There were no dependent efforts captured in Japan.

14On average, companies in the U.S. database spend about $170,000 per full-time-equivalent HTS researcher, compared with about $150,000 in Japan.

15Defined here as those companies having 500 or fewer employees.

Figure 6-l-Comparison of Industrial Superconductivity Research Efforts in the United States and Japan, 1988

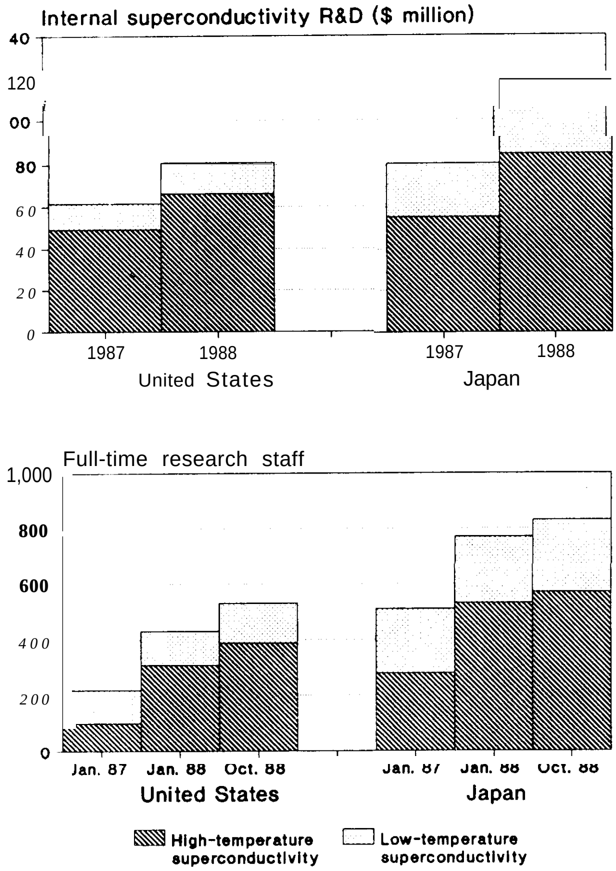


n 1988, U.S. industry internal funding for HTS was about $74 million, with 440 full-time researchers, compared with $107 million and 710 full-time researchers in Japan.

NOTE: The data in this figure are adjusted to include OTA's estimate of research efforts not captured by this survey.

SOURCE: Office of Technology Assessment, 1990.

Figure 6-2—Increase in Industrial Superconductivity in the United States and Japan, 1987-1988



Industry funding and research staff dedicated to HTS grew substantially from January 1987 to January 1988 in both the United States and Japan. The relatively small increase in research staff from January 1988 to October 1988 suggests that this growth was leveling off in both countries.

SOURCE: Office of Technology Assessment, 1990.

companies were captured in the survey database, reflecting the different sampling method used in Japan (see above).

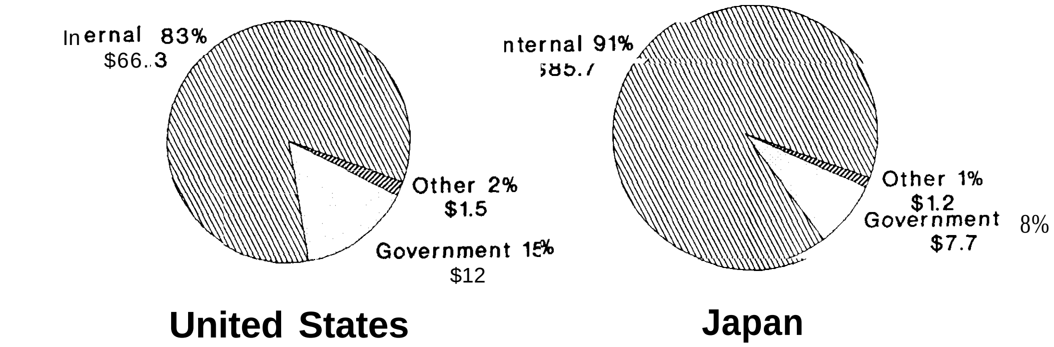
As a group, small companies spent more on applied research and development work than on basic research. (Basic research was heavily concentrated in a few large firms.) Small companies tended to be more optimistic, predicting their first HTS product an average of 3 years earlier than large companies.

Main Business Areas

The main business areas of companies involved in HTS R&Din the United States and Japan are shown in figure 6-6. In both countries, the largest category is ''electronics, ' defined here to include companies in computers and telecommunications.[16] The second largest category could be called "advanced materials. In the United States, companies in the advanced materials category are primarily chemical companies, while in Japan they are primarily metals

[16]In the United States, those companies describing their main business areas as ''electronics'' or ''electrical equipment'' tend to be different companies, whereas in Japan they are the same. This difference is reflected in figure 6-6, and emphasizes the greater tendency toward horizontal integration in Japan. Since electronics applications will generally require HTS thin films, and electrical equipment will generally require bulk materials, (e.g., wires), it follows that the fraction of companies conducting both thin film and bulk R&D is higher in Japan; cf. figure 6-8.

Figure 6-3-Funding Sources for HTS Research Performed by Industry in the United States and Japan ($ million)

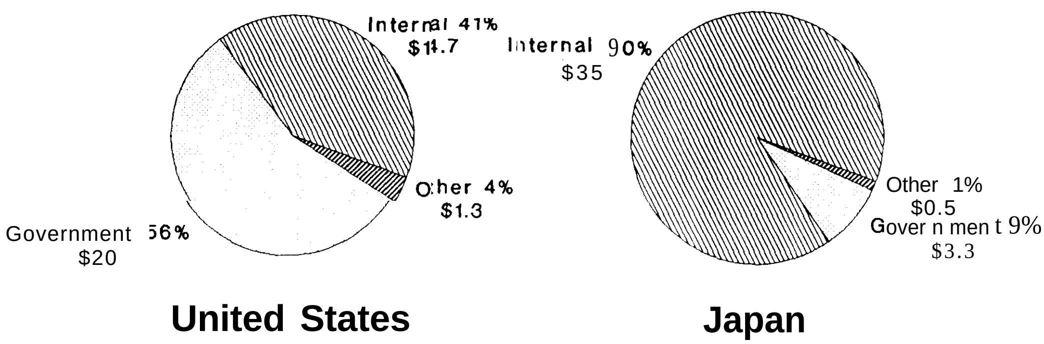


In both countries, the bulk of HTS R&D performed by companies is supported by internal funds. The U.S. Government supports nearly twice as much industry HTS R&D as does the Japanese Government.

NOTE: "Government" funding refers to national government funding only. "Internal" funding refers to companies' own funds; "Other" funding includes State and local government funding, and funding from other companies.

SOURCE: Office of Technology Assessment, 1990.

Figure 64-Funding Sources for LTS Research Performed by Industry in the United States and Japan ($ million)



U.S. and Japanese industry perform about the same amount of LTS R&D. But in the United States, funding comes predominantly from the Federal Government, while in Japan, it comes from internal sources.

NOTE: "Government" funding refers to national government funding only. "Internal" funding refers to companies' own funds; "Other" funding includes State and local government funding, and funding from other companies.

SOURCE: Office of Technology Assessment, 1990.

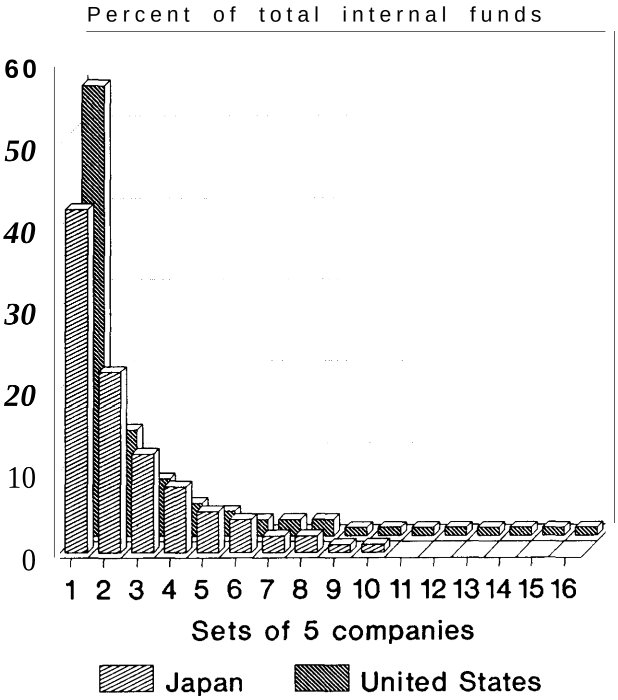
companies. In the United States, aircraft/defense companies invest much more than their counterparts in Japan. Conversely, Japanese electric utilities invest far more than their U.S. counterparts.

Reliance on Defense Markets

In Japan, the companies receiving government funding for HTS are oriented toward commercial markets. Only one company in the Japanese sample depended on the Defense Agency for over one-quarter of its sales, and it did not receive any government HTS funds. In the United States, 63 firms active in HTS were dependent on the Department of Defense for more than one-quarter of their sales. Thirty companies in this group received 58 percent of all Federal HTS funds.[17] Virtually all of the Federal HTS funding for industry in the United States comes from the Department of Defense, while the primary government funding source in Japan is the Ministry of International Trade and Industry (MITI).

[17] An additional seven U.S. companies, which receive 21 percent of all Federal funding, declined to answer the question on defense markets.

Figure 6-5-Distribution of Industry HTS Research in the United States and Japan



Each block represents total internal R&D funding of five companies, ranked according to size of R&D program. In both countries, the bulk of HTS research is concentrated in a few companies. In the left-most block, the five companies with the highest internal HTS R&D expenditures account for around 55 percent of all internal industrial HTS R&D in the United States, and around 42 percent in Japan.

SOURCE: Office of Technology Assessment, 1990.

Type of Research

Companies were asked to break down their superconductivity R&D (HTS and LTS) into three categories: basic, applied, and development.[18] The results, shown in figure 6-7, do not support the contention that Japanese firms simply appropriate the basic research of the United States and concentrate on developing applications. On the contrary, Japanese companies reported spending a larger fraction of their budgets on "basic" research-as defined by OTA—than did U.S. companies (by a margin of 37 percent to 28 percent). This suggests that much of the basic research undertaken in U.S. universities or national laboratories is performed in Japan by companies.

Companies were also asked to characterize whether their HTS research is directed toward thin films or bulk forms. The results are shown in figure 6-8. In both countries, the majority of companies are funding research on thin films. This is consistent with the predominance in both countries of companies with main business areas related to electronics—the field in which thin films are likely to find their broadest applications. But in Japan the fraction of companies with research in both thin film and bulk materials was considerably greater; U.S. companies were more likely to specialize in one or the other. *9

Collaborations

Most U.S. companies performing superconductivity R&D are involved in collaborations with at least one outside organization. Of the 217 companies supporting superconductivity R&D, 183 (84 percent) are either engaged in or plan to engage in some type of collaboration outside their own firm. Similarly, 96 percent of the Japanese firms reported some collaborative R&D.

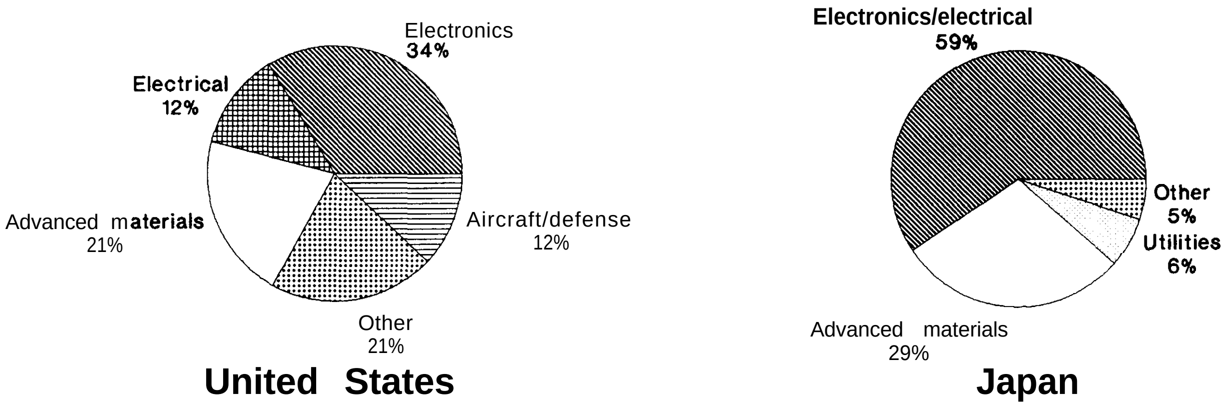
The relative popularity of various collaborative partners in 1988 is shown in figure 6-9. Most of the Japanese companies surveyed are members of the MITI-sponsored consortium ISTEC; thus, 91 percent reported membership in an industry consortium, compared with just 22 percent in the United States. *(J Apart from this, the collaborative behavior in the two countries is similar. Universities were more popular partners than national laboratories in both countries, although Japanese firms were somewhat more likely to be collaborating with a national laboratory than U.S. firms. The popularity of collaborating with other individual firms was about the same in the two samples. Japanese firms moved more quickly than U.S. firms to establish collaborative arrangements, as evidenced by the comparatively large number of U.S. firms in the "plans to collaborate" category as of late 1988.

[18]Companies were asked to check various categories of research that OTA grouped under these headings; see App. 6-B for details.

[19]To some extent, this result is exaggerated by the different sampling methods used in the two countries. Presumably, the Japanese companies with small programs (not captured in the sample) would have been more specialized. But the overall trend toward greater overlap between thin film and bulk research in Japan is also seen when only the large programs are compared (see the section on *Major HTS Programs* below).

[20]Given that ISTEC—itself a consortium—selected the Japanese companies to be surveyed, the results are skewed toward higher rates of collaboration than would be true of the general population of Japanese companies. Nevertheless, almost all major Japanese players in HTS are members of ISTEC.

Figure 6-6-Main Businsss Areas of Companies Performing HTS R&D in the United States and Japan



In both countries, companies with the largest efforts tended to have main business areas in electronics or electrical equipment. (These were distinct categories in the United States, but were inseparable in Japan.) In the United States, aircraft/defense companies play a significant role, whereas in Japan the electric utilities are more heavily involved.

SOURCE: Office of Technology Assessment, 1990.

In 1988, U.S. companies spent about $8 million on collaborative HTS R&D performed outside of the company, compared with a total of $29 million in Japan. However, these dollar figures may not accurately reflect the actual amount of collaboration going on. In both countries, companies often engage in informal collaborative relationships that may involve interchange of personnel or samples, but do not require exchange of funds. In fact, 67 U.S. companies and 14 Japanese companies report ongoing collaborations, but no outside expenditures.

BREAKDOWN OF HTS R&D FUNDING BY SIZE OF RESEARCH PROGRAM

To compare the structure of the U.S. and Japanese superconductivity industries more effectively, company programs were classified into three categories according to their level of internal funding. This breakdown for the United States and Japan is summarized in tables 6-1 and 6-2, respectively (comparable data for LTS are given in appendix 6-A). “Major” HTS R&D efforts are those with $1 million or more of internal funding. ‘‘Midrange” efforts are those in the $100,000 to $1 million range. “Minor” efforts are those less than $100,000 per year.

Although these categories are somewhat arbitrary, OTA thinks they convey a qualitative implication for future competitiveness: companies with sustained annual R&D investments of $1 million or more can be expected to be major players in HTS; companies in the $100,000 to $1 million range are considered serious; and companies investing less than $100,000 are basically “watchers.”

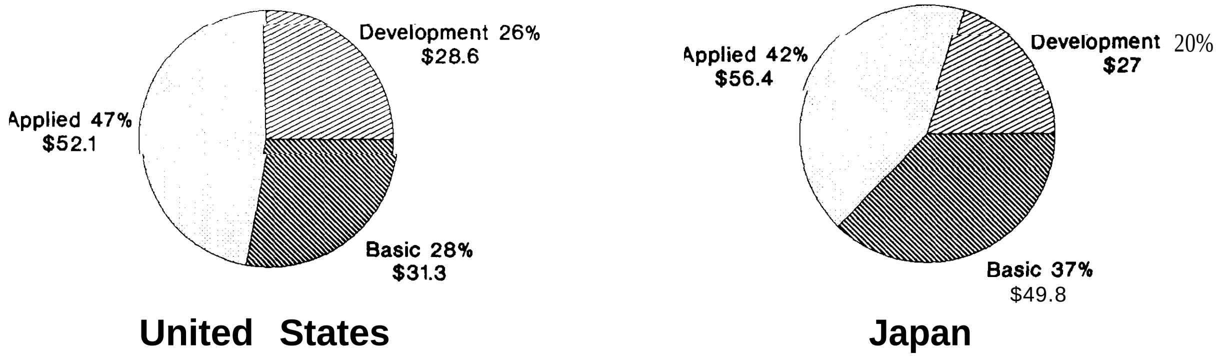
Major HTS Programs

Companies with internal HTS R&D programs of at least $1 million are likely to be in the competitive forefront in superconductivity in the 1990s. In both countries, these companies account for 75 percent or more of the total internal funding for HTS. There are 14 such companies captured in the United States, compared with 20 in Japan.

In the United States, this group of large HTS spenders included 10 large companies (sales over $1 billion), 2 medium-sized companies, and 2 small startup companies. Their dependence on Federal funding varied widely. Of the 14, 7 reported receiving no Federal funds; the other 7 received 42 percent of all Federal funds--on average $714,000 per company—but this was small in comparison with the average amount that the company was putting up: $3.5 million.

In Japan, all 20 of the big HTS spenders had annual sales of over $1 billion. Government funding was concentrated in this group. Although 13 of 20 companies did not report receiving any government

Figure 6-7--Characterization of Industry Superconductivity Research in the United States and Japan ($

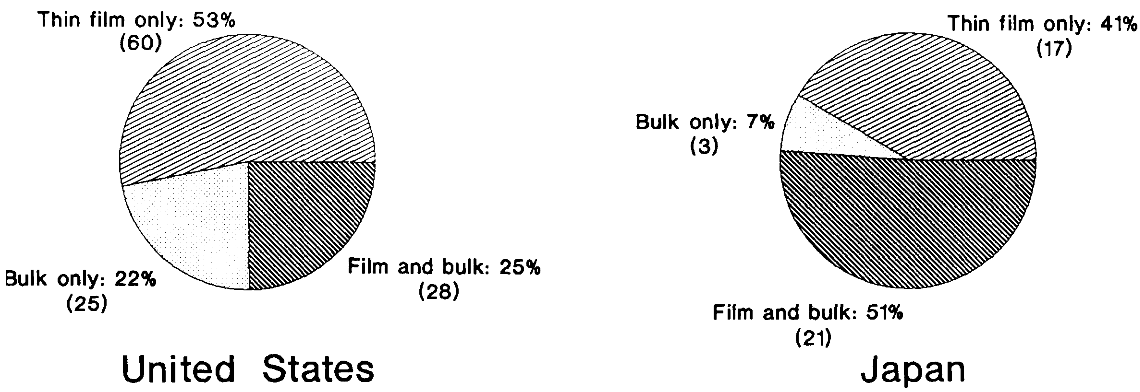


Japanese companies reported performing more "basic" superconductivity research than did U.S. companies,

NOTE: This data includes total HTS and LTS R&D performed.

SOURCE: Office of Technology Assessment, 1990.

Figure 6-8-HTS Thin Film and Bulk Processing R&Din the United States and Japan (number of compa



In both countries, the majority of companies are performing research on processing HTS thin films. However, in Japan, companies are more likely to be conducting both thin film and bulk processing R&D.

NOTE: Each pie represents the set of all companies with some thin film or bulk processing R&D.

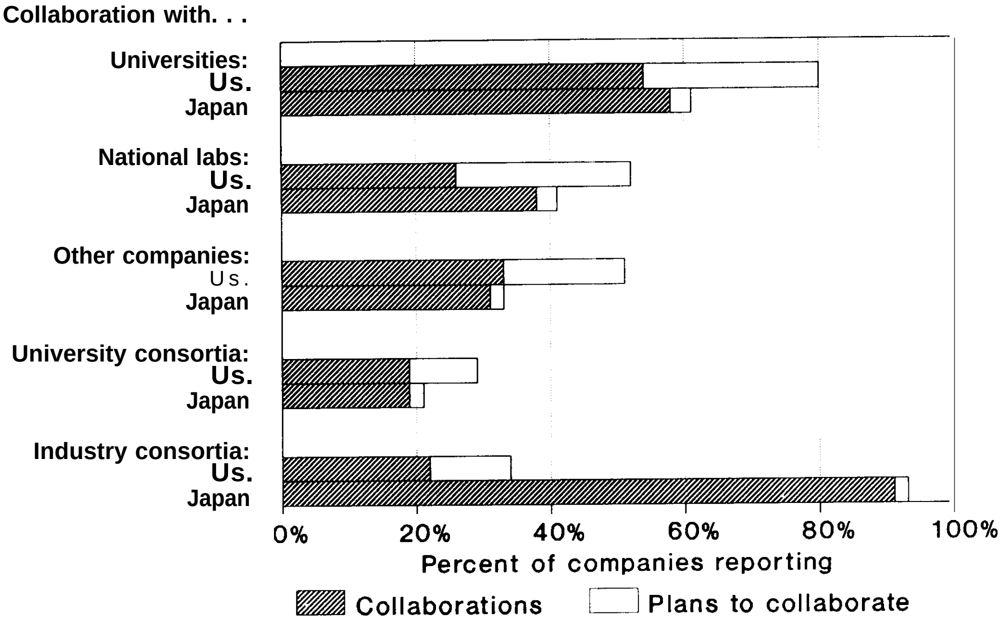
SOURCE: Office of Technology Assessment, 1990.

support for HTS, the other 7 companies received 87 percent of all government funding--on average $953,000 per company. These companies were also investing an average of $3.6 million of their own funds.

Among these big spenders, the Japanese companies were more likely to have broader superconductivity programs—both in terms of types of materials being developed, and the scope of research. For instance, although in both countries a majority of these companies employ research staff who have had experience working in LTS, 11 of 20 Japanese companies actually have ongoing LTS programs of over $100,000 per year, compared with just 4 of 14 in the United States. As discussed in chapter 2, continuing experience with LTS could have valuable carryover to the commercialization of HTS.

While HTS thin films are the most popular research area in both countries, 16 of the 20 Japanese companies also had R&D programs on bulk materials, compared with just 6 of 14 in the United States. This overlap could be important because the cross-fertilization of these two types of research within the same firm could speed the commercialization of both. The greater breadth of the Japanese superconductivity programs reflects the greater horizontal

Figure 6-9--Comparison of Industry Collaborations in HTS R&D in the United States and Japan



As of late 1988, industry collaboration behavior in HTS research was similar in the two countries, except that most Japanese companies surveyed were members of the industrial consortium ISTEC.

SOURCE: Office of Technology Assessment, 1990.

integration of the Japanese firms compared with Us. firms.

Midrange HTS Programs

In 1988,58 U.S. companies spent $100,000 to $1 million on HTS R&D (averaging $245,000-less than the equivalent of two full-time researchers). This compared with 29 companies in this range spending an average of $434,000 in Japan. These companies are maintaining a nucleus of HTS expertise that presumably could be quickly expanded if promising commercial applications are identified. In the United States, the midrange companies accounted for 21 percent of the total HTS R&D, and received 29 percent of Federal funds. In Japan, they accounted for 15 percent of the R&D total, and received 13 percent of government funding.

Small HTS Programs

One hundred and fifteen U.S. companies performing HTS R&D-over half of the sample-have small efforts; i.e., spent less than $100,000 on HTS in 1988 (an average of $23,000 each). These companies can be considered "watchers"; i.e., long-term competitiveness in HTS cannot be maintained at such small expenditure levels. The 115 U.S. small efforts together account for only 4 percent of the total internal company funds, but receive about 29 percent of all Federal funds.[21]

Owing to the different sampling method used in Japan, many small efforts were not captured in the Japanese sample.[22] The 10 small Japanese programs captured spend an average of $40,000 each and none receives government funds. These 10 companies account for less than 1 percent of captured internal funds invested in HTS by Japanese firms.

INDUSTRY ATTITUDES

Companies were asked to project the year in which they expected to bring their first HTS-related product to market, and to specify a category for that

[21] Seventeen companies in the sample spend no internal funds for HTS—they are dependent on other sources for all of their R&D dollars. Twelve of these companies received a total of $830,000 from the Federal Government in 1988.

[22] In a separate survey, Nikkei Superconductor identified some 56 Japanese companies with efforts less than $80,000. See S. Tajima, "HTS R&D Results in 1988 and Prospects for Applications," a paper presented at the New Superconducting Materials Forum's 7th Symposium on Superconductivity, Tokyo, Japan, Dec. 8, 1988.

Table 6-1-U.S. Industry HTS Programs, 1988 (grouped by the amount of company's own funds)

	Major efforts ($1 M or more)	Midrange ($1OOK-$1M)	Small[a] (<$1OOK)	Total, all companies
Number of companies	14	58	115	187
Number of R&D staff	446	299	256	1,001[b]
(>50% time)	203	104	54	361
R&D totals	$54.6 M	$18.4 M	$6.8 M	$79.8 M
Own $	$49.6 M	$14.2 M	$2.7 M	$66.3 M
Federal $	$5.0 M	$3.4 M	$3.5 M	$11.9 M
Other $	$0.0 M	$0.8 M	$0.6 M	$1.4 M

[a]A total of 17 companies have no internal funds for HTS and are dependent on other sources for all of their HTS R&D dollars. Twelve of these companies received a total of $830,000 from the Federal Government.
[b]An additional 9 companies did not report funds, but reported a total of 59 individual researchers, of which 32 spent 50 percent or more of their time on HTS research.
[c]Other sources of funds include State and local governments, other U.S. companies, etc.

SOURCE: Office of Technology Assessment, 1990.

Table 6-2--Japaneae Industry HTS Programs, 1988 (grouped by the amount of company's own funds)

	Major efforts ($1 M or more)[a]	Midrange ($1OOK-$1M)	Small (<$1OOK)	Total, all companies
Number of companies	20	29	10	59
Number of R&D staff	558	235	42	835[b]
(>50% time)	419	130	6	555
R&D totals.	$80.5 M	$13.6 M	$0.4 M	$94.6 M
Own $	$72.7 M	$12.6 M	$0.4 M	$85.7 M
Federal $	$6.7 M	$ 1.0 M	$0.0 M	$7.7 M
Other $[c].	$ 1.1 M	$0.0 M	$0.0 M	$ 1.2 M

[a]Converted from yen values; yen conversion used was 128.2 for 1988.
[b]An additional 7 companies did not report funds, but reported a total of 24 individual researchers, of which 10 spent 50 percent or more of their time on HTS research.
[c]Other sources of funds include local governments, other companies, etc.

SOURCE: Office of Technology Assessment, 1990.

product.[23] The results show that the anticipated relative timing of the products is similar in both countries: e.g., powders, wires, fabrication equipment, and small-scale electronics-related products were expected before large-scale applications such as high-field magnets or electric power equipment. But in Japan, these products were anticipated an average of 8 years later than in the United States.[24] The average first year-to-market in the United States is 1992; in Japan, 2000.

There are several possible interpretations of this result. At first glance, it would appear that U.S. companies are more optimistic about early introduction of HTS products. Actually, though, this may simply reflect the short-term pressures on U.S. managers to produce a product within 3 to 5 years. The willingness of Japanese companies to spend so much on R&D even though commercial products may be at least 10 years away suggests a strong commitment to HTS technology. The continuing commitment of Japanese companies to commercial LTS technology—largely abandoned by U.S. companies —reinforces this conclusion, and raises the troubling question of whether U.S. firms are prepared to compete vigorously in HTS over the long term.

Some Company Comments

In addition to the surveys in the United States and Japan, OTA conducted a number of interviews with industry representatives in the United States on attitudes toward HTS development, Federal Government R&D policy, multisector collaborations, and a

23Only 78 percent of U.S. respondents and 69 percent of Japanese respondents specified a date for their first expected product incorporating HTS materials.

24This generalization held across the board for each product category.

number of related issues.[25] Many survey respondents in both countries also volunteered opinions on subjects covered in the survey questionnaire. Several of these comments and interviews raise doubts about the level of commitment on the part of U.S. companies to long-term R&D programs.

The views of several respondents were summed up by one researcher who cited a need to "show results within 3 to 5 years-although 'corporate' may claim that they are more patient than that. The average year-to-market for a U.S. company's first HTS-based product— 1992—may simply be a reflection of this time horizon: it falls 4 to 5 years after the start of industrial HTS R&D programs. One LTS systems supplier states that his company "cannot afford to spend 5 years and $10 million without some assurance of a nearer term pay back." Another industry representative looks for as short a payback as we can get. " Said one respondent about the erosion of U.S. technological leadership in LTS electronics: "we're not just uncompetitive; we're not competing at all. "

One often-cited source of competitive strength for the United States is the small company. Thought to be more innovative and enthusiastic, small companies sometimes lack the capital and broad resource base of larger companies. U.S. small businesses captured in the survey predict an average year-to-market for their first HTS products about 3 years earlier than larger firms (1990, compared with 1993). This may be a reflection of the small company's enthusiasm and capacity for innovation. Alternatively, it may indicate greater market pressures (particularly from its initial investors) to produce quick results.[26] If progress in improving the properties of HTS materials continues to be incremental, sources of private capital for these small companies could dry up, leaving them in a poor position to compete with larger, better-financed Japanese companies.

U.S. companies are using small-scale products—e.g., powders or simple SQUIDS based on thin films-as a safe way of gaining experience with HTS. Small devices and materials are relatively low value-added products, but they are less risky. These companies plan to approach more challenging but higher-value-added products--e.g., computers—at a later point. Ultimately, though, the profits to be made in superconducting systems may be 10 times higher than the profits in the materials business alone. As one LTS materials supplier noted: "the LTS materials business is $10-30 million per year, compared with the total superconductivity products business of around $300 million per year. "

The discovery of HTS has caused are-evaluation of the feasibility of various LTS applications, precipitating a number of new paper studies on maglev transportation, electric power applications, etc. One HTS researcher cited a "much higher level of enthusiasm for LTS as a result of the HTS activity—and a higher level of comfort in working at low temperatures. ' And the amount of LTS R&D performed by U.S. industry did increase by 71 percent from 1987 to 1988. But only 15 percent of this increase came out of internal funds; 82 percent came from Federal sources such as the Department of Energy's Superconducting Super Collider and DoD's Superconducting Magnetic Energy Storage programs.

Despite the spotlight on superconductivity, industry funding for LTS R&D remains low compared to that for HTS R&D (see figure 6-l). On the other hand, HTS has not caused companies to be more pessimistic about the prospects for LTS, either. Industry interviewees feel that "LTS applications are real" and "realistically will never be replaced" by HTS technologies. OTA reached a similar conclusion in its evaluation of superconductivity applications in chapter 3.

[25] Technology Management Associates, ''Industrial Viewpoints on High-Temperature Superconductivity,'' contractor report prepared for the Office of Technology Assessment, Oct. 28, 1988.

[26] It may also indicate a certain naivete. Typically, companies with long experience grappling with the challenges of bringing LTS materials to market projected a later first year-to-market for HTS, compared with small HTS startup companies without this experience.

APPENDIX 6-A: A BREAKDOWN OF LTS RESEARCH IN THE UNITED STATES AND JAPAN

Table 6-3-U.S. Industry LTS Programs, 1988 (grouped by the amount of company's own funds)

	Major efforts ($1 M or more)	Midrange ($100K-$1 M)	Small[a] (<$1OOK)	Total, all companies
Number of companies	4	17	34	55
Number of R&D staff	63	114	67	244[b]
(>50% time)	23	75	17	115
R&D $ totals	$10.1 M	$21.3 M	$4.6 M	$36.0 M
Own $	$8.0 M	$6.2 M	$0.5 M	$14.7 M
Federal $	$ 1.8 M	$14.3 M	$3.9 M	$20.0 M
Other $[c]	$0.3 M	$0.8 M	$0.2 M	$ 1.3 M

[a]A total of 11 companies have no internal funds for HTS and are dependent on other sources for all of their HTS R&D dollars. These 11 companies receive $3.5 M from the Federal Government.

[b]An additional 11 companies did not report funds, but reported a total of 40 individual researchers, of which 21 spent 50 percent or more of their time on LTS research.

[c]Other sources of funds include State and local governments, other U.S. companies, etc.

SOURCE: Office of Technology Assessment, 1990.

Table 6-4--Japanese Industry LTS Programs, 1988 (grouped by the amount of company's own funds)

	Major efforts ($1 M or more)[a]	Midrange ($1OOK-$1M)	Small (<$1OOK)	Total, all companies
Number of companies	12	7	9	28
Number of R&D staff	272	51	28	351[b]
(>50% time)	190	32	14	236
R&D $ totals	$33.4 M	$4.9 M	$0.3 M	$38.6 M
Own $	$29.9 M	$4.7 M	$0.3 M	$34.9 M
Federal $	$3.3 M	$0.0 M	$0.0 M	$3.3 M
Other $[c]	0.2 M	$0.2 M	$0.0 M	$0.4 M

[a]Converted from yen values; yen conversion used was 128.2 for 1988.

[b]An additional 6 companies did not report funds, but reported a total of 54 individual researchers, of which 21 spent 50 percent or more of their time on LTS research.

[c]Other sources of funds include State and local governments, other companies, etc.

SOURCE: Office of Technology Assessment, 1990.

APPENDIX 6-B: OTA R&D SURVEY

United States Congress
Office of Technology Assessment

SURVEY OF SUPERCONDUCTIVITY

RESEARCH, DEVELOPMENT AND APPLICATION IN INDUSTRY

Congress has asked for an assessment of the commercial prospects of the new high temperature superconductors. We at OTA are convinced of the importance of an industrial perspective commercializatlon issues. The fallowing questionnaire was designed to capture the views of both U.S. and Japanese Industry on this Interesting new technology. Please help us to inform the Congress of the state of industrial superconductor research, and of potential problem areas in the commercialization of these materials, by participating in this survey.

The results of the American and Japanese surveys will be presented in an upcoming OTA assessment on high temperature superconductivity scheduled for release in mid-1989. You will receive complimentary copies of this assessment as soon as it is available for release. We hope that you will use this survey as an opportunity to express your views to the Congress and we thank you in advance for participating.

ALL INFORMATION PROVIDED FOR THIS SURVEY WILL REMAIN CONFIDENTIAL AND WILL NOT BE DISCLOSED TO THE PUBLIC EXCEPT IN AN AGGREGATED FORM THAT DOES NOT PERMIT IDENTIFICATION OF THE RESPONDENT OR THE RESPONDENT'S ORGANIZATION. The Office of . Technology Assessment is exempt from compliance with Freedom of Information Act requests. OTA Is not seeking proprietary data from any participants. Respondent information will be shared with the National Science Foundation, with the understanding that NSF will abide by the stated conditions of confidentiality. Richard E. Morrison [NSF (202) 634425] may contact you regarding NSF's participation In this survey.

If you have any questions about this survey, contact Laurie Gavrin at (202) 228-6283 or Jane Alexander at (202) 228-6274. Please return the completed survey to:

Superconductivity Assessment
Office of Technology Assessment
Energy and Materials Program
U.S. Congress
Washington, D.C. 20510-8025

Company Name and Address:

Name of Respondent and Title:

Telephone:

( ) ____________________ Ext. __________

Reporting year (check ONE only - if possible, please use calendar year)

___ **Calendar year OR**

___ **Fiscal year beginning ____________________, ending ____________________**

Month day **Month day**

September 30, 1988

If you feel that this questionnaire does not apply to your company (e.g., your company does not conduct any business or R&D activity related to superconductivity and is not contemplating any), please indicate this below and mail the questionnaire back to OTA Fed free to answer any questions which do apply to your company. Your participation will still remain confidential.

_____ My organization is not conducting or planning to conduct any business or R&D activity in superconductivity or superconductivity-related products

OTA would still be interested in knowing why your organization is interested in superconductivity, however limited this interest may be, and would appreciate your description below of the reasons behind your interest.

INTRODUCTION

This survey covers both traditional, low temperature superconductivity (LTS) R&D as well as the newer high temperature superconductivity (HTS) R&D activities. Except as otherwise noted, data for HTS R&D and for LTS R&D are to be reported separately.

if you fed that you cannot complete this questionnaire, please forward it to the person within your company who would be better able to complete it.

if the answer to a given question is zero, indicate by writing "zero" or "0"; do not use a dash and do not leave blank. if you don't wish to answer the question for any reason, please indicate that you have seen the question by marking the question in some obvious fashion, such as putting a slash mark across it. Do not leave any question unmarked.

Please read the "Definitions" page found at the back of this survey, and refer to it if you are unsure about a question.

For questions on value of sales and number of employees, please report only the data for your company and its dependent divisions; do not include your parent company, or any independent divisions or subsidiaries. if your company has foreign-based operations, please report availabie or estimated data for U.S.-based operations only.

Personnel data should be reported as of January of your reporting year.

When reporting total sales, if your company performs contract research or other services, report sales of research and other services as well as components, systems, and other commodities.

Please report R&D which is performed in-house separately from R&D which is contracted out to a university, Federal laboratory, industry association or consortium, or another company.

All requested financial data should be provided in thousands of dollars. An expenditure of $25,643 should be rounded to the nearest thousand dollars and be reported as $26K if exact data are not available, reasonable estimates are welcome. To the extent possible, ail data should be reported by calendar year.

A. DESCRIPTION OF COMPANY

1. Provide a description of your organization and its main business areas by checking any and all of the fallowing categories that apply.

___Aircraft/aerospace

___Ceramics/glass

___chemical

___Computers/data processing

___Contract research

___Cyogenics

___Defense

___Electrical/power systems

___Electronics

___Energy

___Fabrication equipment

___Industrial manufacturing

___Industry association

___Land/sea transportation

___Magnets

___Medical

___Metals

___Petroleum

___Public utility

___Research consortium

___Scientific instruments

___Semiconductors

___Sensors

___Superconductor materials

___Telecommunications

___Wire/tape mfg.

Other (describe)____

2. is your organization a recent start-up (within the past five years)?

___Yes ___No

3. What percent of total company sales are to:
(Check one for each row)

	0-25%	25-50%	50-75%	75-100%
military markets?	_____	_____	_____	_____
other Federal Government markets?	_____	_____	_____	_____

4a. is your company an independent division or subsidiary of another company

___Yes ___No ___Not applicable

if no, goon to question 5.

4b. What is your parent company____

4c. U.S. respondents: is your parent company at least 50 percent foreign-owned?

___Yes ___No ___Not applicable

5a. Is your' company a parent of any independent divisions or subsidiaries which are involved in superconductor R&D or sales?

____Yes ____No ____Not applicable

comments? ____________________

5b. If yes, list the U.S.-based independent divisions or subsidiaries, their locations, and potential contacts within these companies:

B. COMPANY SIZE

6. What was the value of **total sales for your company in 1987? (For purposes of this survey, use the conversion rate $1 = 133 yen.)**

____No sales
____Less than $1 million
____$1-10 million
____Not available
____$10-100 million
____$100 million to $1 billion
____Greater than $1 billion
____Not applicable

7. How many people are employed within your organization?

____10 or less ____11 to 50 ____51 to 500 ____501 to 10,000 ____Over 10,000

C. COMPANY HISTORY IN SUPERCONDUCTIVITY

8. Has your company performed low temperature superconductor (LTS) R&D and/or produced LTS-related products?

____Yes ____No ____Not applicable

Comments? ____________________

9. Approximately when did your organization first become involved in superconductivity (LTS and/or HTS) R&D activities?

Year ____________ Month, if known ____________

D. SUPERCONDUCTIVITY R&D EXPENDITURES BY SOURCE OF FUNDS

10. Please indicate below your company's expenditures on both high and low temperature superconductivity R&D for 1987 and 1988. Allocate expenditures by the source of the funds. [As in other questions about R&D expenditures, include only expenditures for R&D activities performed by your organization.] Report expenditures in thousands of dollars, e.g. $26K instead of $25,643.

	1987 HTS	1987 LTS	1988 HTS	1988 LTS
a) TOTAL SUPERCONDUCTIVITY R&D EXPENDITURES	$____	$____	$____	$____
b) Company's own funds	$____	$____	$____	$____
c) Other industry	$____	$____	$____	$____
d) Federal Government	$____	$____	$____	$____
e) State & Local governments	$____	$____	$____	$____
f) Foreign	$____	$____	$____	$____
[Foreign industry]	[____]	[____]	[____]	[____]
[Foreign government]	[____]	[____]	[____]	[____]
g) All other sources	$____	$____	$____	$____

E. SUPERCONDUCTIVITY EXPENDITURES BY TYPE OF R&D ACTIVITY

In this section we would like to obtain a rough breakdown of industrial R&D expenditures by type of R&D activity, and to become familiar with what areas of research industries are most interested in. (See the end of this survey for a definition of R&D activities.)

11. Allocate your total superconductivity (HTS and/or LTS) R&D expenditures (from question 10a above) for 1987 and 1988 (estimated) across the three major types of R&D activity listed below. If your expenditures cover multiple or overlapping activities, you may allocate proportionally among activities or allocate them entirely to a primary expenditure activity, but please make sure that the total here adds up to the total indicated above in question 10a.

Within each of the three major R&D activity areas, indicate with checkmarks any and all of the following HTS and LTS R&D performed in-house at your organization.

	1987	1988 (estimated)	
BASIC RESEARCH	$______	$______	___Not applicable

Basic research is defined to include the following:

	(Check as applicable) HTS	LTS
Theory/Experimental characterization of superconductivity	___	___
Characterization of presently known materials, including property analysis, and composition/structure characterization	___	___
Searching for new types of materials (metallic, ceramic, or organic) and/or materials with more desirable properties	___	___
Other basic research not covered above	___	___

	1987	1988 (estimated)	
APPLIED RESEARCH:	$________	$________	____Not applicable

Applied research is defined to include the following: (Check as applicable)

	HTS	LTS
Cryogenic systems research	____	____
Processing research for tape or wire development	____	____
Thin film processing research	____	____
Josephson junctions/Prototype devices	____	____
Powder/raw material processing	____	____

Processing research in any of the following technologies:
developing high quality raw materials, thin film formation, wire, tape, fiber, encapsulation, or bulk superconductors (magnets) for the purpose of:

	HTS	LTS
Improving superconducting/mechanical properties	____	____
Finding economical processes	____	____
Compatibility with semiconductor processing	____	____
Processing research for other technical reasons	____	____
Applied research (not specified)	____	____

	1987	1988 (estimated)	
DEVELOPMENT WORK	$________	$________	____Not applicable

Development work is defined to include the following: (Check as applicable)

	HTS	LTS
Component development or modification (e.g., magnet, Josephson junction circuits, SQUID) Briefly describe this component ____________________	____	____
System development or modification (e.g., a cryogenic system, a motor, an MRI system) Briefly describe this system ____________________	____	____
Systems design	____	____
Development work (not specified)	____	____

12. PRELIMINARY WORK - As in question 11, please indicate with checkmarks any and all of the following activities which your firm has conducted or is conducting. (Check as applicable)

	HTS	LTS
Technology monitoring	____	____
Feasibility and/or Market studies	____	____

Describe any types of HTS-related research which your organization performs in-house, but which is not covered by the above listings in questions 11 and 12.

F. FEDERAL GOVERNMENT FUNDING

In this section we would like to get a picture of the need for Federal funding of industrial superconductivity (HTS and/or LTS) research.

13a. Did you apply for money from Federal government sources for HTS R&D conducted during 1988?

___Yes ___No

13b. If you did apply, were any of your applications approved?

___Yes ___No ___Not applicable

13c. (For U.S.-based respondents only) From which Federal agencies have you obtained financial assistance for 1988? (Check all that apply.)

___Air Force (including AFOSR)
___Navy (including ONR)
___Army (including ARO)
___Defense Advanced Research Projects Agency (DARPA)
___Strategic Defense Initiative Office
___Other U.S. Department of Defense agencies
___Other National security agencies
___NASA
___National Institute of Standards and Technology (formerly NBS)
___National Science Foundation
___U.S. Department of Energy
___U.S. Department of Transportation
___Other (specify)________________

G. R&D WORKFORCE

From this section we would like to know the size of the industrial superconductivity (HTS and/or LTS) R&D workforce and the ease or difficulty of finding trained superconductivity researchers.

14a. How many scientists and engineers were employed by your organization and engaged in all types of R&D activities (not just superconductivity) as of: January 1987?________________

January 1988?________________

14b. How many of these were employed in superconductivity (HTS and/or LTS) R&D as of January 1987 January 1988, and October 1988? (Report in the first column all individuals spending at least part-time on superconductivity, and in the second column those spending greater than 50% of their time.)

	Part-time	Greater than 50%
number of HTS researchers (Jan. 1987)	______	______
number of LTS researchers (Jan. 1987)	______	______
number of HTS researchers (Jan. 1988)	______	______
number of LTS researchers (Jan. 1988)	______	______
number of HTS researchers (Oct. 1988)	______	______
number of LTS researchers (Oct. 1988)	______	______

14c. Has the upsurge in superconductivity R&D activities required or induced you to hire new science and engineering personnel to pursue this work?

____Yes ____No

14d. Have you encountered significant difficulties in hiring appropriately trained science and engineering personnel to conduct superconductivity (HTS and/or LTS) activities?

____Yes ____No

14e. To what extent have you been able to reassign personnel already employed by your organization to fulfill your superconductivity (HTS and/or LTS) R&D personnel needs? (Check the percentage of your superconductivity R&D workforce that was assembled through reassignment rather than through new hires.)

Less than 25% ____25 to 50% ____51 to 7596 ____76 to 100%

Comments? ____

H. COOPERATIVE ARRANGEMENTS

This section is intended to give us a picture of the extent of cooperative arrangements between industry, universities, and the national labs at this point in time. Japanese respondents should report information only for cooperative efforts with institutions located in Japan. U.S. respondents should report information only for cooperative efforts with institutions located in the United States.

15a. Does your organization currently participate in any cooperative arrangements for HTS R&D with:

(Check one for each row)	Yes	No	No, but plan to
National labs?	____	____	____
Universities?	____	____	____
University-based consortia?	____	____	____
Other individual companies?	____	____	____
Industry consortia/associations?	____	____	____

____not applicable

15b. Please indicate below your company's expenditures on any collaborative superconductor R&D activities in 1987 and 1988. Report expenditures only for research performed outside your organization. List in the first column below only expenditures on researchers that are not working with you through their affiliation with other firms, universities, industry consortia, or university-based consortia.

1987

	Indiv. Researchers	Nat'l Labs	Other Industry*	University
HTS	$________	$________	$________	$________
LTS	$________	$________	$________	$________
Total	$________	$________	$________	$________

1988

	Indiv. Researchers	Nat'l Labs	Other Industry*	University
HTS	$________	$________	$________	$________
LTS	$________	$________	$________	$________
Total	$________	$________	$________	$________

* - Includes other individual firms, industry consortia, and industry associations.

I. COMMERCIALIZATION ATTITUDES

The aim of this section is to discover the attitudes of industry representatives about the commercialization and timing of superconductor-based products, and is not intended as a future prediction measure.

16a. Indicate below roughly in what year you first expect to reach market with a final product or process that is a result of your HTS R&D activity.

Year_______________

16b. What are the natures of these products/processes? (Check as many as apply.)

_____Computers/data processing
_____Cryogenic systems
_____Electrical machinery
_____Electronics/avionics
_____Fabrication equipment
_____Ground or sea transportation
_____Industrial processes
_____Magnets
_____Medical applications
_____Power applications
_____Scientific instruments
_____Space applications
_____Superconductor powders
_____Tape/Wire
_____Military
_____Unspecified commercial

17. List the companies world-wide that you think will be on the forefront in developing superconductor-related products in each of the following areas. (Mark no opinion where you are unfamiliar with the area.)

Area	Companies (up to five, in any order)	No opinion
Computers/data processing	______________________	____
Cryogenic systems	______________________	____
Electrical machinery	______________________	____
Electronics/avionics	______________________	____
Fabrication equipment	______________________	____
Industrial manufacturing	______________________	____
Magnets	______________________	____
Medical applications	______________________	____
Power applications	______________________	____
Scientific instruments	______________________	____
Superconductor powders	______________________	____
Tape/wire	______________________	____

Comments? ____

J. PRODUCTION AND SALES OF SUPERCONDUCTING COMPONENTS AND SYSTEMS

18. Estimate roughly your 1987 gross sales of products incorporating one or more superconducting components. (Rounded to the nearest thousand dollars).

$______________________

19. Estimate roughly the total number of jobs, in 1987, involved in the production of superconducting components or systems by your company.

____

K. TIME TO COMPLETE SURVEY

20. Please estimate how long it took you to fill out this form.

_____Less than 1 hour

_____1 to 2 hours

_____2 to 4 hours

_____4 to 8 hours

_____More than 8 hours

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY.

Please use the following space to comment on any aspect of superconductivity research, development and commercialization that was not sufficiently covered by this survey.

DEFINITIONS

Research and development(R&D) - Research and development includes basic and applied research in the sciences and in engineering, and design and development of prototype products and processes. For the purposes of this questionnaire, research and development includes activities carried on by persons trained, either formally or by experience in the physical sciences including related engineering, and the biological sciences including medicine but excluding psychology, if the purpose of such activity is to do one or more of the fallowing things:

1) Pursue a planned search for new knowledge, whether or not the search has reference to a specific application;

2) Apply existing knowledge to problems involved in the creation of a new product or process, including work required to evaluate possible uses; or

3) Apply existing knowledge to problems involved in the improvement of a present product or process.

R&D Scientists and engineers are defined as all persons engaged in scientific or engineering work at a level that requires a knowledge of physical or life sciences, engineering, or mathematics, equivalent at least to that acquired through completion of a four-year college program with a major In these fields, regardless of whether such persons hold a degree In the field. Exclude technicians and other supporting staff unless successful performance of their job responsibilities requires having the qualifications above.

Superconductivity - A physical state of a material in which the material presents zero resistance to an electrical current and simultaneously excludes magnetic fields (the Meissner effect).

HTS - high temperature superconductors These include: LaSrCuO materials; YBaCuO or other 1-2-3 materials; BISrCaCuO materials; TlBaCaCuO materials; BaKBiO materials; and other new materials with transition temperatures above 30K

LTS - low temperature superconductors These include: NbTi materials; NbN materials; NbSn materials; and other known LTS materials.

Industry associations - Consortia are defined as any research organizations comprised of industrial members, performing precompetitive research. (e.g., MCC, ISTEC)

Comments? Section - Use this part of each question to explain anything you wish about your answer or to provide your answer in a format not compatible with the question as asked.