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Measuring Service-Sector Research and Development

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Measuring Service-Sector Research and Development

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1 Introduction

The U.S. service sector is the largest sector in the economy[1] and accounts for an increasingly significant share of gross domestic product (GDP).[2] If we define the service sector as the nonmanufacturing, nonagricultural, nonmining, and nonconstruction sectors, it accounted for 78.9 percent of GDP in 2002 (Council of Economic Advisors, 2004) and for 83 percent of nonagricultural employees (Council of Economic Advisors, 2004). In addition to being a driving domestic economic force, service-sector revenues in the United States account for about one-third of service-sector revenues worldwide.[3]

Service-sector industries are characterized by a close interaction between production and consumption, high information content, the intangible nature of their output, and a heavy emphasis on labor capital in the delivery of their output (Sirilli and Evangelista, 1998). Historically, the service sector was viewed as having little or no productivity growth and an inability to innovate. It was also characterized by low-paying jobs, low levels of technological dependence, and a relatively undeveloped level of institutional organization (see Table 1-1). In contrast, the manufacturing sector, producing tangible outputs, was seen as the source of most innovation.

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[1]The service sector is also referred to as the nonmanuracturing sector. However, there is some disagreement among policy makers and economists as to a precise definition of what constitutes the service or service-providing sector.

[2]From a North American Industry Classification System (NAICS) data classification perspective, the definition of services is still evolving. See Mohr (1999).

[3]Between 1980 and 2001, revenues from U.S. service industries relative to the rest of the world have averaged 32.3 percent. See National Science Board (2004).

Table 1-1. Traditional Comparison of Manufacturing and Services Systems' Traits

System Trait	Manufacturing	Services
Intellectual property rights	Strong; patents	Weak; copyright
Technology orientation	Technology "push"; science and technology led	Technology "pull"; consumer/client-led (co-terminality)
Research/innovation	"In-house"	Out-sourced—embodied in purchases, inputs
Labor productivity	High impact	High impact (since the 1980s)
Innovation cycle times	Short	Long (except for computer services)
Product characteristics	Tangible, easy to store	Intangible, difficult to store
Spatial scale of system or "reach"	National, global	Regional, national

Source: Adapted from Howells (2000a).

The intangible nature of service products makes distinguishing between product and process difficult.[4] For this reason, industries in the service sector have traditionally been viewed as "laggards" or static, technology-consuming, noninnovative companies that provide nontechnical products (Tether and Metcalfe, 2002; Tether, Hipp, and Miles, 2001; Sundbo, 1997; Miles, 1993).

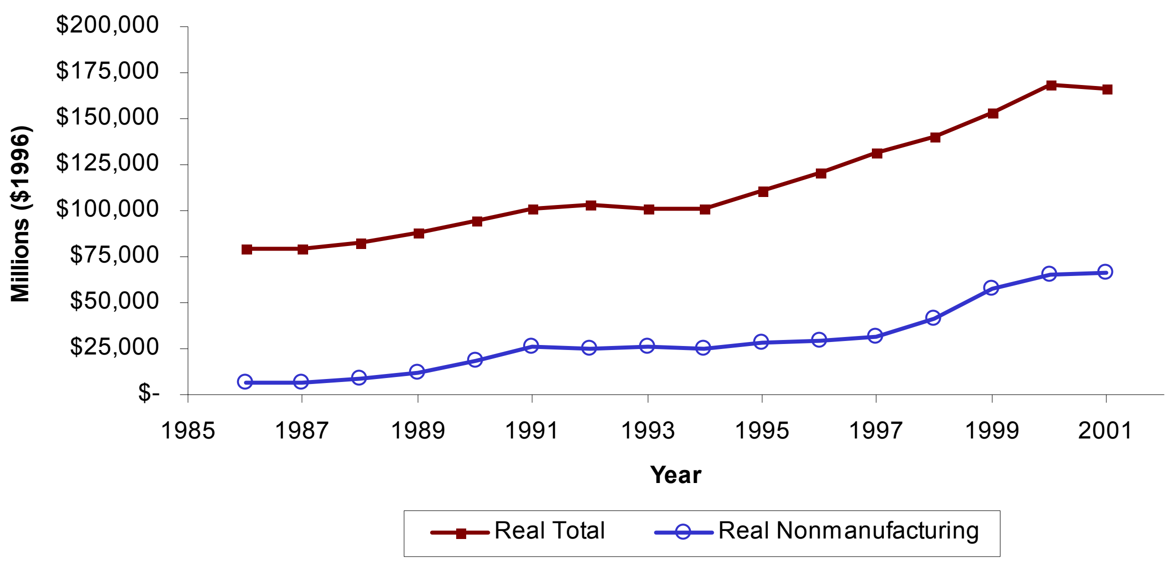
In recent years the service sector has come to be viewed as a dynamic component of the economy, characterized by the large consumption of new technologies and human capital. As one example, the observable growth in Internet and Web-based services and high-technology environmental services indicates that knowledge-intensive services are taking on a more active economic role (Howells, 2001). As a second example, the NAICS is revising its classifications to represent more accurately the evolving nature of services. Traditionally, services were described narrowly as discrete products. However, as the nature of services has become more complex largely because of technological advancements, service providers are offering bundles of products. As a result, organizations in the service sector are becoming more research intensive and are, in fact, taking on a central role in the innovation activities of their client industries.

[4]According to Mohr (1999 p. 4), "A service is a change in the condition of a person, or a good belonging to some economic entity, brought about as the result of the activity of some other economic entity, with the approval of the first person or economic entity."

1.1 TRENDS IN RESEARCH AND DEVELOPMENT (R&D) ACTIVITY

Innovative activity in the service sector is difficult to define. R&D activity in that sector has been measured using the RD-1 survey, which was primarily developed for manufacturing firms. Figure 1-1 shows real, inflation-adjusted R&D performed in industry (company and other, nonfederal funds for performance) over the years 1986 through 2001 in total and for nonmanufacturing (defined as total less manufacturing R&D).[5]

Figure 1-1. Real Industrial R&D, Total, and Nonmanufacturing Performance ($1996)

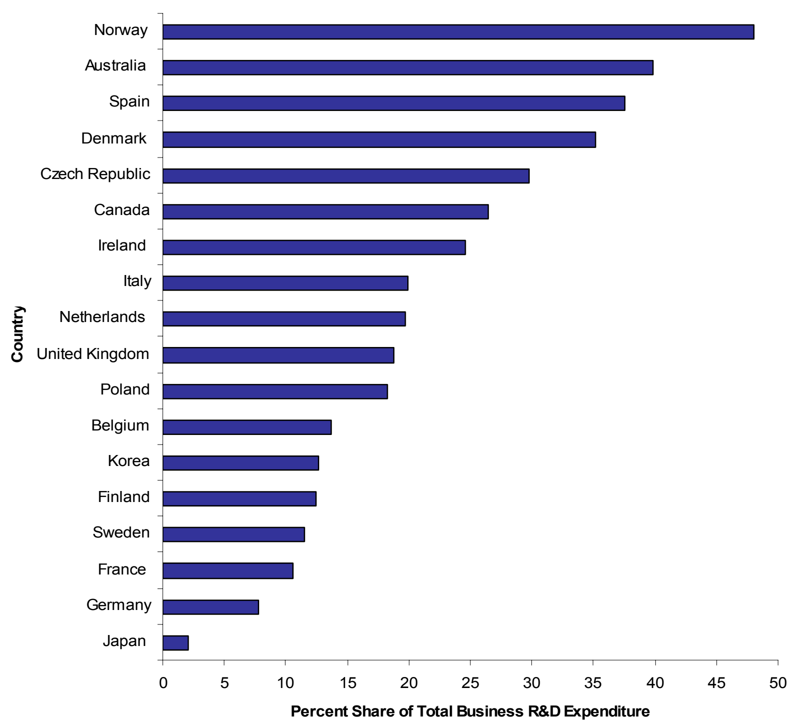


From a National Science Foundation (NSF) (2000) reporting perspective, the nonmanufacturing sector includes transportation and utilities (e.g., communications); trade; finance, insurance, and real estate; and services (e.g., health). In 2001, the nonmanufacturing share of total industry R&D was about 40 percent. That percentage, which was 38 percent in 1999, has increased steadily over the years shown, in part because of improved sampling procedures by NSF to collect nonmanufacturing sector data, as discussed below.

[5]Nominal R&D data came from NSF (1998). The calendar year GDP deflator was used to adjust for inflation (see National Science Board [2004] Appendix Table 4-1).

For purposes of comparison, the nonmanufacturing shares for selected Organisation for Economic Co-operation and Development (OECD) countries is shown in Figure 1-2 for 2001.[6] Except for several Scandinavian countries, the United States reports a larger share of its R&D as nonmanufacturing compared to most OECD countries.

Figure 1-2. Nonmanufacturing Share of Total Business R&D in 2001, Selected OECD Countries



1.2 INSTITUTIONAL HISTORY OF SAMPLING NONMANUFACTURING R&D FIRMS[7]

Since 1953, NSF has collected and published industrial R&D statistics. Historically, a sample of firms was selected every 4 to 6 years for the RD-1 survey. In the intervening years, a subsample of only the largest firms was surveyed. In the early years of the RD-1 survey, R&D was performed in a small number of industries, and it was reported along with

[6]See OECD (2003). Data in the figure are generally for 2001. The exceptions are Australia, France. Germany, Japan, Netherlands (2000), Ireland (1999), Denmark (1999), and Norway (1998).

[7]This section draws directly from Jankowski (2001) and from the technical notes in *Research and Development in Industry* (OECD, 2001).

a catch-all category of nonmanufacturing. For example, in 1987 a sample of about 14,000 firms was selected to receive the RD-1 form. From 1988 through 1991, about 1,700 of these firms were resurveyed, and about 300 of the 1,700 were companies from nonmanufacturing industries.

In the early 1970s, there was a general recognition at NSF that more detailed information on nonmanufacturing R&D was needed, and recognition continued into the 1980s. Beginning in 1987, NSF's annual R&D reports included R&D estimates separated into three broad groupings: communication, utility, engineering, architectural, research, development, testing, computer programming, and data-processing service industries; hospitals; and medical labs. By 1992, a decision was made to draw new samples annually with broader industrial coverage, increase the sample size from 14,000 firms to 23,000 firms, and add 25 new nonmanufacturing industries to the sampling panel. Included in these 25 new industries were finance, computer and other business services, and engineering and management services.[8] In 1992, the number of manufacturing firms nearly equaled the number of nonmanufacturing firms—11,818 compared to 11,558. However, in 1993 and 1994, the nonmanufacturing firms sampled fell below the number of manufacturing firms sampled.

In 1995, the sample of nonmanufacturers was expanded by 60 percent. In that year, R&D expenditures for the following industries were for the first time reported in *Research and Development in Industry* (OECD, 2001): transportation and utilities, including communications; trade; finance, insurance, and real estate; services, including computer-based business services, health services, and engineering and management services; and other. In 1998, 19,973 nonmanufacturing firms were surveyed compared to only 4,836 manufacturing firms.

1.3 UNRESOLVED ISSUES

Although NSF had responded to underrepresentation of the nonmanufacturing sector in national R&D statistics, it has done so using a single survey instrument, the RD-1 form that was originally developed on the basis of an understanding of the manufacturing innovation process (Link, 1996). By so doing, it is implicitly being assumed that the

[8]A complete listing of the new industries is in Technical Note 47 of *Research and Development in Industry: 2000* (OECD, 2001).

innovation process underlying the expenditure of R&D is the same in manufacturing as in nonmanufacturing.

The first objective of this report is to posit a model of the innovation process relevant to the nonmanufacturing sector, the service-providing or service sector in particular. This model is posited on the basis of both the extant literature and the information learned through case studies conducted in four industries. The second objective of this report is to recommend changes in the RD-1 form to capture more accurately firm investments in innovative activity.

1.4 FOCUS INDUSTRY CASE STUDIES

Throughout this report we draw inferences from case studies conducted for four service-sector industries:

- telecommunications
- software
- financial services
- research development and testing (RD&T)

The purpose of the case studies was to determine the nature of the innovation process therein and from that information glean an understanding of whether there are areas of significant over- or underreporting of R&D activities and to assess issues of misclassification. In addition, we investigated how each industry categorizes its own R&D activities and how these activities relate to NSF's definition of R&D.

1.5 OUTLINE OF THE REPORT

The remainder of the report is outlined as follows. Section 2 begins with the definition of R&D and current R&D statistics. Then we discuss measurement and classification issues related to service-sector R&D expenditures. Section 3 presents a model of service-sector innovation (largely based on four industry case studies that are presented in Appendix A through Appendix D) and discusses the process by which firms develop and acquire intellectual capital. Section 4 then presents taxonomies for service-sector R&D and provides recommendations for modifying and enhancing the RD-1 survey instrument used by the U.S. Bureau of the Census to collect R&D data.

2 Currently Reported Service-Sector R&D

Innovation and technological change in services are increasingly dependent on service-sector R&D, in addition to acquired technology (Pilat, 2001). As discussed in Section 1, the service sector accounts for an increasing share of total R&D expenditures in the United States. However, this trend is a result of many underlying factors, some of which reflect actual increases in R&D activities and some of which are reclassifications of R&D activities. In addition, there is concern that current R&D statistics do not fully capture the level of R&D activity being performed within the service sector or indirectly the level or rate of change of innovative activity therein.

This section begins by presenting the definition of R&D and current R&D statistics. We then discuss measurement and classification issues related to service-sector R&D expenditures.

2.1 DEFINITION OF R&D

For reporting purposes, R&D is defined slightly differently across different U.S. and international agencies. However, most U.S. agencies and many foreign agencies follow NSF's definition of R&D. The definition of R&D makes no distinction between manufacturing and service-sector R&D. However, as discussed in the following sections, determining which innovative activities targeted at developing new and improved services qualify as R&D under current definitions is less clear.

Based on NSF's definition, an activity is considered R&D if it is related to one or more of the following goals:

- Pursue a planned search for new knowledge, regardless of whether the search has reference to a specific application.

- Apply existing knowledge to problems involved in creating a new product or process, including work required to evaluate possible uses.
- Apply existing knowledge to problems related to improving a present product or process.

“Research” is defined as a systematic study directed toward fuller knowledge or understanding of the subject studied. “Development” is defined as the systematic use of knowledge or understanding gained from research, directed toward the production of useful materials, devices, systems, or methods, including the design or development of prototypes or processes.

Research is further classified as either basic or applied, dependent on the objectives of the investigator.

- Basic research is research directed toward increases in the knowledge or understanding of fundamental aspects of phenomena and of observable facts without specific application toward processes or products. This type of research is limited to the federal, university, and nonprofit sectors.
- Applied research is research directed toward gaining knowledge that will meet a specific need. This includes research for specific commercial objectives.

Development is defined as the systematic use of knowledge directed toward the production of a product, service, or method. This includes the design and development of prototypes and processes. However, it excludes quality control, routine product testing, and the development of internal software for internal business use.

Appendix E provides additional detail on NSF’s definition of R&D and also includes a discussion of R&D definitions used in Europe and for U.S. tax laws.

2.2 R&D EXPENDITURES BY SECTOR

NSF’s *Survey of Industry Research and Development* is the primary source of information on R&D performed within the United States. The survey results are used by government agencies, corporations, and research organizations to assess trends in R&D expenditures. The data are also used to investigate productivity determinants, to formulate tax policy, and to compare company performance with industry averages.

Table 2-1 summarizes U.S. R&D expenditures by industry. Manufacturing accounts for approximately 62 percent, with the largest sectors being classified under NAICS 33, which includes transportation equipment, electrical equipment, and metals. Nonmanufacturing accounts for the remaining 38 percent of U.S. industry R&D, with trade and scientific information R&D services accounting for the largest shares. The telecommunications sector is not disclosed but also accounts for a significant share of nonmanufacturing R&D.

Professional, scientific, and trade services account for 11 percent of U.S. R&D, with the two major sectors being scientific R&D services and computer system design and related services. Entities in these sectors are a combination of large and small companies and are engaged in a wide variety of activities ranging from systems integration to biotechnology research.

Table 2-1 also indicates the source of the funding—federal versus company. Federal funding accounts for approximately 10 percent of manufacturing R&D expenditure and 7.6 percent of nonmanufacturing's R&D.

2.2.1 R&D Flows Within and Between Sectors

It is widely accepted that a significant share of R&D conducted in the manufacturing sectors supports the provision of products and services provided by the nonmanufacturing sectors. Service-sector industries' increased reliance on information technology is a prime example. Using both direct R&D expenditures and indirect R&D consumed, such as R&D incorporated in equipment and intermediates, provides a different estimate of technology intensity for the service industry. In a study by Amable and Palombarini (1998), when assessing both direct and indirect R&D, some service sectors incorporate as much or more R&D into their products and services as compared with manufacturing industries.

However, with increased outsourcing, a growing share of R&D supporting the manufacturing sector is now captured under service-sector activities. For example, pharmaceutical companies use RD&T companies to conduct a significant amount of their Phase III testing for drug development, and manufacturing companies of all types are conducting less software development in house and relying on large computer and information service providers.

Table 2-1. R&D Expenditures

2000 Industry	NAICS Code	Total ($ millions)	Total (Basic, Applied, and Development): Percentage of Total	Federal ($ millions)	Company ($ millions)
All industries		**199,539**	**100.0%**	**19,118**	**180,421**
Manufacturing	**31–33**	**124,078**	**62.2%**	**13,328**	**110,750**
Food, tobacco, and textiles	31	1,828		(D)	1,828
Wood, paper, petroleum, coal, chemicals, plastics, and mineral	32	27,265		(D)	27,265
Metals, machinery, computer, electrical, transportation, furniture, and miscellaneous products	33	103,907		24,800	79,107
Other Manufacturing	339	2,642		93	2,549
Nonmanufacturing	**21–23, 42, 44–81**	**75,461**	**37.8%**	**5,790**	**69,671**
Trade	42, 44, 45	24,959	12.5%	30	24,929
Information	51	16,830	8.4%	540	16,290
Software	5112	12,639	6.3%	78	12,561
Telecommunications	5133	(D)	(D)	(D)	(D)
Other Information	51 (minus 5112, 5133)	2,844	1.4%	81	2,763
Finance, insurance, and real estate	52, 53	4,024	2.0%	0	4,024
Professional, scientific, and technical services	54	22,577	11.3%	4,628	17,949
Computer systems design and related services	5415	5,169	2.6%	226	4,943
Scientific R&D services	5417	12,892	6.5%	3,177	9,715
Other professional, scientific, and technical services	54 (minus 5415, 5417)	4,517	2.3%	1,226	3,291
Health care services	621–23	536	0.3%	59	477
Other nonmanufacturing	21, 22, 23, 48, 49, 55, 56, 61, 624, 71, 72, 81	6,515	3.3%	513	6,002

(D) = Not disclosed.

Source: NSF, 1998.

In addition, most service firms expect that their R&D activities will result in productivity impacts on their customers that include intermediate suppliers in both manufacturing and nonmanufacturing industries. This pushes the productivity effect to their downstream industries. Lecht and Moch (1999) found that R&D in information technology (IT) conducted by service-sector firms greatly affected the flexibility of manufacturers in adjusting products to customer needs, user-friendliness of the products, and the temporal availability of delivery speed.

Table 2-2 provides summary information that illustrates the flow of R&D for selected service industries. The table was constructed from the Bureau of Economic Analysis's (BEA, 1998) input-output tables in conjunction with NSF's sector-level R&D expenditures. A description of the underlying data and the calculations used in Table 2-2 is presented in Appendix C.

Table 2-2. R&D Intensity of Inputs and Value Added

	R&D Embedded in Inputs from Outside Sector (million $1998)	R&D Embedded in Inputs as a Share of Input Expenditures[a]	R&D Expenditures within Sector (million $1998)	R&D Expenditure as Share of Value Added
Telecommunications	$1,369	0.72%	$2,015	0.98%
Finance	$2,458	0.45%	$1,850	0.32%
Computer and data processing	$1,411	0.93%	$14,822	4.12%
Legal, engineering, accounting, and related services[b]	$693	0.53%	$11,835	4.81%
Health services	$3,316	1.08%	$1,207	0.26%

[a]Underreporting of service-sector R&D may be contributing to the relatively low R&D shares (%) for both inputs and expenditures.

[b]RD&T is included in this category.

Note: Sectors were built up from Standard Industrial Classification (SIC) code definitions and aggregated to represent service sectors of interest. Thus, R&D expenditures do not directly map to expenditures listed in Table 2-1 that are based on NAICS code definitions.

The first data column in Table 2-2 represents a measure of the R&D consumed by a sector through the products and services it purchases as inputs from outside its own sector. For example, an estimated $1,369 million in R&D is embedded in the inputs the telecommunications industry purchases from outside its sector (i.e., all nontelecommunications inputs). The second data column shows the relative level of R&D intensity of products and services purchased by each selected service sector. Health services have the highest share of embedded R&D in the inputs they purchase, reflecting large-scale purchases of medical equipment and medicine.

The third data column shows the R&D expenditures within each selected service sector, and the fourth column provides a measure of R&D intensity defined as R&D expenditures divided by value added. The table indicates that the highest levels of R&D intensity are in computer and data processing and legal, engineering, accounting, and related services (which includes RD&T). Telecommunications and finance both conduct approximately $2 billion in R&D per year, but this amount represents a smaller share of their total value added. Finally, the within-sector R&D conducted by health services and other business services is relatively small compared to their value added.

2.3 R&D MEASUREMENT AND CLASSIFICATION ISSUES

Worldwide, services account for an increasing share of reported R&D. However, the service sector's share of R&D varies greatly across OECD countries. For example, in Canada and Australia the service sector accounts for approximately 35 percent of industry R&D, whereas in the United States and Great Britain, the service sector's share is about 20 percent, and in Germany and Japan it is less than 10 percent (OECD, 2001). In contrast, the service sector's role in terms of its share of economic activity and growth is similar across most of the OECD countries.

These cross-country differences highlight the difficulties in identifying, measuring, and classifying R&D expenditures in the service sector. These issues are further complicated by the background of individuals completing the surveys and the diversity of business lines within modern evolving corporations.

2.3.1 Identifying Service-Sector R&D

Classifying innovative activities in the service sector as R&D-driven or not is frequently difficult. The service sector has developed and implemented significant innovations related to Web-based applications, information management, and data transfer. In addition, new sectors have evolved that supply system and component integration services to manufacturers and service providers. However, the historical view of R&D and product development (engineering design, prototype testing, and manufacturing process design leading to mass production) does not fit well when services are built on unique applications that are continually customized, incorporating incremental improvements (as opposed to discrete new product models or software versions).

The classical definitions of R&D are grounded in the creation of an "artifact" or physical product (Tether, Hipp, and Miles, 2001) and therefore are harder to apply to intangible outputs of services, such as methods or organizational theory. For example, Sundbo and Gallouji (1999) identify four major categories of service innovation—product, process, organizational, and market—not all of which are considered R&D. In addition, the difficult distinction in services between product and process, also referred to as "coterminality," often makes it difficult to interpret what is R&D and non-R&D (Evangelista, 1999; Sirilli and Evangelista, 1998).

2.3.2 R&D Measurement Issues in the Service Sector

Classifying Innovative Activities in the Service Sector as R&D vs. Non-R&D

In addition to identifying R&D activities, service-sector R&D is also inherently more difficult to measure. For example, R&D can be carried out in formal R&D departments or in an informal nature carried out in facilities where R&D is not the main activity. In theory, NSF's *Survey of Industry Research and Development* should identify and measure all resources devoted to R&D. However, breaking out informal R&D may be difficult or costly in some businesses.

Because service innovations are more likely to be customer driven, related R&D activities are typically integrated into user companies' business units. There is less likely to be a stand-alone R&D facility or division in which R&D activities can be readily quantified by existing accounting systems.

Service innovation is more likely to be carried out in a multidisciplinary business unit that combines IT system integrators, managers, and market researchers. This places more responsibility on the organization to determine what share of its innovation expenditures is to be classified as R&D when completing the survey.

In addition to business units composed of teams of multidisciplinary staff, it is also common for individual staff members supporting innovation in the service sector to have multiple responsibilities and functions. For example, IT managers need to maintain and improve their networks and systems. It is not uncommon for them to spend part of their time managing and overseeing the day-to-day operations of the system and also to contribute to developing the next generation system or service. Again, this makes quantifying R&D difficult, because fractions of expenditures based on existing accounting systems (primarily staff labor) need to be assigned as R&D.

Multidisciplinary business units and staff with multiple responsibilities are not business structures unique to the service sector. IT managers in manufacturing companies also pose the same measurement issues. However, the problem has historically been more pervasive in service firms because the R&D supplier and user are more often the same firm, implying that the same individual can be involved in operations/delivery and R&D activities.

2.3.3 Industry Classification Issues

Because the *Survey of Industry Research and Development* is enterprise based, NSF tabulates each establishment by the major NAICS code of the company as determined by the company's payroll. This results in all of a firm's R&D expenditures being assigned to a single NAICS category, regardless of the actual focus of R&D activities.

The industry sector to which R&D expenditures are assigned may have little relationship to the underlying focus of R&D activities (Payson, 1999). For example, in the health care industry, continual innovation in medical services results from R&D performed outside the health services industry in the manufacturing of pharmaceuticals and medical equipment (Jankowski, 2001).

Large conglomerate and diversified companies may be a major source of industry misclassification. For example, patent-holding companies account for a large share of R&D reported as being conducted by the financial services sector. As a result, a large share of the R&D reported under finance (NAICS 52,53) is associated with biotech and pharmaceutical research and is virtually identical to R&D conducted in the chemical industry. However, because of ownership, this R&D is classified under financial services even though it is not related to the provision of financial services such as banking or stock market transactions.

Similar issues exist in the RD&T sector in which outsourcing has resulted in a shift of activities previously classified as manufacturing R&D to now being classified as service-sector R&D. Outsourcing does not change the fundamental research activities being conducted, but it does have the potential to change its industry classification.

A parallel but opposite trend is that many service activities, and hence their supporting R&D, have migrated from the service sector to the manufacturing sector. Many large manufacturers have financing divisions that compete directly with traditional financial service companies. This trend in bundling products and services includes maintenance and in many cases has evolved to the provision of the full service provided by the manufacturer's product. Xerox was one of the first manufacturing companies to provide full-service leases, in effect selling the service of copying. Today, full-service leases are common in automotive, aircraft, and agriculture equipment industries. They are also common in these industries for companies that provide financing services. Thus, industry misallocation of R&D activities (service related vs. manufacturing related) may go both ways.

Misallocation due to servicisation also implies that, if service R&D measurement issues discussed above are leading to underrepresentation of service R&D expenditures, this could affect both the manufacturing and service sectors. For example, if manufacturing firms do not completely capture their service R&D as they increase service provision, this could result in misleading trends in decreased R&D intensity for some manufacturing sectors.

2.4 SUMMARY OF COMPOSITION OF CURRENT R&D STATISTICS

Current institutional definitions of R&D are not completely applicable for the service sector because the historical definitions and examples have evolved primarily to characterize manufacturing-sector R&D activities. As a result, the definition of which service activities fall under the R&D classification may not accurately or fully capture service-sector R&D. A review of existing literature and informal interviews with industry have led to two preliminary observations.

First, it appears that the distinction between the manufacturing and service sectors is becoming increasingly blurred. For example, preliminary case-study research and interviews indicate that in some industries, a significant share of the R&D reported under service-sector NAICS codes is product/production-related research outsourced from traditional manufacturing sectors. Also, published literature highlights the trends of manufacturing firms increasingly providing services and hence conducting service-related R&D activities.

Second, the industry misclassification issue, driven by the unavoidable need to aggregate R&D to the establishment level, has led to uncertainty in trends for R&D activities targeted at service innovation (i.e., efforts targeted at advancing the provision and content of services). A significant amount of literature has been devoted to discussing misclassification issues with little success at quantifying the impacts on aggregate R&D statistics used for policy analysis. As a result, what is lost is the potentially important distinction between R&D expenditures targeted at enhancing manufacturing vs. service activities across ***all*** sectors of the economy. This distinction may be as important as gaining a better understanding of the types of R&D activities conducted by manufacturing vs. service-sector firms, as classified by establishment NAICS codes.

3 Innovative Activity in Services

As stated in Section 1, a purpose of this report is to posit a model of the innovation process relevant to the service-providing or service sector. Such a model is important because it serves as a basis, or conceptual framework, for policy recommendations regarding changes in the RD-1 form. It highlights differences in service-sector investments in innovative activity from the manufacturing sector and more broadly helps to inform policy makers about unique characteristics and interrelationships associated with innovation in the service sector.

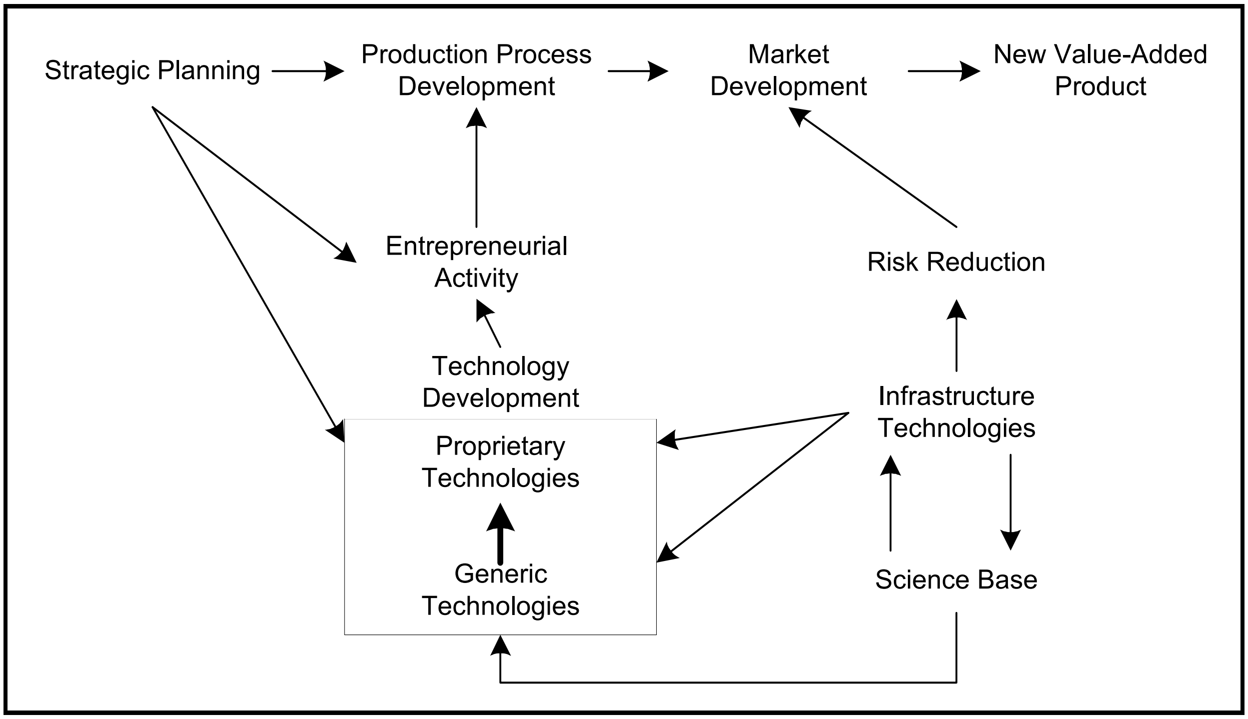
For decades, academics and policy makers have theorized about the innovation process as it relates to traditional manufacturing firms. This was logical because innovative activity had long been unique to manufacturing firms. Also, Vannevar Bush's report, *Science—The Endless Frontier* (1945) sowed the seeds for thinking of innovation in a linear framework because that is what was observed in practice during the post-war era. However, the United States is no longer an economy in which manufacturing dominates, and innovative activity and R&D spending are no longer the sole purview of manufacturing firms.

As a benchmark for understanding innovative activity in service firms, we begin with a basic model of innovation activity in manufacturing.

3.1 INNOVATIVE ACTIVITY IN MANUFACTURING

A well-established model of innovation activity relevant to a technology-based manufacturing industry comes from Tassey (2005). Figure 3-1 illustrates the different technology elements, which have slightly different degrees of public good attributes. These distinctions make the Tassey model especially relevant for policy analysis, but also useful as a

Figure 3-1. Model of Innovation in a Technology-Based Manufacturing Industry



benchmark for manufacturing and thus a point of departure for modeling service-sector innovation.

At the root of the model is the science base, referring to the accumulation of scientific and technological knowledge. The science base resides in the public domain. Investments in the science base come from basic research primarily funded by the government and primarily performed globally in universities and federal laboratories.

In the manufacturing industry, technology development, in the form of basic and applied research, generally begins within industrial laboratories. It involves the application of scientific knowledge toward the proof of concept of a new technology. Such fundamental research, if successful, yields a prototype or generic technology. If the prototype technology has potential commercial value, follow-on applied research takes place toward development, and if successful, a proprietary technology results.

Basic, applied, and developmental research occur within a firm as a result of the firm's strategic planning and guide entrepreneurial activities. Entrepreneurial activity implies perception of opportunities and the ability to act on those perceptions (Hébert and Link, 1988). Much of the product and process development research is conducted as part of the entrepreneurial activity.

Infrastructure technologies, or infratechnologies, support the processes that lead to both generic and proprietary technologies. Infrastructure technologies are a diverse set of technical tools that are necessary to conduct all phases of R&D efficiently. Following Tassey (1997, 2005), examples of infrastructure technologies include measurement and test methods, process and quality control techniques, evaluated scientific and engineering data, and the technical basis for product interfaces.

The managerial skills necessary for a firm to move its proprietary technologies to a value-added product or process are also shown in Figure 3-1. After production, market development takes place. Markets do not always accept new technology for a number of reasons, including transaction costs associated with verification of the new technology’s attributes and interoperability of the new technology with existing technologies. Infrastructure technologies can reduce such risks and thus speed market development.

3.2 INNOVATIVE ACTIVITY IN THE SERVICE SECTOR

To compare and contrast the established manufacturing innovation model with innovation in services, we conducted four case studies investigating telecommunications, financial services, systems integration services, and RD&T services. Each case study is discussed in detail in Appendices A through D.

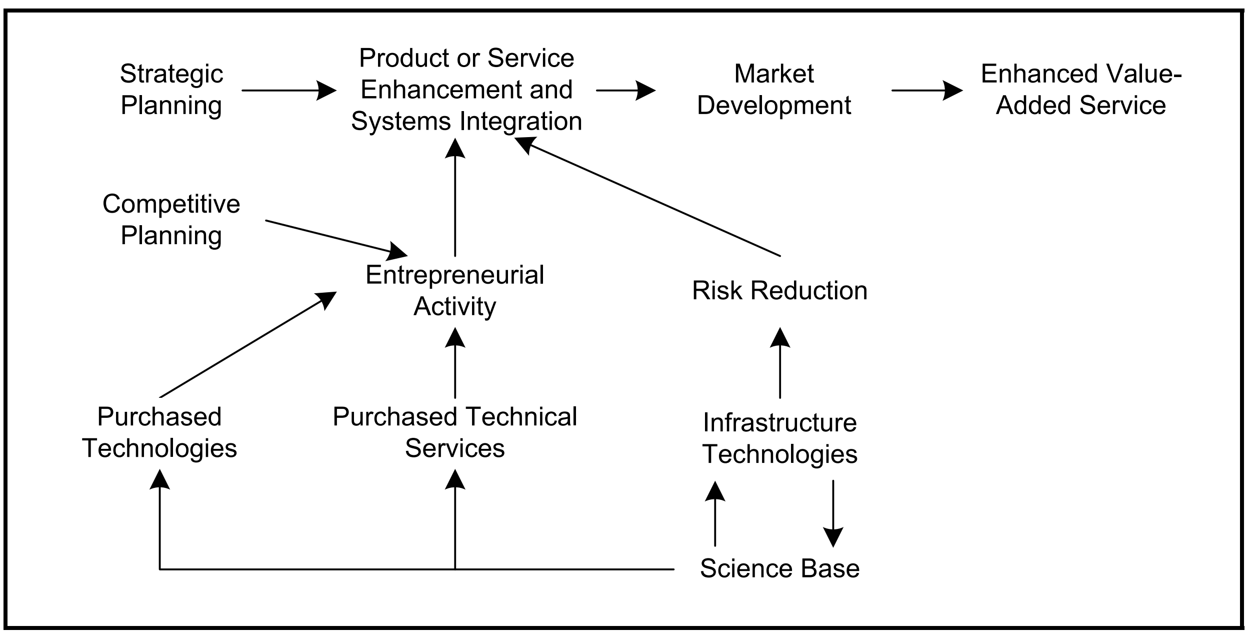
Based on the case studies, several themes emerge regarding innovative activity in service sectors. Many of the fundamental characteristics of the innovation process differ between manufacturing and services. These include the following:

- **Ability to develop and protect proprietary technologies**: Imitation is simpler in the services sector—process/system patents are more difficult to obtain and protect.
- **Incremental nature of innovation versus discrete technology transition/obsolescence**: Because of competitive pressures and the relatively low cost of modifying service provision (compared to changes to manufacturing processes), services are continually evolving.

- **Degree of interoperability required among related technologies**: Service innovations involve interactions among many products and systems, and a large part of the R&D process involves systems integration. In addition, because services are less likely to be stand-alone products, they need to be integrated with larger IT and societal systems.
- **Ability to build prototypes or conduct tests in a controlled environment**: Services need to be tested with real customers, making it difficult to isolate R&D testing activities in stand-alone laboratories, limiting the number of tests that can be performed, and increasing the cost of poor performance or failures.

Based on these generalizations, Figure 3-2 is posited as representative of an economic model of innovation in a technology-based service industry. A mathematical model of the process underlying Figure 3-2 is in Appendix F. The following discusses the components of the innovation process in the service sector and describes how they differ compared to their manufacturing counterparts.

Figure 3-2. Model of Innovation in a Technology-Based Service Industry



Strategic Planning. Both manufacturing and service innovation processes are driven by strategic planning. However, service-sector activities are more influenced by competitive planning because the technology-based service firm is more likely to innovate on the basis of customer input and on the basis of competitors that continually seek to challenge the firm for its customers. Whereas manufacturing firms strategically formulate road maps for developing new emerging technologies, in the service-sector firms strategically formulate road maps for deploying modifications of existing products. Because manufacturing firms are more likely to target discrete technology jumps, creating new technologies that make their competition obsolete, their strategic plans are long term and are linked less to current competitive planning. In contrast, service firms' strategies are typically focused on retaining or gaining market shares and involve more continual/incremental transition strategies that are/will be integrated with competitive planning.

Entrepreneurial Activity. Both strategic and competitive planning drive the firm's entrepreneurial activity. Whereas entrepreneurial activity drives the manufacturing firm toward the production of new products and processes, the entrepreneurial activity of the service firm drives enhancements (redesign or reconfigure) of its existing products. At the root of entrepreneurial activity are others' intellectual capital and technologies that are licensed or purchased to meet the firm's road maps for deploying modifications of its existing products.

This product and service enhancement often involves system integration where systems integration facilitates the intersection of hardware, software, and the synthesis of application domains such as finance, manufacturing, transportation, and retail.

Technology Development. A key distinction between manufacturing and service firms' R&D is that manufacturing firms conduct a larger share in house, and the output of that internal activity is more likely to be a proprietary technology. In the service sector, little research (R) occurs in house, and the development (D) activity that occurs is primarily related to enhancing, redesigning, or reconfiguring others' proprietary technologies.

Whereas manufacturing firms license/purchase others' technologies in the form of intellectual capital or equipment to be used to produce proprietary technology, service firms purchase others' technology in the form of equipment to be modified and integrated into their operational system to deliver modifications to existing products. In addition, manufacturing firms strategically, through their research, introduce new technologically advanced products and processes to *anticipate* new consumer wants; whereas service firms strategically, through information gathering, modify existing products to meet *existing* consumer needs.

Science Base. Both manufacturing and service innovation is built on the scientific base of knowledge. The manufacturing sector is more likely to build on the science base directly or in collaboration with universities. In contrast, the service sector purchases inputs (products and services) that have incorporated others' research from the science base.

Infrastructure Technologies. The role of infrastructure technologies is different between the two sectors. Whereas infrastructure technologies reduce the market risk (from the introduction into the market of a new product or process) of the manufacturing firm, infrastructure technologies ensure that purchased technologies interface or integrate with the service firm's existing systems. Such infrastructure technologies emanate from the science base, and it is the science base that is at the root of purchased technologies.

Risk Reduction. An important component of the innovative process in both manufacturing and service sectors is risk reduction. However, the focus of the activities differs. In the manufacturing sector, innovation is likely to be less integrated with marketing. Once a new product has been designed and tested, technical risk may be relatively low, but market risk may be significant because the product needs to be accepted and integrated into existing systems. In contrast, service-sector innovation is more likely to involve enhancements to products in existing markets, lowering market risk. However, limitations and the cost of testing increase technical risk, making risk reduction a key objective of the product enhancement phase of service innovation.

3.3 DIFFERENCES WITHIN SERVICE-SECTOR INNOVATION ACTIVITIES

Figure 3-2 presents a generic model of innovation in a technology-based service industry. However, as the four case studies included in the appendices confirm, the service sector is an extremely diverse set of industries. One difference that is important for identifying R&D activities is the distinction between

- firms that assimilate technologies to provide enhanced services, and
- firms that provide/develop technology as a service.

Figure 3-2 illustrates the process by which service firms access and integrate technology with the goal of developing and providing enhanced services to their customers. These firms lead the strategic planning and entrepreneurial activities, as well as market deployment. They are likely to be heavily involved in the final stages of developmental research but may outsource a large share of the applied research and early stage developmental research. Their role is often an integrator of existing technologies; however, they may also outsource significant systems integration activities. Telecommunications- and financial services-sector firms are examples of technology integrators.

In contrast, many service firms provide research as their primary service. These firms provide a key input into entrepreneurial activities similar to the purchase of technology embedded in products or licensing of technology. These include biotechnology firms in the RD&T sector as well as systems integration firms in the information services sector. In many ways technology/research service providers follow an innovation process similar to that illustrated in Figure 3-2. They conduct strategic planning, build on the scientific base, leverage purchased technologies and manage risk—all as part of their innovative process to remain competitive. However, the distinction is that a much larger share of their activities is likely to be classified as formal R&D as opposed to non-R&D innovative activities.

4 Recommendations for the RD-1 Survey Instrument and Instructions

One goal of this study is to make recommendations for more accurately measuring service-sector R&D; thus, most recommendations are proposed changes in terminology and examples to clarify the innovative activities conducted by service firms that qualify as R&D expenditures. A second goal of this study is to achieve the first goal in a manner that facilitates meaningful comparisons between manufacturing R&D and service-sector R&D investments.

To these ends, recommendations are put forth for modifications to existing questions and for new questions that could be added to the RD-1 instrument. The recommendations were developed in light of the following assumptions and limitations:

- There will remain only one survey instrument (i.e., separate surveys for manufacturing and nonmanufacturing are not a viable option at this time).
- The core definitions of basic, applied, and developmental research will not be changed to maintain longitudinal consistency.
- The length (burden) of the survey will not be increased significantly.

This section begins with recommendations for modifications to the existing survey instrument and to the survey instructions. Each recommendation contains specific suggestions along with the general rationale and relevance for the service sector. Recommendations are presented in the order in which they occur in the 2003 RD-1 survey and its instructions (see Appendix F). They are followed by suggestions for new questions that could be added to the RD-1 to better assess activities and trends in service-sector R&D and innovation in general.

4.1 RECOMMENDATIONS FOR EXISTING SURVEY INSTRUMENT AND INSTRUCTIONS

4.1.1 Recommendation for Title

Change the name of the survey from "Industrial" R&D to "Private Sector" R&D.

Rationale

The survey is no longer administered solely to industrial firms.

4.1.2 Recommendation for the Definition of R&D in the Instructions

State that expenditures qualifying under the NSF's definition of R&D should be reported even if they are not classified internally by the organization as R&D or even if staff are not specifically classified as R&D personnel.

Rationale

R&D activities are frequently decentralized through different business units in the service sector. Particularly, the IT staff members in small to medium-sized organizations are likely to split their time between R&D activities and internal system operations.

4.1.3 Recommendation for Question 3

Either expand the scope of full-time equivalent personnel referenced in Question 3 to include any IT and information management specialists or add a separate question that focuses on research conducted by these specialists.

Rationale

In the service sector, workers other than computer scientists and engineers are critical to the process of development, but the term "computer scientist" may not cover all the IT and information management research activities being conducted in the service sector. Computer science may be interpreted as primarily hardware and software development. Information management encompasses information security, reliability, and accessibility research.

4.1.4 Recommendations for Question 4

a) In Question 4.C, define development to more closely align with the description of development in the instructions to RD-1.

Rationale

In Question 4.C, the description of development emphasizes the transformation of research into new or improved goods, but in the instructions the emphasis is broader—on transforming knowledge toward not only new or improved goods but also toward product and process improvements. In the service sector, the latter is critically important. A potential change would be to emphasize in the instructions "systems engineering" as an important part of R&D to capture service companies' integration of hardware and software imported from manufacturing.

b) Break "Company and other" column into "R&D internally funded" (overhead or internal IR&D projects) and "Nongovernment external funding" (i.e., contract research or part of services provided).

Rationale

This change would provide insights into the motivation and initiatives driving R&D in the service sector. For example, RD&T firms could be conducting entrepreneurial R&D research for themselves or they could be conducting outsourced R&D research on behalf of other companies.

c) Expand the examples in the instructions describing development (page 10) to include more service-sector activities, such as systems integration services.

Rationale

The term "software development" may be too restrictive because it implies that only commercial, off-the-shelf software development qualifies as R&D. Customization and systems integration research should also be included.

4.1.5 Recommendation for Question 7: Source of Federally Funded R&D

Add India and China to the list of countries in 7B.

Rationale

The relatively low wages of computer scientists and engineers in these countries make them attractive in a global research market.

4.1.6 Recommendation for Question 8: Source of Federally Funded R&D

Add NIH to the list of options.

Rationale

Health-related research is an important and growing part of service-sector R&D.

4.1.7 Recommendation for Question 9: Types of R&D Expenses

In the instructions, add guidance or procedures for estimating what share of building/equipment depreciation or secretaries are allocated to R&D. The issue is that a company with a centralized R&D laboratory counts the entire building and all support staff as an expense. Companies, especially service-sector companies, with decentralized or fragmented R&D activities will need guidance on what to count.

Rationale

In general, this may be too difficult or time consuming to estimate, and it may be a source of underreporting. The survey needs to address the situation where a division or group of staff members spends only some fraction of their time on R&D activities. This is much more common in the service sector.

4.1.8 Recommendations for Question 10

a) Regarding Question 10.A.4, list specific areas here, such as the modification of purchased technology or the integration of purchased technologies into an internal system, and then add 10.A.5 as Other Areas.

Rationale

In services, the role of purchased technology that is either modified toward new or improved products/services or integrated into systems that provide new or improved products/services is dominant.

b) In Question 10A.2 change “software development” to “software and *information systems* development.”

Rationale

As previously discussed, the term “software development” is too restrictive.

4.1.9 Recommendation for Question 13

Add "Industry Consortium" to the list of collaborators identified in Question 13.

Rationale

There is an increasing trend for service firms to perform their R&D cooperatively through consortia and other partnership mechanisms.

4.2 NEW QUESTIONS

The following are new questions that potentially could be added to the RD-1 survey to gain more insight into the differences between service-sector and manufacturing R&D, in particular, and service-sector and manufacturing-sector innovation, in general.

4.2.1 New Question #1

What share (%) of your company-funded R&D is targeted at developing

- ___ generic/fundamental technologies?
- ___ discrete proprietary technologies (including distinctly new service innovations)?
- ___ entrepreneurial proprietary technologies (systems design improvements, organizational/delivery modifications)?
- ___ infrastructure technologies?

Rationale

Service-sector firms are more likely to engage in entrepreneurial (systems design improvements, organizational/delivery modifications) innovative R&D and less likely to develop proprietary technologies. However, the share of activities devoted to infrastructure technologies is unclear because of the series sectors focus on information services.

4.2.2 New Question #2

What share (%) of your company-funded R&D is conducted in conjunction with

- ___ your company's marketing department?
- ___ your customers?
- ___ your suppliers?

Rationale

Little is known about service-sector firms' involvement in collaborative research relationships. Collecting such information may indicate that service-sector firms engage in similar or different R&D strategies.

4.2.3 New Question #3

Company-funded R&D represents what percentage of your investment in product or process innovation?

Rationale

Formal R&D represents a smaller share of innovative activity for service-sector firms compared to manufacturing firms. Thus, R&D expenditures alone many not be an accurate measure of innovative activity or future productivity trends.

4.2.4 New Question #4

What share (%) of the R&D conducted by your company is performed at the following venues:

- ___ centralized R&D laboratories or science parks?
- ___ decentralized business units?
- ___ customers' facilities?
- ___ others?

Rationale

R&D conducted at decentralized locations or on customers' premises is more difficult to measure and may be underreported.

4.2.5 New Question #5

What share (%) of your company's R&D would you describe as

- ___ parallel research between two competing companies that results in almost identical products?
- ___ research associated with integrating technologies acquired from outside the company (embedded in purchased or licensed products or processes)?
- ___ research associated with adopting an existing technology or process?
- ___ entrepreneurial activities associated with system improvements?

Rationale

In manufacturing, research to develop generic and proprietary technologies is at the core of the innovative process and is unambiguously R&D. In services, entrepreneurial activities are at the core of the innovative process. It is unclear what share of these activities is being reported as R&D versus non-R&D innovative activities.

References

Amable, Bruno, and Stefano Palombarini. 1998. "Technical Change and Incorporated R&D in the Service Sector." OECD. <http://netec.mcc.ac.uk/WoPEc/data/Papers/ cpmcepmap9808.html>.

Bureau of Economic Analysis (BEA). 1998. Annual Input-Output (I-O) Accounts Data. Washington, DC: BEA. <http://www.bea.doc.gov/bea/dn2/i-o_annual.htm>.

Bush, Vannevar, United States Office of Scientific Research and Development. 1960. Science, The Endless Frontier. A Report to the President on a Program for Postwar Scientific Research. July, 1945, *Science—the Endless Frontier.* National Science Foundation, Washington DC.

Council of Economic Advisors. 2004. *Economic Report of the President.* <http://www.gpoaccess.gov/eop/index.html>.

Evangelista, Rinaldo. 1999. *Knowledge and Investment.* Northampton, MA: Edward Elgar Publishing Inc.

Hébert, Robert F., and Albert N. Link. 1988. *The Entrepreneur: Mainstream Views and Radical Critiques,* Second Edition. New York: Praeger.

Howells, Jeremy. 2000a. "Services and Systems of Innovation." In Birgitte Andersen, et al. (eds.), *Knowledge and Innovation In the New Service Economy.* Northampton, MA: Edward Elgar Publishing Inc.

Howells, Jeremy. 2001. "The Nature of Innovation in Services." *Innovation and Productivity in Services. OECD Proceedings Industry, Services and Trade*. Paris: Organisation for Economic Co-operation and Development (OECD).

Jankowski, John E. 2001. "Measurement and Growth of R&D Within the Service Economy." *Journal of Technology Transfer* 26:323-336.

Lecht, Georg, and Dietmar Moch. 1999. "Innovation and Information Technology in Services." *Canadian Journal of Economics* 32(2):363-383.

Link, Albert N. 1996. "On the Classification of Industrial R&D." *Research Policy* 25:397-401.

Miles, Ian. 1993. "Services in the New Industrial Economy." *Futures* July/August:653-672.

Mohr, Michael F. 1999. "Identification and Classification of Service Projects: Phase I of an Initiative to Create a North American Product Classification System." Mimeograph. <http://www.census.gov/eos/www/napcs/papers/cacapr99.pdf>.

National Science Board. 2004. *Science & Engineering Indicators, 2004.* Arlington, VA: National Science Foundation.

National Science Foundation (NSF). 1998. "Survey of Industrial Research and Development." <http://www.nsf.gov/sbe/srs/nsf01305/pdf.start.htm>.

National Science Foundation (NSF). 2000. "Research and Development in Industry: 1998 Detailed Statistical Tables." Arlington, VA. <http://www.nsf.gov/sbe/srs/nsf01305/pdfstart.htm>.

Organisation for Economic Co-operation and Development (OECD). 2001. *Research and Development Expenditure in Industry 1987-1999*. Paris: OECD Publication Service.

Organisation of Economic Co-operation and Development (OECD). 2003. "The Science, Technology and Industry (STI) Scoreboard 2003—Towards a Knowledge Based Economy." Paris: OECD. <http://www.oecd.org/document/21/0,2340,en_2649_33703_16683413_1_1_1_1,00.html>.

Payson, Steven. 1999. "National Patterns of R&D Resources: 1999." NSF 99-335, Arlington VA. <http://www.nsf.gov/sbe/srs/nsf99335/pdf/nsf99335.pdf>.

Pilat, Dirk. 2001. "Innovation and Productivity in Services: State of the Art." In *Innovation and Productivity in Services*, pp. 17-58. Paris: Organisation for Economic Co-operation and Development (OECD).

Sirilli, G., and R. Evangelista. 1998. "Technological Innovation in Services and Manufacturing: Results from Italian Surveys." *Research Policy* 27:881-899.

Sundbo, Jon. 1997. "Management of Innovation in Services." *The Services Industries Journal* 17:432-456.

Sundbo, Jon, and Faïz Gallouji. 1999. "Innovation in Services in Seven European Countries." Report to the EU Commission. Research report 99:2, Roskilde University, Roskilde.

Tassey, Gregory. 1997. *The Economics of R&D Policy.* Westport, CT: Greenwood Publishing Company.

Tassey, Gregory. 2005. "Underinvestment in Public Good Technology." *Journal of Technology Transfer* 30(1-2):89-113.

Tether, Bruce, and Stan J. Metcalfe. 2002. "Services & Systems of Innovation." Paper presented at the DRUID Academy Winter Ph.D. Conference, Aalborg, Denmark.

Tether, Bruce, Christiane Hipp, and Ian Miles. 2001. "Standarisation and Specialisation in Services: Evidence from Germany." *Reseach Policy* 30:1115-1138.

Appendix A: Telecommunications Sector

Telecommunication has facilitated the “death of distance,” enabling service providers and users to conduct business without regard to geographical location. Information and communication technology has become an inseparable component of any business in the economy of the 21st century. The telecommunications industry’s innovations have lowered transaction costs to domestic businesses and individuals through continued efforts toward developing and improving standards, technological infrastructure, reliability, and security. R&D in the telecommunications industry ranges from basic and applied research for electronic devices to development for the integration of networks and systems. However, almost all of the R&D expenditures reported for NAICS 5133 appear to be directly related to the provision of communications services.

This appendix begins with a profile of the telecommunications industry and its ongoing R&D expenditures and activities. We then present a case study focused on the development of wireless communications (specifically, Wi-Fi [short for wireless fidelity] applications) to investigate the roles different stakeholders play in the technology development and deployment process.

A.1 INDUSTRY PROFILE AND R&D STATISTICS

The telecommunications industry consists of a broad range of firms operating, maintaining, or providing access to facilities for the transmission of voice, data, text, and full motion picture video between network termination points and telecommunications reselling. Local, long-distance, and international voice telephony and data transmission services are the three main sources of service provider revenue. In 1997, total revenue for this sector exceeded $260 billion with employment of approximately one million.

In recent years, the telecommunications industry has been integral in the development of the information economy. Telecommunications is a dynamic industry that has undergone tremendous change. Today's telecommunications market is the product of deregulation, consolidation, and technological innovations.

During the 1980s, partial deregulation focused on long-distance operators at a modular point of intersection between local and long-haul voice networks. Deregulation intensified in the 1990s, resulting in the 1996 U.S. Telecommunications Reform Act. This prompted investment for innovations in areas outside the traditional telephone market of the telecommunications industry. The local area network (LAN), a simple, flexible technology enabled by Internet protocol (IP) and ethernet standards, spawned innovations such as the multiprotocol router that disrupted a series of highly reliable but rigid incumbent technologies and accelerated the rise of a new paradigm. Improvements in Voice over IP (VoIP) technology are finally enabling the multiplexing of voice, video, and data onto a single data network (Christensen, Anthony, and Roth, 2001).

Once closely linked, division has emerged between transport and services since the emergence of IP networking. IP networking allows the decoupling of network services from their reliance on transmission media. Another important distinction is that of wireless versus wired connections. Although still dependent on the transmission network infrastructure for origination and completion, wireless technologies have untethered devices from the Public Switched Telephone Network (PSTN) and enterprise data networks, creating new opportunities associated with mobility.

Regarding the size (sales) and technology areas of telecommunication companies, the top 10 publicly traded telecommunication companies are listed in Table A-1. R&D expenditures for most large companies are not available in COMPUSTAT.

Table A-1. Top 10 Telecommunications Firms by 1999 Sales

Name	NAICS	Number of Firms	Sales ($ millions)	R&D ($ millions)	Employment (thousands)	R&D Intensity ($/employee)
Wired telecommunications carriers	5171	72	$271,927	$314	811	$388
Wireless telecommunications carriers (except satellite)	5172	41	$79,937	$16	176	$91
Telecommunications resellers	5173	15	$3,316	$10	12	$887
Satellite telecommunications	5174	8	$7,625	$33	3	$9,635
Cable and other program distribution	5175	13	$22,159	$56	74	$748
Other telecommunications	5179	23	$3,635	$74	21	$3,488
Telecommunications	517	172	$388,598.82	$503.44	1,097.64	NA

NA: not available from COMPUSTAT.

Source: COMPUSTAT, 2003.

AT&T, the largest company by sales, had R&D expenditures of $550 million in 1999. The firm provides a variety of services covering the spectrum of media delivery systems, from television and telephone to Internet and satellite. AT&T operates its own R&D research labs working on innovations in communications based on network operations, IP applications, and systems automation, in addition to other more long-term interests in communications technology. GTE, which is currently owned by Verizon, reported $131 million in R&D in 1999. Verizon specializes in telephone services through wire line and cellular telephone technology designed for personal or business applications. Verizon also acts as an Internet service provider (ISP) with digital subscriber line (DSL) capabilities.

Table A-2 provides a list of sample companies with significant R&D expenditures based on information contained in COMPUSTAT (2003). The list does not contain the largest telecommunications firms, but it does contain a mixture of multimedia service providers.

The most rapidly evolving areas in telecommunications are related to wireless application. Wireless service technologies, such as 1G–Analog,[1] 2G–Digital,[2] and 3G–Broadband, are the focus of significant R&D. Consolidation in the industry has produced the following domestic leaders in wireless communications services:

- Verizon (merger of Vodafone and AirTouch [GTE])
- Cingular (merger of SBC Communications and BellSouth)
- AT&T
- Sprint
- Nextel

A.2 R&D ACTIVITIES IN WIRELESS COMMUNICATIONS SERVICES

In the telecommunications industry, our investigations focus on research to support wireless communication services. Moving into the 21st century, wireless communication has expanded rapidly. While maintaining wireless telephone service, service providers have begun to offer business applications such as wireless LANs (W-LAN), pagers,

[1]Analog is a continuous electrical signal that sends and receives information.
[2]Digital is the replication of signals through the translation to and from binary code.

Table A-2. Sample of Telecommunications Firms with Significant R&D Expenditure in 1999

Name	NAICS	Employment (thousands)	Sales ($ millions)
AT&T Corporation	517110	61.6	$34,529
Echostar Communication Corporation	517510	15.0	$5,739
Echostar DBS Corporation	517410	NA	$5,732
IDT Corporation	517110	3.8	$1,835
General Communication	517110	1.3	$391
PTEK Holdings Inc.	517910	2.0	$381
ITXC Corporation	517310	0.2	$338
Corvis Corporation	517910	1.2	$314
ZTEL Technologies Inc.	517110	1.2	$289
LodgeNet Entertainment Corporation	517410	0.79	$250.15

NA: not available from COMPUSTAT.

Source: COMPUSTAT, 2003.

laptops with wireless modems, personal digital assistant (PDAs) with wireless connectivity, and cellular phone service. In general, wireless communications services can be grouped as follows:

- Hybrid approach: The hybrid approach is personal communication services (PCS), which incorporates both wire and wireless technology. Hybrid technology allows carriers to bypass the traditional stationary wireless local loop technology.
- Dispatch Services: Intercom communication for people who need to communicate frequently each day.
- Wireless Data and Internet Access: Combination of W-LAN and broadband to create fixed wireless broadband services like local multipoint distribution service (LMDS) and multichannel multipoint distribution service, which support simultaneous voice and data transfers and eventually video.
- Wi-Fi: Wi-Fi (short for wireless fidelity), also referred to as W-LAN, is the transmittance of data over high radio frequencies (2.4 GHz) designed for short distances such as a hotel, office building, or college campus.

The wireless industry categorizes its technologies by generations. The first generation (1G) was the introduction of analog service using advanced mobile phone service (AMPS), a standard developed in the 1980s used predominantly in the United States.

2G was the introduction of digital wireless service using code division multiple access (CDMA), which allowed for several voice or data packets to be transmitted over the same frequency. CDMA began to address the issues associated with limited bandwidth access. However, it was limited in that it was based on circuit-switch communications and required users to dial in to a network.

3G is the combination of high-speed data, advanced voice capacity, and streaming video transmitted over broadband high-speed, packet-based wireless networks. 3G's network is "always on" and does not require dialing in. In 2002, 2.5G was rolled out as an interim stage for the United States.

Today's wireless service providers are working to improve security, accessibility, reliability, and speed through advances in the wireless technology.

Below is a brief discussion of R&D activities in these areas. This is followed by a case study of the Wi-Fi technology supply chain.

A.2.1 Security

A recent survey conducted by *CIO Magazine* found that enterprise wireless solutions (a.k.a., wireless broadband) are becoming increasingly important in business operations for both manufacturing and nonmanufacturing companies. Companies are increasing consumption of the wireless infrastructure motivated by productivity increases, streamlining, and customer satisfaction.

As businesses become more dependent on wireless networks for their operations, the demand for security has dramatically increased. Security was the primary topic of a recent meeting of the world's largest communications companies, as the industry organization Alliance for Telecommunications Industry Solutions (ATIS) hosted a security summit entitled "Security of Service Provider Infrastructure in the Era of Convergence." The wireless communication industry is increasingly interested in eliminating unauthorized access to operations support systems.

The 3G Partnership Project, a consortium of wireless industry global leaders formed to develop and standardize 3G technology, is addressing the security issues related to 3G wireless technology. Their research activities include

- general packet radio service (GPRS) ciphering algorithms,
- immediate service termination (IST) and access security for IP-based services,
- network domain security (NDS),
- requirements for security architecture and interfaces,
- interoperability of multitechnology networks and encryption, and
- user authentication of information as it travels from server to user.

A.2.2 Improved Accessibility

Research to support accessibility includes developing and standardizing wireless markup languages. Wireless providers are working to further the wireless application protocol (WAP) programming languages. WAP is a grouping of standards related to accessing the Internet, using e-mail, receiving faxes, and conducting monetary transactions via digital wireless products such as mobile phones, pagers, and PDAs.

Other activities include “Bluetooth” technology research to offer short-range wireless connections between mobile phones and headsets, keyboard or mouse with personal computer or mobile phone and PDA. This includes research on Wi-Fi and W-LAN to support the transmittance of data over radio frequencies designed for short distances such as a hotels, office buildings, or college campuses. This technology is preferable to its wired counterpart LAN, mostly because of the increase in mobility of workers across a workspace.

A.2.3 Reliability

Wireless networks pass large amounts of information through the air quickly. In early wireless applications, reliability was always an issue. Mobile phone users could suddenly lose their connection or intercept other information. The Institute of Electrical and Electronics Engineers (IEEE) developed a set of standards known as 802.11 that were designed to manage data packets as they are transmitted across the wireless network to avoid collision and disruption.

A.2.4 Improved Transmission Speed for Voice and Data

Synthesizing voice, data, and video requires large amounts of information to be transferred from sender to receiver. 3G technology is therefore concerned with increasing the speed of transmission. 2G technology is relatively slow because the data connections are circuit-switched resulting in transmissions at 14 Kbps (kilobytes per second).

2.5G technology was designed to use packet-switched networks combined with always-on data connections as a way of increasing the rate of transmission to about 56 Kbps. 3G has the capability to transmit data at 384 Kbps, fast enough to allow streaming video (Dunne, 2001).

There is an ongoing debate concerning what wireless markup language should be used. Most wireless service providers in the United States during the early 1990s implemented CDMA or code division multiple access, while their European counterparts implemented global systems for mobile communications (GSM).[3]

CDMA separates transmissions, used by wireless companies, including Sprint PCS and Verizon, that are traveling in a bundle on a single wireless signal. CDMA compresses transmissions on a signal requiring less bandwidth.

CDMA2000 is a 3G technology that offers both high-speed and high-quality transmission. CDMA2000 is an evolution of CDMA technology. WCDMA digitizes and transmits data on a range of frequencies. WCDMA requires more bandwidth but optimizes the use of multiple wireless signals.

General packet radio service (GPRS) is a technology designed to work with GSM to send data packets across a wireless network at 114 Kbps. The technology for GPRS is a step above circuit-switched methods and creates an always-on wireless device, eliminating the need to dial in for downloads.

A.3 CASE STUDY OF THE WI-FI TECHNOLOGY SUPPLY CHAIN

RTI conducted interviews with five organizations throughout the supply chain for Wi-Fi products and services. Wi-Fi has become a catch phrase to describe W-LANs, electronic equipment, and services enabled by one of several 802.11 standards from the IEEE. Wi-Fi functionality includes the ability to share resources such as Internet content, e-mail, voice communications, and video and pictures.

Table A-3 lists the names of the companies interviewed. Three original equipment manufacturers (OEMs) were interviewed to obtain their

[3] GSM (65 percent of the world market) is the predominant markup language worldwide and especially in Europe, while CDMA (15 percent of the world market) is used only in the United States and Korea.

Table A-3. Organizations Interviewed Related to Wi-Fi Services

Name	NAICS	Sales ($ millions)	Employees (thousands)	R&D ($ millions)	Service Description
AT&T Corporation	517110	$34,529	61.6	$277	Multimedia delivery service
Corvis Corporation	517910	$314	1.2	$59	Networking equipment design
Echostar Communication Corporation	517510	$5,739	15.0	$32	Satellite network services
TIVO Inc.	517510	$141	0.3	$22	Cable and other program distribution
Echostar DBS Corporation	517410	$5,732	NA	$20	Wired telecommunications carriers
IBASIS Inc.	517110	$178	0.2	$13	Wired telecommunications service
Boston Communications Group	517212	$103	0.4	$13	Cellular and other wireless telecommunications
XM Satellite Radio Inc.	517410	$92	0.4	$12	Satellite telecommunications
PTEK Holdings Inc.	517910	$381	2.0	$9	Other telecommunications
ZTEL Technologies Inc.	517110	$289.18	1.19	$6	Wired telecommunications carriers

NA: not available from COMPUSTAT.

Source: COMPUSTAT, 2003.

perspectives on the role that Wi-Fi service providers play in developing new or enhanced products and services. RTI contacted numerous network operators, including market leaders such as BellSouth and T-Mobile, and aggregators such as Boingo Wireless and iPass. Unfortunately, only two network operators responded to our requests for an interview, and none of the aggregators we contacted agreed to talk with us.

A.3.1 Description of Wi-Fi Services and Technologies

Wi-Fi technology allows the exchange of information, such as Internet content, e-mail, and digital images, at speeds ranging from 2 to 100 Mbps (megabytes per second) from a remote location over a W-LAN. The market for Wi-Fi products such as notebooks and other portable devices has been growing for several years. Based on a study conducted by Pyramid Research, the number of individual Wi-Fi subscribers is projected to increase from 12 million to over 700 million in the next 5 years.

There are a number of variations to the 802.11 standard. The most current version relating to access speed is 802.11g. Ratified by the IEEE standards committee on June 12, 2003, this standard allows information transmission rates of 20+ Mbps in the 2.4 GHz radio frequency spectrum. Wi-Fi network equipment currently available to consumers is built on 802.11g or one of two older standards known as 802.11a and 802.11b. Devices enabled with the most recent standard are compatible with the 802.11b standard equipment and devices. The equipment market for Wi-Fi includes network infrastructure, end-user devices, back-end software applications, authentication software, and subscriber usage track software.

Network infrastructure includes access points or “hotspots” that transmit and receive Wi-Fi signals from individual user’s devices. Hotspots consist of a radio frequency base station and a wired high-speed network connection. Depending on the location, hotspots also use amplifiers, antennae, cellular-to-Wi-Fi switching devices, and network management platforms to manage and extend the reach of a network connection. Furthermore, networking equipment designed for commercial use is integrated with back-end network management software applications, allowing the network operator to monitor, manage, and track subscriber usage and to allocate additional bandwidth during peak usage. A network operator provides high-speed connection services to subscribers using this equipment.

Wi-Fi service is defined as the aggregation of the equipment outlined above to allow an end user or service subscriber, such as a business traveler, to connect to the Internet via one of the network’s hotspots. Wireless Internet service provider (WISP) is the term used to describe firms that provide wireless Internet connectivity. Similar to cellular phone carriers, WISPs monitor their networks, track usage, and expand their coverage to remain competitive. Activities performed by the service providers include developing customized access portals to ensure security and privacy to subscribers, monitoring subscriber usage, adjusting broadband allocations to individual hotspots, and expanding the reach of their existing network infrastructure.

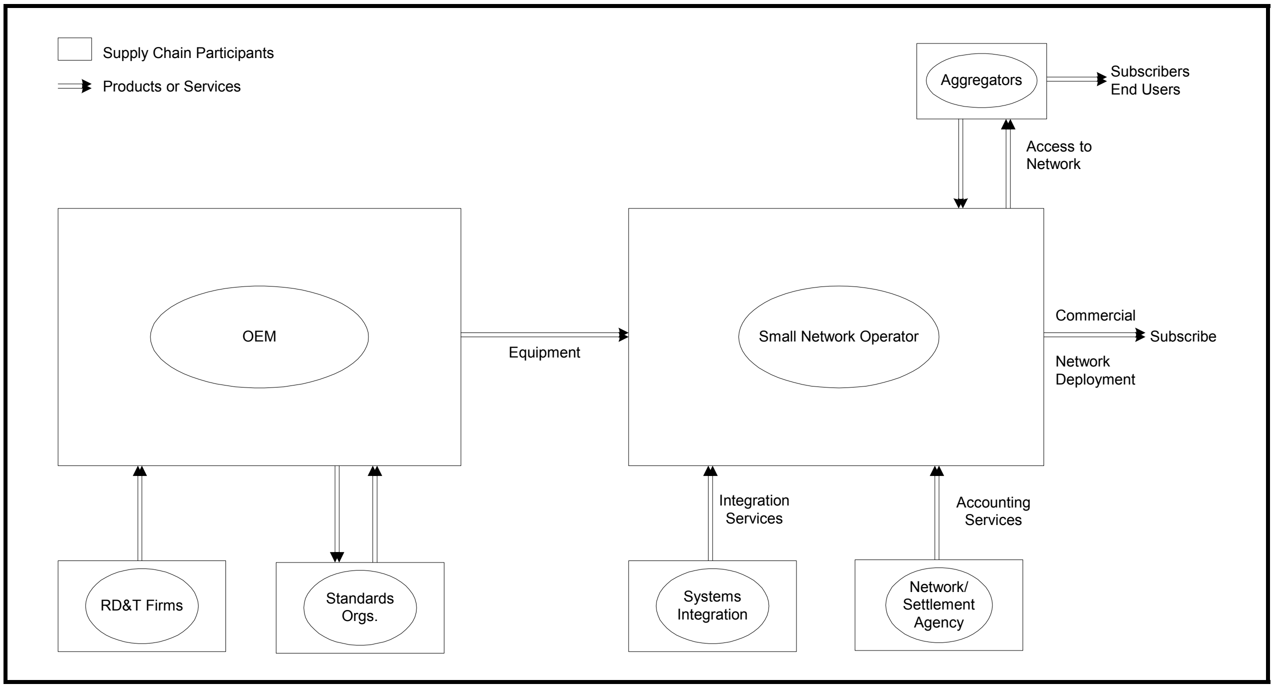
Software development of access portals is performed in house or outsourced depending on the level of complexity and required security encryption. Billing system software applications integrated with subscriber usage tracking software (which represents component technology) can be purchased or developed through in-house R&D. Expansion of the network is another activity service providers perform. However, networks suffer from the limited reach of access points. As a result, WISPs, much like cellular phone providers, enter into service roaming agreements with other regional-specific networks as a way of expanding the number of access points a network operator can offer to its subscribers.

A.3.2 Wi-Fi Equipment Manufacturers and Service Industry Description

This section identifies the key participants in the supply chain for the development and deployment of Wi-Fi services and products. The supply chain is identified as beginning with OEMs and software programmers, most of whom participated in developing the 802.11 standard within the IEEE standards organization. Equipment and software applications developers then work with Wi-Fi service providers to help them develop network connectivity and security services. There activities would fall under the category of systems management R&D. Also supporting network operators are system integration companies and business support software developers. Network operators then provide services either directly to end users (e.g., individual consumer, institution, or enterprise) or through aggregators. Figure A-1 illustrates the development supply chain for Wi-Fi services.

IEEE develops network standards using input from manufacturers, vendors, and network operators from around the world. Participation in wireless networking standards development has traditionally been dominated by OEMs. However, the number of service providers participating in these standards committees has been growing rapidly (Meyers, 2004). Telephony Online, a communications industry information source, points out the trend in increased participation from service providers in the standards development of wireless broadband access technologies. Two major reasons for the increased participation reported in the TelephonyOnline.com article for involving service providers were to educate them on the technology's capabilities and to gain information on the functional requirements that need to be included in the standard.

Figure A-1. Development Supply Chain for Wi-Fi Services



The equipment market is built on a number of strategic partnerships between OEMs and software development firms. OEMs spend considerable time identifying the operational needs of their Wi-Fi service provider customers. Operation requirements articulated by service firms include interoperability with existing data services, security, and accounting systems. OEMs, in cooperation with specialized “back-end” business process software development companies, then create both a Wi-Fi networking technology business platform and the equipment required to operate a network. OEMs often contract with other upstream suppliers to build and install the network access points or hotspots.

Wi-Fi service providers’ overall strategy for market growth is to target people in transit. This targeting includes business travelers, public service employees on the go, and metropolitan public networks. The Wi-Fi service market (or hotspot market) revolves around expanding the overall reach or scope of a service provider’s network. The goal is to maximize the number of locations that the service provider can offer to subscribers as access points. Taking the purchased technology platform developed by the OEM, the Wi-Fi service provider builds out a physical network of access points in a certain geographical location. Most likely this location is in an urban setting, where there is potential for a large number of mobile users. Another strategy has been to build networks in more remote locations to act as a “last mile” option for rural communities, where the cost-effective concerns have limited the development of wired network infrastructure. The Wi-Fi service provider then manages access and authentication, security, and roaming subscriber authentication through an operation support system (OSS) that enables the operator to manage a large hotspot market.

Aggregators specialize in developing roaming agreements that expand the reach of any single network.[4] These firms do not operate networks but instead develop a subscriber base under a brand name (e.g., Boingo Wireless, iPass, and GRIC) and then contract with existing Wi-Fi network operators to gain access for their subscribers to an assortment of networks, thereby expanding the reach of a given network for the end user. Conversely, the aggregator can work as a contract vehicle, providing a network operator with extended network roaming capabilities for its subscriber base via the network roaming agreement that the aggregators have already established.

A.3.3 Wi-Fi Technology Development and Deployment Process

The origin of the Wi-Fi service market lies in specifying the new 802.11 standard for wireless networking from IEEE. Following (and even during) ratification of 802.11g by the IEEE in 2003, electronic and networking equipment manufacturers began to integrate this new wireless networking technology into their existing products (such as laptops) and develop a network management platform for Wi-Fi network operators. The development and deployment process is described for two types of service firms: wireless service providers *without* traditional R&D activities and wireless service providers *with* traditional R&D activities.

Service Providers Without Traditional R&D Divisions

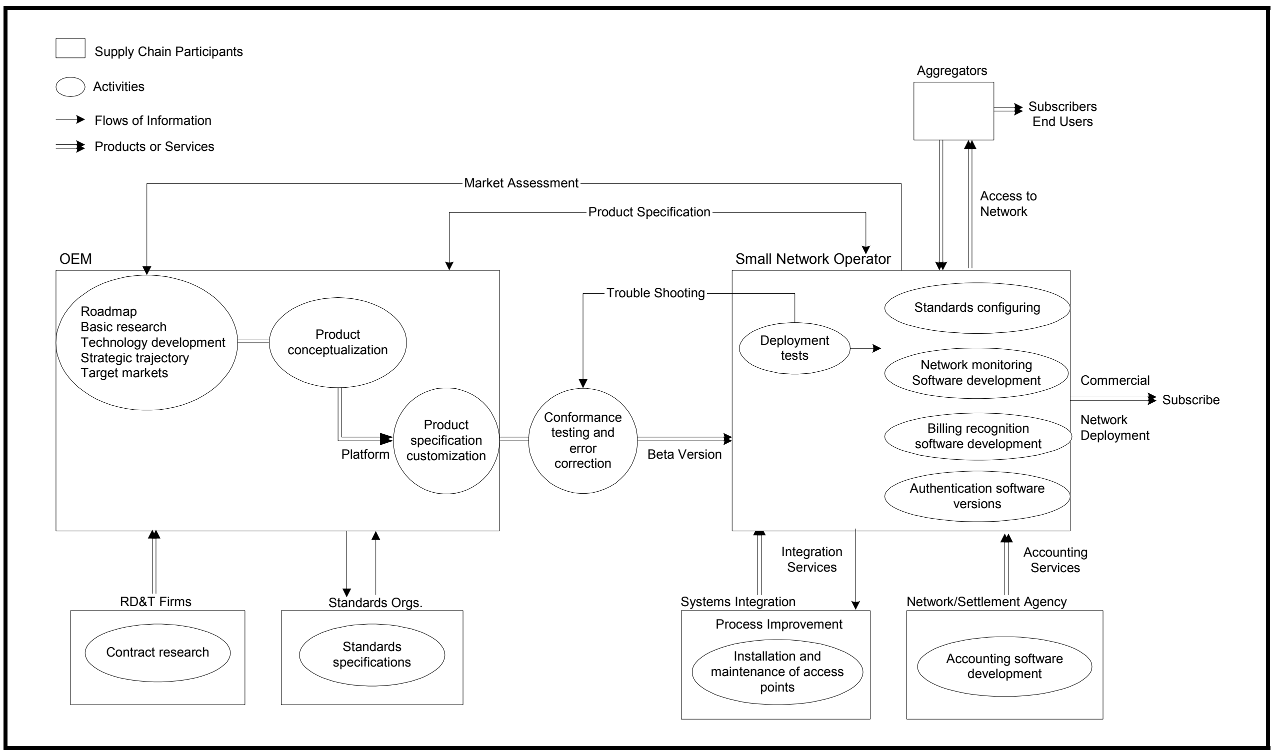
Wireless service providers use technology products manufactured by OEMs to allow subscribers to wirelessly connect to the service provider’s network. The extent to which a service firm plays a role in developing new products and services is determined largely by the overall size of the firm, either in revenue or market share. This section describes the

[4] Aggregators include companies such as Boingo Wireless, iPass, and, GoRemote (formerly GRIC). These companies are involved in building access agreements between numerous independent wireless networks enabling nationwide access to customers without having to build out independent network infrastructure such as wireless towers and access nodes.

development process for Wi-Fi services and identifies possible R&D activities performed by smaller wireless network operators. A typical company might be MHO Networks, which offers regional service in Denver, Colorado. This firm started out as a retail custom computer reseller and has evolved to a full-blown wireless network operator offering wireless network access in select cities and communities throughout the state of Colorado. Figure A-2 depicts a small network operator's involvement in developing its wireless service capabilities (technologies) and its interactions within the supply chain. The figure illustrates that small network operators are involved in product development primarily through

- providing feedback into OEM road-mapping activities,
- providing feedback into product specifications,
- participating in deployment tests,
- coordinating system integration, and
- leading service support software development.

Figure A-2. Development Activities Performed by Small-Sized Network Operators



OEMs coordinate the product development process, building on basic and applied research performed through a combination of in-house, institutional, and commercial partnerships. The OEM typically identifies those industries or markets that would derive the greatest benefit from wireless technology. Then in conjunction with the current technology capabilities and trends in future standards development, the OEM articulates a technology road map. The road map aligns the firm's internal strategic trajectory with the current and future trends of wireless technology. The manufacturing firm leverages input from the industry leaders, such as existing network operators, to fine tune a technology road map, aligning its development strategy with market trends reported by the perspective consumers. OEMs spend considerable time iterating with network operators to ensure that the product or equipment being developed under the 802.11 standard addresses the operator's business process needs.

Equipped with knowledge of the network operator industry's market trends, the OEM engages in product conceptualization and begins to build the wireless networking platform aimed at addressing the business needs of the targeted industry of wireless network operators. The OEM partners with software application development firms that specialize in back-end business software for the wireless network operators to build the initial structure of the wireless networking platform. Following the development of the platform, the OEM again seeks network operators' feedback on product specifications, and for larger service firms this may include some customization. The network operator articulates the specific capabilities and operational requirements that the networking platform must address to meet their business needs.

Next, the platform enters a conformance testing (also known as alpha testing) phase, where network operators take part in developing test scenarios that will allow the product designers to evaluate how well the product will perform in a real business environment. The service firm provides feedback on bugs and glitches in the system. The OEM then sends the initial product to wireless network operators to use in a real-world environment. This portion of the process is known as a deployment testing phase (also referred to as beta testing). At this point, the network operator takes a role in the development process through testing and offering feedback to the OEM, creating a virtually integrated supply chain for R&D activities. Once all issues and bugs have been sufficiently addressed, the OEM can roll out its new wireless networking platform.

The network operator purchases the platform from the OEM and then begins to build out its wireless network. The operator integrates the new platform with any existing data services it operates. The operator then develops customized software for authentication and access applications and ensures security and a methodology to ensure that the network is configured to meet all current standards in use. In addition, network operators work to develop methods to more effectively track subscriber usage and link usage to billing software applications. Development of the physical infrastructure, such as access points, is typically outsourced to network construction service companies.

Once their local network is in place, network operators use aggregators to maximize geographical coverage. This optimization enables the subscribers to have the greatest mobility and variety in access points from a particular network operator. Roaming agreements allow networks to expand without large capital investments.

Service Providers with Traditional R&D Divisions

Network operators with larger development budgets have more traditional research labs. Product and service development occurs in much the same way as described above, but the large network providers internalize more of the development process within technology divisions. These larger firms, unlike smaller firms, tend to lead (as opposed to participate in) development activities related to

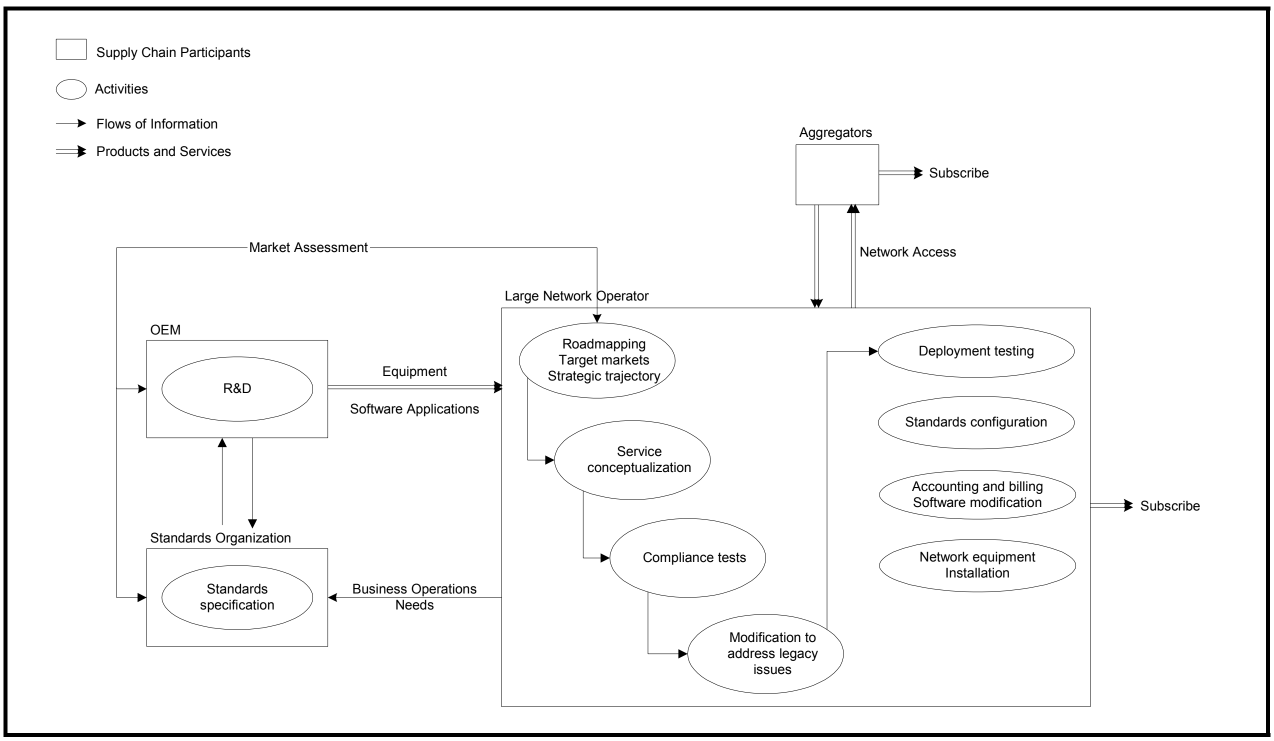
- technology road mapping,
- service conceptualization,
- compliance testing,
- integration of new systems with existing legacy systems,
- deployment testing,
- standards configuring, and
- accounting and billing software development.

Technology divisions for larger network operators serve to maintain an awareness of the existing and emerging equipment and software on the market for various networking standards and technologies, including Wi-Fi, VPN (virtual private network), and WiMax. This technology monitoring is used to inform their strategic planning, and these service providers are likely to lead the development of their own technology road mapping activities (whereas in the case of small network providers, the firm simply provides input on emerging market industry trends). Large network operators have knowledge of available equipment and systems and their capabilities.

The network operator's in-house resources allow it to conduct compliance and deployment testing and network modification internally. However, the carrier still offers feedback to manufacturers during the development of the platform and networking equipment. Figure A-3 suggests an optional scenario in which these larger firms conduct more development activities in house.

In Figure A-3, the network operator is still providing market assessment input to the OEM's product development process and some product specification. However, compliance and deployment testing, as well as required modification, is typically conducted internally.

Figure A-3. Development Activities Performed by Large-Sized Network Operators



Larger network operators also invest significant resources in standards development organizations as noted earlier in this discussion. Their involvement in developing standards serves three purposes. First, they are exposed to the array of competing vendors for various technologies, which allows the network operator to make a better informed purchase of networking equipment that will meet the specific business needs of individual network operators. Second, by offering knowledge of business operations requirements, network operators shorten the time required to bring new or improved services to subscribers. Finally, these firms are enhancing their ability to absorb future technology change through establishing a continued presence in the standards development process.

A.4 SUMMMARY OF ACTIVITY CATEGORIES AND RESEARCH TAXONOMIES

Network operators are involved in the product development process throughout the technology supply chain. Both large and small network operators contribute to similar development tasks to roll out new services. However, in the case of a small network operator, many R&D activities take place outside the firm, with suppliers receiving input from the network operator, while the larger-sized firms are more likely to internally lead many of the activities, such as compliance and deployment testing activities and customization.

Potential R&D activities conducted by network operators include

- road mapping activities (in house or supporting suppliers) and participation in standards organizations;
- product conceptualization, specification, and customization (in house or supporting suppliers);
- compliance testing (alpha testing);
- deployment testing (beta testing); and
- development and integration (often with legacy systems) of network monitoring and business support software.

These product development terms are used by the telecommunications industry, and they could be used in the RD-1 instrument/instructions to describe potential R&D activities.

A.5 REFERENCES

Christensen, Clayton M., Scott D. Anthony, and Erik A. Roth. October 2001. "Innovation in the Telecommunications Industry: Separating Hype from Reality." Harvard Business School Working Paper. <http://newsroom.cisco.com/dlls/tln/Disruption_study/telecompaper.pdf>.

COMPUSTAT. 2003. American Stock Exchange Database. Contennial, CO: Standard & Poor's, McGraw Hill Companies, Inc.

Dunne, Danniel. 2001. "What is 3G Technology?" *DarwinMag* <http://www.darwinmag.com/learn/curve/column.html?ArticleID=182>.

Meyers, Jason. 2004. "Telephony's Complete Guide to WiMAX: The Business Case for Service Provider Deployment." <http://telephonyonline.com/ar/telecom_telephonys_complete_guide/index.htm>.

Appendix B: Financial Services Sector Case Study

Over the past decade, changes in the economy and the increased use of information technology in financial services have significantly influenced innovation activities in the financial services sector. Increased competition through deregulation, consolidation, and disintermediation is forcing the financial service companies to innovate to maintain profitability.

At the same time, there is an increased demand for financial services as the "baby boom" generation approaches retirement. The simultaneous increase in competition and demand is driving the industry to increase R&D to develop both new services and also efficient and low-cost delivery devices for new and existing services.

The introduction of e-money, smart cards, e-checks, e-funds transfer, and improved encryption are some of the innovations developed in financial services in the 21st century. An additional trend influencing innovation is the "disintermediation" of financial services as manufacturers begin to "encapsulate" their products with services and deal directly with customers. This is forcing service firms to reduce costs by developing more efficient technologies and move into new product and service areas to maintain profitability.

This case study begins with a profile of the financial services sector and its ongoing R&D expenditures and activities. Findings from industry interviews are presented to provide an overview of the technology development and deployment process, with a focus on financial Web-based services.

B.1 FINANCIAL SERVICES (NAICS 52, 53) R&D EXPENDITURES AND ACTIVITIES

The financial services sector, as defined in NSF's R&D performance reports (see NSF, 1998) includes NAICS 52 and 53. Firms in this sector consist of depository institutions; nondepository institutions; security and commodity brokers; insurance carriers; insurance agents, brokers, and services; real estate; and holding and other investment institutions.

- Depository institutions include firms engaged in deposit banking and fiduciary activities.
- Nondepository institutions include firms engaged in extending credit in the form of loans but not engaged in deposit banking.
- Security and commodity brokers, dealers, exchanges, and services include firms engaged in the underwriting, purchase, sale, or brokerage of securities and other financial contracts on their own account or for the account of others, and exchanges, exchange clearinghouses, and other services allied with the exchange of securities and commodities.
- Insurance carriers include carriers of insurance of all types, including reinsurance.
- Insurance agents, brokers, and service include agents and brokers dealing in insurance and organizations offering services to insurance companies and to policyholders.
- Real estate includes real estate operators and owners and lessors of real property as well as buyers, sellers, developers, agents, and brokers.
- Holding and other investment offices include investment trusts, investment companies, holding companies, and miscellaneous investment offices.

In 1999, total revenue for this sector exceeded $1.9 trillion with employment of approximately 4.3 million. The Census Bureau aggregates firms classified under the financial sector into seven subcategories by NAICS code. Table B-1 provides numbers of firms, employees, and revenue for each of the eight subsectors.

Table B-2 lists the top 10 finance firms by sales. When ranked by sales, the financial sector's top 10 are familiar names such as Merrill Lynch, Citigroup, Morgan Stanley, and Chase Manhattan. These large financial institutions characterize the financial sector; however, their R&D expenditures were not available. Table B-3 provides a sample of publicly traded finance firms with significant R&D expenditures contained in COMPUSTAT.

Table B-1. Summary of Financial Services Sector

NAICS	Name	Number of Firms	Employment (thousands)	Sales ($ millions)
5222	Depository Institutions	672	2,228	$715,938
5222	Nondepository Intuitions	99	359	$217,974
5231	Security, Commodity Broker	98	322	$188,342
5241	Insurance Carriers	200	1,007	$694,385
5242	Insurance Agents, Brokers, Services	43	165	$30,021
5311	Real Estate	92	79	$14,533
5511	Holding and Other Investment Offices	875	168	$66,600
52, 53	Finance, insurance, and real estate	2,079	4,329	$1,927,792

Note: Based on companies contained in COMPUSTAT.

Source: COMPUSTAT, 2003.

Table B-2. Top 10 Finance Firms by Sales

Name	Employment (thousands)	NAICS Code	Sales ($ millions)
Citigroup Inc.	115.0	5223	$82,005
Prudential PLC-ADR	23.0	5241	$51,745
Bank of America Corporation	155.9	5221	$51,526
ING Groep NV-ADR	82.7	5241	$43,819
American International Group	55.0	5241	$40,656
Fannie Mae	N/A	5222	$36,968
Merrill Lynch & Company	67.2	5231	$34,879
Morgan Stanley Dean Witter	55.3	5231	$33,928
Chase Manhattan Corporation	74.8	5221	$33,544
Allstate Corporation	52.0	5241	$26,959

COMPUSTAT contained no R&D information for the top 10 finance firms by sales.

NA: not available in COMPUSTAT.

Source: COMPUSTAT, 2003.

Table B-3. Sample of Firms within NAICS 52 and 53 with Significant R&D Expenditure

Name	Employment (thousands)	NAICS Code	Sales ($ millions)	R&D Expenses ($ millions)	Business Description
SEI Investments Company	1.5	5239	$456	$43	Investment technologies firm
Anglo American PLC-ADR	0.2	5239	$11,923	$34	Holding company
Gemstar-TV Guide International Inc.	0.3	5331	$241	$24	Global media and technology company
MIPS Technologies Inc.	0.1	5331	$71	$21	Technology design and patent leasing
Interdigital Communications Corporation	0.3	5331	$70	$20	Designer of wireless telecom technologies
IGEN Inc.	0.2	5331	$14	$14	Biodetection platform-leasing
Investment Technology Group Inc.	0.3	5231	$232	$10	Technology-based trading company
Health Risk Management Inc.	0.9	5242	$162	$9	Managed health care and consulting
Macrovision Corporation	0.1	5331	$37	$9	Patent manager and software design
Rambus Inc.	0.2	5331	$43	$8	Licenses semiconductor chip connections

Source: COMPUSTAT, 2003.

As shown in Table B-3, most of the firms with significant R&D expenditures in COMPUSTAT are holding or technology investment companies and are not necessarily conducting R&D related to the provision of financial services. For example:

- SEI Investments Company is a consulting firm specializing in financial management and investment technology solutions. Although the firm is oriented around the financial sector, the R&D reported seems to be emerging from the development of software applications that enable clients to make decisions concerning their investment portfolios.
- Anglo American PLC-ADR, with the second largest reported R&D expenditure, is a holding company, controlling the majority of shares for some of the world's largest diamond (45 percent of DeBeers), gold (53 percent Anglogold), and platinum (50 percent Anglo American Platinum) companies. Also Anglo American PLC-ADR is one of the world's largest independent coal miners,

with interests in ferrous and base metals, industrial minerals, and forest products. Only $4 million, or 0.17 percent, of the total $2.4 billion operating profit for Anglo American was dedicated to financial services in 2001, yet they reported a $34 million investment in R&D. Given the brief company description, it is unlikely that the amount invested in R&D is being used to innovate in the financial sector.

- IGEN Inc. is another example of a company whose product is not related to the financial sector. IGEN designs and manufactures diagnostic systems that aid in the mapping of the human genome. It holds the patent rights for this cutting-edge technology and leases its use to clients such as the Human Genome Project and other molecular biologists. The firm's SIC code 6794 classifies the company as a patent owner and lessor. The company's description demonstrates that the R&D reported to COMPUSTAT is advancing medically related service industries, not the financial sector.
- MIPS Technologies is a design company, classified as a patent owner and lessor, specializing in developing the low-power 34 and 64 bit core chips that are found in most video game consoles in today's markets. In addition to gaming system chips, they offer microprocessors and architecture design systems. Instead of manufacturing these products, they simply license their intellectual property to large manufacturers of high-tech products, such Hewlett-Packard, NEC, and Philips Semiconductors.
- Rambus provides chip and system companies with interface solutions to enable high performance and system bandwidth for a range of consumer, computing, and networking applications. Rambus provides its customers with interface solutions and comprehensive engineering services to support implementation of its interfaces in customer products.

Table B-4 provides a sample of firms with R&D expenditures contained in COMPUSTAT that are performing R&D activities related to the financial sector.

For those firms reporting R&D expenditures in COMPUSTAT related to the financial sector (Table B-4), their Web sites revealed the following innovation activities:

- Investment Technology Group Inc. is a full-service trade execution firm that uses technology to increase the effectiveness and lower the cost of trading by emphasizing R&D in the products they offer, which are as follows:
  - POSIT: an electronic stock crossing system
  - QuantEX: a Unix-based decision-support, trade management, and order routing system
  - SmartServers: server-based implementation of trading strategies

Table B-4. Sample of Companies Reporting R&D Expenditure in COMPUSTAT Related to Financial Services

Name	Employment (thousands)	NAICS	Sales ($ millions)	R&D Expenses ($ millions)
Investment Technology Group Inc.	0.3	5231	$232	$9.7
A B Watley Group Inc.	0.1	5231	$21	$6.0
ILIFE.com Inc.	NA	5231	$12	$3.0
Mortgage.com Inc.	0.5	5223	$43	$2.9
LendingTree.com Inc.	0.1	5223	$7	$1.1

NA: not available in COMPUSTAT.

Source: COMPUSTAT, 2003.

- Electronic Trading Desk: an agency-only trading desk offering clients the ability to efficiently access multiple sources of liquidity
- ITG Platform: a PC-based order routing and trade management system
- ITG ACE and TCA: a set of pre- and posttrade tools for systematically estimating and measuring transaction costs
- ITG/Opt: a computer-based equity portfolio selection system
- ITG WebAccess: a browser-based order routing tool
- Research: research, development, sales, and consulting services[1]

- A B Watley Group Inc. is a New York registered broker-dealer that operates both direct-access trading and third market institutional sales trading brokerage businesses. The company offers a proprietary technology called Direct-Access Vertical Exchange (DAVE) to brokerage and banking industries. DAVE consists of a ticker plant, order entry and trade processing, and data delivery engines.
- LendingTree.com Inc. is a lending exchange that attracts customers looking for loans and processes loan requests through a number of banks. LendingTree licenses their technology platform LEND-X(SM) (which powers their Internet-based lending exchange) to other businesses to create exchanges on their own Web sites.

[1]Company product information was retrieved from the SEC's 10-K fillings archive.

B.2 R&D CHARACTERISTICS AND ACTIVITIES

The finance industry, at the NACIS two-digit level, is too large to examine in its entirety. In addition, much of the R&D performed by companies classified under NAICS 52 and 53 is not directly related to the provision of financial services. Therefore, the focus of the remainder of this case study is the financial organizations classified under NAICS 523 as securities, commodity, contracts, and other financial investments and related activities.

A report by Mintel International Group Ltd.[2] suggests that the financial services industry is in the midst of redefining its business processes by developing and adopting technologies such as data warehousing and mining, customer service and support software, and client relationship management tools. Their goal is to provide either the individual or the corporate investor with easy and reliable access to real-time market investment information. These services are being provided via networks that require higher levels of security to ensure the confidentiality of monetary transactions.

In addition to improving the services for customers, financial institutions are also interested in developing technology for investment tools that will enhance a financial analyst's ability to make the most lucrative investment decision and gain competitive advantage. Industry leaders have focused on developing databases that update information in real time, thus equipping investors with up-to-the-minute market information and assisting investment managers in decision making.

The following examples describe the types of R&D activities performed by financial services companies. Financial markets can be extremely volatile in both the short run and the long run, and without a way of providing up-to-the-minute market information investment managers' firms may realize large losses.

- **Morgan Stanley** has developed real-time international hedge fund and equity indices informed by market data via Reuters and Bloomberg. Morgan Stanley will be able to offer emerging market, regional, country, and sector equity indices in real time. "Real time indices provide a unique insight into the intraday movements of the global equity markets and enable clients to evaluate their portfolios' performance versus the benchmark (Morgan Stanley) index at any point in the day."

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[2]Downloaded from www.marketresearch.com/product/display.asp?productid=805899.

- **JP Morgan's** Investor Services product development division announced in October 2002 a strategic alliance with Investors, a leading supplier of performance measurement services for equity research. The collaboration goal is to develop an integrated research and benchmarking tool that will "help institutions maximize returns through better analysis of their supplier networks and relative contribution to performance" (JP Morgan, 2002). Benchmarking tools are a way for financial institutions to demonstrate the value added from their research and evaluate comparatively the performance of research analysts in house against other institutions.
- **Merrill Lynch** decided to enhance its services by developing a superior platform for their financial advisors. In November 2002, they partnered with Thomson Financial, a unit of the Thomson Corporation, to develop a "Wealth Management Workstation" (WMW). The workstation will be designed to support financial advisors through the use of robust market data, news and portfolio management tools, and client relationship management (CRM) software.

In addition to product development efforts using partnerships as exemplified above, broad research consortiums are formed to conduct and coordinate generic and infrastructure R&D. Interoperability issues can be addressed through the cooperative efforts of member organizations, with individual institutions realizing gains in competitive advantage through the development of proprietary technology. For example, the Financial Services Technology Consortium (FSTC)[3] is a member organization of the leading financial firms in North America. The FSTC coordinates collaborative technology research and development through pilots, proof of concept, tests, and demonstrations to develop interoperable, open-standard technologies that answer core competency needs for industry. FSTC prototypes new infrastructures for financial transactions, confirms new specifications for the industry, and evaluates new technologies in lab settings.

The FSTC has conducted projects since 1994 in areas such as customer authentication, branch automation, check truncation, Web services, wireless banking, and biometrics. By developing these services through cooperative efforts of the organization's members, the technology developed ensures open architectures and interoperability. The financial services industry identified the need for technological innovation in the areas of voice authentication, Web services for corporate cash management, automated intrainstitutional exchange systems, and

[3]See www.fstc.org for additional information.

electronic checking. The following are some examples of the type of projects performed by the consortium's working groups.

- **Universal value exchange (UVX)** is a set of protocols that define the internal architecture, interfaces, and gateways to existing payment systems for financial institutions. Thought to be "middleware," the UVX protocols will support payment processing such as paper check processing, wire transfer services, ACH, ATM/EFT, and credit card processing. Initially, the architecture is planned for transactions between banks and patrons; however, following the adoption by two or more banks, UVX is designed to conduct intrainstitutional transactions. The technology goal is to reduce the operational costs of legacy payment systems by connecting existing systems to a modern payment infrastructure using XML, state-of-the-art security technology, and current Internet protocols.
- The **ANS X9.85** project will test the viability and performance of a prototype check validation program by designing a system that uses the ANS X9.85 standard, "*Specifications for Automated Identification of Security Features*." The system will be evaluated using a metric developed by financial institutions. The goal of the project is to surmise the degree of difficulty in modifying current check-processing systems to identify security features, assess the scalability and ease of integration with existing systems, and specify technical and operational barriers to implementation.

B.3 FINDINGS FROM FINANCIAL SERVICES SECTOR INTERVIEWS

RTI conducted interviews with five firms from the financial services sector (see Table B-5). The financial services firms interviewed included large retail banks and major investment service institutions. Web services technology was identified for this project as a case study to demonstrate how innovation occurs within financial services firms. However, in a number of our interviews there was a shift in the discussion from Web service innovation to more general concepts about R&D, how those activities are measured, and how they relate to the innovation process in general.

B.3.1 Defining Financial Services

Companies interviewed defined financial services as an industry that provides services in, but not limited to, retail banking, debt and asset management, and private and institutional investment. Financial services firms provide service to a variety of clients, ranging from individuals to large institutions. Institutional client services include debt

Table B-5. Financial Services Firms Interviewed

Company Name	Position
Computer Service Companies	
Accenture	Associate Partner for Financial Services Group
Niteo Partners	Project Manager
Financial Service Institutions	
Merrill Lynch	Chief Technology Architect
JP Morgan Chase	VP of Treasury Security Services
Wachovia	VP of Retail Integration
Industry Research Company	
Forrester Research	Principal Analyst

management, capital financing, public and private offerings of debt (stock and bonds), and equity, as well as other securities. The provision of these services is based on a skills set of underlying knowledge and experience to ensure high returns on investment for the client (consumer) and the financial services firm (producer).

Financial services change over time in response to consumer preferences. Firms are continuously working to develop higher quality, more efficient, and less expensive products that will allow them to gain competitive advantage in their industry or sector. To this end, technology is developed and/or acquired and used to increase the productivity of the existing service and to develop new services. The development and application of intellectual capital (IC) is the driving force behind innovation.

Financial services can be either labor intensive, relying heavily on personal interactions and human capital, or capital intensive, relying on automation to lower the cost of transactions and the dissemination of information. During our conversations with industry, we focused on two general categories of services: investment services and retail banking. The distinction between these two segments lies in the level of technology needed to meet consumer demand for services in the respective segments.

Investment services rely heavily on a number of different technologies to ensure that accurate and complete information is available to investors. A high rate of innovation is required as the leading firms compete for customers through differentiation via technology. We found that investment services firms were conducting a large share of innovation in house. The largest investment services firms even have teams referred to as Advanced Development Groups (ADGs) that are responsible for innovation and development projects within the firm.

Conversely, retail banks see themselves as competing for customers through the quality of service rather than the development of and innovation within services. Retail banks believe they have found an optimal distribution between maintaining and enhancing the level of technology facilitating the provision of retail banking service. In recent history, the trend in the provision of services has been to move from human interaction toward total automation via the Internet and ATMs. In some cases, banks began to charge customers for using bank branches and human tellers to make transactions. However, recent literature suggests that this trend is reversing. Although retail banks are maintaining the use of the Internet and ATMs for simple banking services, such as balance inquiries, deposits, and withdrawals, these banks are relying more on face-to-face interactions when providing more complex services, such as mortgages and mutual fund investments.

Clearly there are many differences in the level of technology and innovation required to be competitive in investment and retail banking. Informed by interview responses, RTI constructed a model of innovation relevant to the financial services industry, which we outline later in this discussion. By applying this innovation model to both investment services and retail banking, we begin to see where the most concentrated development activities lie.

B.3.2 R&D and Innovation

NSF's definition of R&D activities includes the following components:

- the planned, systematic pursuit of new knowledge or understanding toward general application (*basic research*);
- the acquisition of knowledge or understanding to meet a specific, recognized need (*applied research*); and
- the application of knowledge or understanding toward the production or improvement of a product, service, process, or method (*development*).

Based on our interviews, we found that these concepts of R&D did not resonate well within the financial services industry. None of the firms interviewed indicated that they conduct activities in either basic or applied research. Most of the individuals interviewed could relate to the concept of development; however, traditional research, either basic or applied, was not commonplace in their operations. RTI found that the ideas underlying the development phase of R&D resonated best for investment services institutions. However, only the largest retail banking firms thought that they were performing development activities, and the smaller retail banks indicated they were not doing any R&D.

For large investment firms, development activities mentioned in the interviews included conceptual design, articulation of technical specifications and capabilities, integration, and deployment of new technology. The research activities of large retail banks are primarily related to initial conceptual design, with only a small role in the development and deployment of the technology. Table B-6 identifies and compares development activities performed within investment and retail service firms.

Table B-6. Differences in Investment Service and Retail Banking Development Strategies

	Investment Services			Retail Banking		
Innovation Process	**In House**	**Vendor**	**Consortiums**	**In House**	**Vendor**	**Consortiums**
Generation of new technology idea	●			●		
Initial development	●				●	
Sources of generic technology		●	●		●	●
Technology Infrastructure			●			●
Modification and implementation	●	●			●	
Operation and maintenance	●			●	●	

Bullets indicate the stages in the innovation process where the financial services firm or the external technology vendor is conducting development activities. This table highlights the fundamental difference between investment services and retail banking in terms of development activities performed in house versus by vendors. Large investment services firms conduct most of their development activities in house, relying on external technology vendors only for existing technologies that meet capability requirements and for assistance in implementing the purchased technology. Retail banking firms perform very few development activities in house, relying on off-the-shelf technologies developed by vendors.

The interviews suggested that different types of financial services require different levels of technological innovation. In addition, a firm that is considered a market leader may differentiate itself from other competing firms through the continued development of new products or services. Smaller industry participants are reluctant to compete in innovation and instead find it more cost-effective to adopt off-the-shelf innovations from vendors.

B.3.3 Innovation Process

The innovation process is a term used to describe the continuum of activities associated with how firms or industries develop and deploy new ideas and technologies. This process has long been discussed in the academic and policy literatures with respect to the manufacturing and industrial sectors of the U.S. economy (e.g., research, prototype development, and scale up to full production).

However, RTI found the same process does not characterize financial services. Innovation in financial services seems to be driven by customer demand, where only the larger firms participate in innovative activity and that activity is a strategic response to compete for customers, as is the case in manufacturing firms. Smaller financial services firms do innovate but generally not in terms of enhancing state-of-the-art consumer services. Rather, smaller firms innovate by providing consistency in the level of customer service.[4]

Larger financial services firms are conducting activities that conceptualize and develop technological advancements. Retail banking firms innovate through the adoption and some modification of existing technologies from vendors. Large investment firms either develop technologies in house or purchase technologies from vendors. Large firms then significantly modify vendors' technologies to meet their system needs. Smaller investment firms, on the other hand, could be considered imitators. They adopt technologies developed by external vendors, similar to the approach taken by smaller commercial banks and use that modified technology to provide a differentiated product.

[4]Small manufacturing firms behave similarly in that they locate close to the downstream customer (such as an OEM) to provide quick and consistent delivery and after-sales service.

The innovation process for financial services firms begins in house with the following steps:

- The firm identifies a new service product to meet an actual or perceived customer need.
- In-house development occurs to specify the attributes of the needed innovative technology that will support the new or enhanced service.
- The firm contracts an IT specialist to build the new technology.
- The firm incorporates the purchased technology into its business process.

Retail banks conduct very little of the development activities in house. However, based on our interviews, investment firms spend less than 20 percent of a project's total cost on purchased technology from external vendors. The majority of the costs are incurred though in-house activities relating to the adoption and modification stages of this innovation model.

The following are examples of innovation from our interviews:

Retail banking:

- *ATMs and the Internet*—Retail banks incorporate Internet capabilities into retail banking ATMs by purchasing ATMs from vendors and then incorporating Internet capabilities (in house) to allow customers to perform online activities, such as bill paying and financial transfers to third parties. The distribution of development costs for this service was 40 percent to purchased IC and 60 percent to in-house adoption and modification. Purchased IC is embedded in ATMs from vendors and the application of existing technologies related to Internet Web services. In-house activities include the large amounts of computer programming necessary to synchronize the ATM's Internet-based transactions so that the customer's accounts are updated automatically.
- *Web Services*—This area involves the adoption of Web service technology to increase efficiency in intrainstitutional banking. This innovation is taking place through a collaborative cost-sharing project at the FSTC in cooperation with NEC and Stanford researchers. The distribution of development costs was 80 percent to purchased IC and the remaining 20 percent of costs accounts for in-house activities. In the case of Web services, only a small amount of development was done in house. Purchased IC is embedded in technical consulting services from Niteo Partners. In-house activities include the bank's time spent overseeing the project and offering insight into the business practices the consultants were trying to model in their Web services applications.

Investment services:

- *Virtual Desktop*—This technology allows a financial firm's employees to log in to an institution's internal system via the Internet to conduct business or modify documents. The innovation is that the virtual desktop will not lose data if the user's connection is terminated. This means that an employee working off-site can log in to a firm's internal system, work off of shared documents that are housed on a server, terminate his or her connection, reconnect, and continue working on the same document without losing any information. The distribution of development costs for this example was 5 percent to purchased IC and 95 percent for in-house development activities. Purchased IC is embedded in the computer software platform developed by a vendor. In-house activities include performing tasks such as writing code, integrating the information format from the vendor with the in-house code, testing, and implementing the technology.
- *Virtual Private Networks (VPNs)*—Aimed at addressing the security issues associated with connecting and conducting monetary transactions over the Internet, this technology ensures that the customer is able to access all or almost all of the firm's internal information system from a remote location as if he were accessing the system on site or from within the firm's network firewall. The distribution of development costs for this example was 20 percent to purchased IC and 80 percent to in-house development activities. Purchased IC is embedded in networking consultancy services specializing in network security. The consultant was responsible for developing the security code specification that ensured the security of information shared between the financial institution and the customer over the VPN. In-house activities include the articulation of specifications and capabilities that the VPN needed to meet. After the consultant built the VPN, the financial institution took the system and integrated it into the institution's existing line of service products.

B.3.4 R&D Metrics for Financial Services

NSF has traditionally reported the ratio of R&D to sales as a metric to characterize the investment innovation intensity of manufacturing firms. Academics and policy makers have similarly relied on this measure, and the measure is one that aptly characterizes manufacturing's view. From a policy perspective, maximizing the R&D intensity of firms is viewed as a positive (and meaningful) objective to achieve growth.

However, our interviews indicate that this metric may be less useful for firms in the financial services sector. First, R&D is not a generally accepted descriptor of innovative investments, and second, no individual in financial services spoke of maximizing innovative investments as being associated with growth. Growth, in the traditional paradigm, comes from in-house development of proprietary knowledge that is either cost reducing or product enhancing. In fact, whereas innovation in manufacturing is often cost reducing, that concept is orthogonal to strategic planning in services. Semantically, financial services firms do not call this R&D, but compared with activities that occur in manufacturing this activity is the same in nature as what many manufacturing firms call R&D.

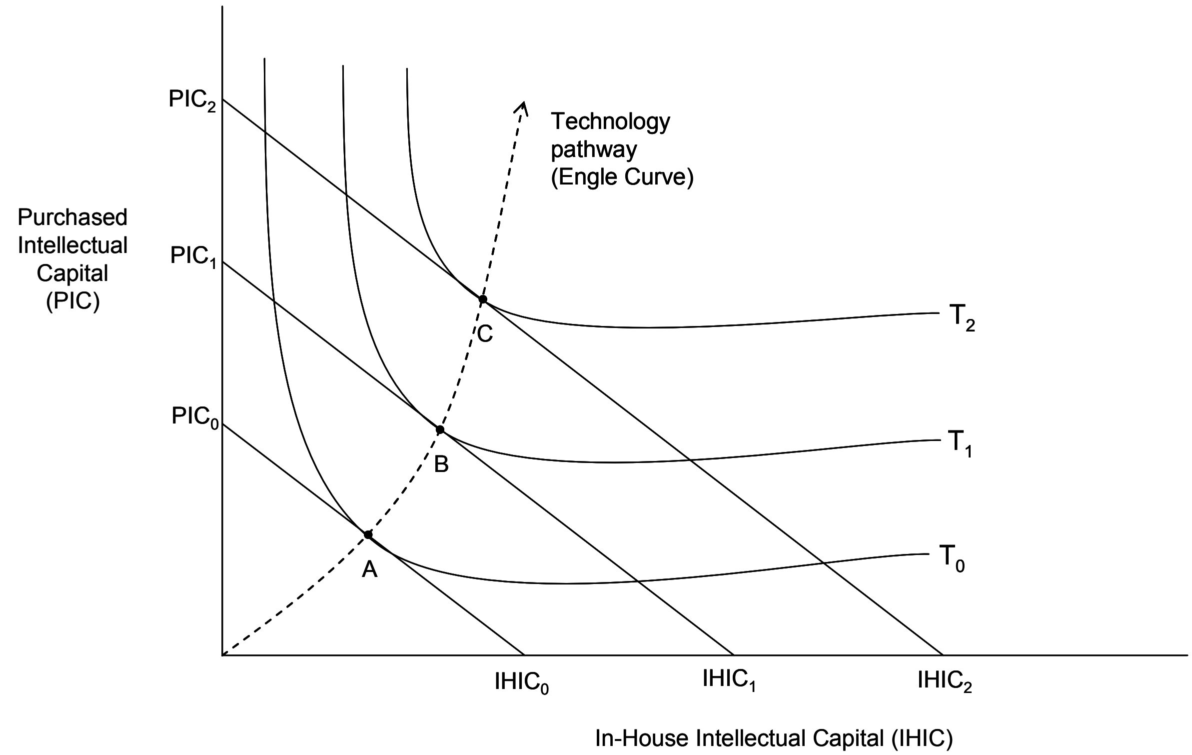
For the financial services sector, a more relevant metric proposed was the ratio of dollars spent to maintain existing technology versus the dollars spent to enhance or purchase new technology. An industry rule among larger retail banking institutions is 70 percent maintenance and 30 percent enhancement, or 2.3 to 1. If a firm moves closer to 80 percent maintenance and 20 percent enhancement, or 4 to 1, that firm would not view itself as competing successfully for customers. Small retail banks do not follow this metric because of their strong reliance on prepackaged software and off-the-shelf solutions.

The 30 percent in enhancement or innovation is then optimally (i.e., in a cost-minimizing manner) allocated between in-house development activities and the purchasing of IC from vendors. This rule could be considered the optimized innovation ratio for financial services firms.

In investment services, an “efficiency measure” in technological innovation was suggested as the best way to evaluate a firm’s level of innovativeness. This metric measures technological success through a ratio of the cost of technology to the firm’s revenues. The cost of technology represents the sum of purchased intellectual property from outside the firm and in-house development activities. Holding the quality of service constant, the firm’s goal should be to minimize the ratio of its total technology-related expenditures to services. As part of meeting this goal, the firm minimizes technology costs by optimizing the ratio of in-house development activities to the purchasing of IC from vendors.

To illustrate the in-house development versus IC purchase decision, consider the diagram in Figure B-1 that depicts what could be referred to as an iso-technology curve, T_o. The vertical axis represents purchased IC. The horizontal axis represents in-house IC. Purchased IC generally takes the form of purchased equipment and labor including human capital, and in-house IC generally takes the form of human capital. For the financial services sector firm at point A, corresponding to a given level of purchased and in-house IC, innovation by the firm could be

Figure B-1. Iso-Technology Curve



described as an outward shift in T_0 to T_1, where T_1 represents a new bundle of services to meet customer needs.

A firm maximizes technology output by selecting the most cost-effective combination of in-house to purchased IC. As technology demands for new products and services increase, the optimal pathway for service firms may diverge from manufacturing firms because of differences in core capabilities and business models. Although RTI did not collect financial information from those interviewed, it was our impression that a greater percentage of IC in service firms came from purchased technology than from in-house technology. And this trend was likely to increase as systems become more complicated, resulting in the curvature of the technology pathway.

B.4 WEB SERVICES CASE STUDY SPECIFICS

This section takes a closer look at the role retail banks play in technology development activities and investigates if they contribute to applied research being performed to support the financial services sector. The following is a case study of the proof-of-concept project performed by a group of retail banks in cooperation with NEC and Stanford University through the FSTC.[5] We find little evidence that retail banks were involved in applied research other than through funding of consortium activities. Our interviews indicate that NEC performed all basic and applied research and that only a small percentage of the total project cost was spent by banks for in-house development activities.

FSTC recently completed the proof-of-concept project related to Web services. The project's goals were to promote shared learning and develop technologies related to Web services for identification, aggregation, and composition of corporate account data and services. The Web services project was cosponsored by NEC's Niteo Partners and three retail banking firms—Wachovia, Bank of America, and JP Morgan Chase.

Niteo Partners is a wholly owned subsidiary of NEC (NEC has worked on innovation in technology for over 100 years). NEC has a large investment in technology research labs around the world. These labs work on issues related to Internet software, nanocomputing, quantum cryptography, and other networking-related technologies. In addition to applied technology research, NEC also invests in academic or basic research. NEC has worked closely with a multidisciplinary research faculty at Stanford University. Areas of research include

- knowledge representation,
- machine-to-machine communication and interaction, and
- automated computing.

NEC invested $2 to $3 million for academic research in machine-to-machine interactions and wanted to set up a project that would advance awareness of its technology. NEC was looking for market exposure in the financial services sector specifically. NEC called on their wholly owned subsidiary, Niteo Partners, to design or craft a project in conjunction with the Stanford research team that would demonstrate the machine-to-machine interaction technology in combination with existing standards related to Web services to reduce the cost of intrabank interactions.

[5]The term "proof-of-concept" is used by the participants in this case study to refer to applied research to demonstrate real-world applications of a technology.

The goals of this project were to

- gain market exposure for NEC technology related to Web services and
- demonstrate what Web services have the potential to provide in the future for the financial sector.

When Niteo approached the FSTC, they discovered that the financial services sector was just beginning to understand the current capabilities and applications for Web services. Niteo spent 6 months educating industry participants on the state of standards related to Web-service applications. Niteo then created case examples to demonstrate the market potential for Web services in the financial services sector.

Once the returns on investment were visible, retail banking institutions entered into a cost-share project with Niteo through FSTC. This project allowed industry experts to share knowledge of the business and specify the special needs that the technology needed to address. Niteo used this input to develop reference materials that could be implemented in house by the participating banks.

The latter project was co-funded by NEC and the FSTC participants, including

- Bank of America,
- Wachovia, and
- JP Morgan Chase.

These firms agreed to fund the proof of concept jointly in return for the rights to core findings and any intellectual property developed.

Niteo ran the project. The knowledge and learning occurred at Niteo but was informed by the business expertise of the banking executives from the participating banks. The project has moved into a second phase concerned with implementing the findings from Phase 1. Phase 1 lasted approximately 2 years.

As part of the implementation phase of the project, participating banks have the opportunity to become more involved in developing and deploying the technology. At this point JP Morgan Chase is the only one of the three banks that is proceeding with implementation. They are funding the implementation of the basic standardized codes developed as part of Phase 1 and are creating a test bed to work through the remaining technological issues. Most of these activities will be conducted in house, with NEC working as a consultant. Insights gained in Phase 2 will be IC owned by JP Morgan Chase and will not be shared with the other banks that participated in the first phase of the project.

B.5 REFERENCES

COMPUSTAT. 2003. American Stock Exchange Database. Contennial, CO: Standard & Poor’s, McGraw Hill Companies, Inc.

JP Morgan Press Release. October 2, 2002.

National Science Foundation (NSF). 1998. “Survey of Industrial Research and Development.” <http://www.nsf.gov/sbe/srs/nsf01305/pdf.start.htm>.

Appendix C: Systems Integration Services Sector

Software has become an intrinsic part of business activities. Virtually every business in the United States depends on software to aid in the development, production, marketing, and support of their products and services. This software may be written either by developers who offer a shrink-wrapped product for sale or developed by organizations for custom use.

Software development is a “gray” area and is often not covered by R&D definitions (Marklund, 2000; Young, 1996). For software development to fall under R&D, it must embody scientific and/or technological advance, and the project’s goal must be resolution of scientific and/or technical uncertainty on a systematic basis. However, firms seem to be unclear as to how much of software development conducted as part of the innovation process should be reported as R&D expenditures (Marklund, 2000). This appendix investigates innovation in the Computer Systems Design and Related Services (NAICS 5415) sector.

C.1 INDUSTRY PROFILE AND R&D STATISTICS

The software industry is defined as computer and data processing services (NAICS 5415). Within computer and data processing, there are computer services (IBM), computer programming services (Complete Business Solutions Group), packaged software (Microsoft), computer integrated designs (Unisys Corporation), data processing services (Automatic Data Processing), information retrieval services, computer facilities management, computer rental and leasing (Comdisco Inc.), computer maintenance and repair, and computer-related services. Table C-1 lists sales, employment, and R&D expenditures for companies contained in COMPUSTAT by four-digit NAICS codes.

Table C-1. Software Services Sectors

Software NAICS	Description	Number of Firms	Sales ($ millions)	R&D Expenses ($ millions)	Employment (thousands)	R&D Intensity ($ per employee)
5415	Computer services	272	$104,595	$6,118	671.3	$9,114
5415	Computer programming services	25	$6,090	$38	67.9	$556
5112	Packaged software	488	$86,523	$325	13,988.1	$23
5415	Computer integrated designs	185	$34,442	$180	2,426.6	$74
5142	Data processing services	20	$19,992	$133	690.1	$193

Note: R&D intensity based on information in COMPUSTAT by four-digit SIC code. Note that NAICS 54191 (On-Line Information Services), NAICS 541513 (Computer Facilities Management), NAICS 811212(Computer Maintenance and Repair), and SIC 7379 (Computer Related Services) have no entries in COMPUSTAT but are included in the software services sector for this study.

Note: Computer Integrated Designs (5415 NAICS) includes companies engaged in the writing, modifying, and supporting software to meet the needs of a particular customer and/or planning and designing computer systems that integrate computer hardware, software, and communications technologies.

Source: COMPUSTAT, 2003.

The last column of Table C-1 reports the estimated R&D intensity per worker in each of the different subsectors. The subsector computer services has a high level of R&D intensity per worker compared with the other subsectors for the software industry: $9.1 thousand per worker. Computer programming follows at a distant third with $556 per worker.

Table C-2 lists the top 10 publicly traded software publishers by sales. International Business Machines Corporation (IBM) holds the top spot for 1999 at $87.5 billion, followed by Microsoft at $19.7 billion, Computer Associates with $6.1 billion, and Oracle at $10.3 billion.

Table C-2. Top 10 Software Publishers by Sales

Name	Employment (thousands)	NAICS	Sales ($ millions)	R&D Expenses ($ millions)
International Business Machines Corporation	307.4	5415	$87,548	$4,575
Microsoft Corporation	31.4	5112	$19,747	$2,970
Electronic Data Systems Corporation	121.0	5415	$18,534	NA
Oracle Corporation	NA	5112	$10,130	$1,010
Computer Sciences Corporation	58.0	5415	$9,371	NA
Unisys Corporation	35.8	5415	$7,545	$339
Computer Associates International Inc.	21.0	5112	$6,103	$1,363
Automatic Data Processing	37.0	5142	$5,540	$412
First Data Corporation	31.0	5142	$5,520	NA
Sap Ag-Adr	21.7	5415	$5,071	$750

NA: not available in COMPUSTAT.

Note: Figures are total company sales and R&D, not just for software

Source: COMPUSTAT, 2003.

Table C-3 provides a sample of companies in the software services sector with significant R&D expenditure in 1999 for the software industry based on COMPUSTAT (2003).

IBM, the largest producer of R&D in the software industry, designs both hardware and software system applications. IBM spent $4.6 billion on R&D in 1999. Microsoft Inc. is the second largest with reported $2.9 billion in R&D expenditures. Microsoft specializes in developing software applications for multiple computing devices. Microsoft's products include scaleable operating systems for servers, business solutions applications, software development tools, server applications, personal computers, and other various specialized products.

C.2 R&D CHARACTERISTICS AND ACTIVITIES

Similar to the telecommunications industry, the software industry is well defined in that most companies classified under NAICS 5415 are conducting R&D related to the sector's classification. CSTB reports that over the past 20 years the areas of computer architecture, compliers, and memory management have seen the largest number of innovations. The factors that are impeding further progress and areas in which new

Table C-3. Top 10 Sample of Software Service Firms with Significant R&D Expenditure, 1999

Name	Employment (thousands)	NAICS	Sales ($ millions)	R&D Expenses ($ millions)	Business Description
International Business Machines Corporation	307.4	5415	$87,548	$4,575	Software design and services
Microsoft Corporation	31.4	5112	$19,747	$2,970	Software design
Computer Associates International Inc.	21.0	5112	$6,103	$1,363	Data management
Oracle Corporation	NA	5112	$10,130	$1,010	Enterprise software
Automatic Data Processing	37.0	5142	$5,540	$412	Data communications
Unisys Corporation	35.8	5415	$7,545	$339	Computer services
Peoplesoft Inc.	6.9	5112	$1,429	$297	Software design
BMC Software Inc.	6.7	5112	$1,719	$294	Software design
America Online Inc.	12.1	5415	$4,777	$286	Internet service
Electronic Arts Inc.	3.1	5112	$1,420	$267	Gaming software

NA: not available in COMPUSTAT.

Source: COMPUSTAT, 2003.

R&D is being focused on a wide range of general issues, including scalability, complexity, interoperability, flexibility, security, and emergent behavior in systems (CSTB, 2000).

- **Scalability** is an important issue pertaining to systems integration in two ways. As systems expand, they require more components and are expected to serve a larger number of users simultaneously.
- **Complexity** results because the number of required components, lines of code, and elements that interact and share information, combined with the accompanying feedback loops, create a complex system, which makes understanding the underpinnings of systems functioning more difficult.
- **Interoperability** results because when systems are built, the components come from a wide array of vendors all using different object-oriented coding. The vendors have no way of knowing what systems or applications certain software will need to communicate with. This issue requires that the computer science community develop a well-understood methodology to avoid system design failures. Currently, there is no accepted method or standards other than trial and error.

- **Flexibility** means systems must have the ability to integrate smaller systems and components that apply to the design phase as well as after deployment. Because of the time span for the larger system development projects, the initial demands and objectives for the system can change. These systems are characterized by long life spans once the system is put into use, and the components will require replacements and more frequent upgrades to the most recent technology without having to restructure the entire system once any new component is introduced.
- **Trustworthiness** is becoming increasingly important as the amount of “critical infrastructure” becomes dependent on networking, which creates opportunities for outside sources to corrupt systems.
- **Security** is becoming increasingly important as industries such as health care and e-commerce develop a larger need for passing personal information over a networked system. A breach in the security of a networked system could result in huge financial loss, accidental disclosure of personal medical records, and reduction of consumer confidence.
- **Availability and Reliability** is the concern that a large-scale system will be available and functioning when it is needed despite varying environmental conditions. Distributed computing is an area of study concerned with computer systems interconnected via networks, and researchers have started to develop algorithms that ensure delivery of data packets despite changing factors in the performance of the network.
- **Systems Operation and Management** has become increasingly difficult to control because of the size of systems and the management responsibilities delegated over several organizational units. Increased automation in operational support and enhanced tool kits could potentially facilitate and improve efficiency in distributed systems. Solutions to these types of problems have yet to be adequately addressed in the research community.

C.3 INTERVIEWS WITH SYSTEMS INTEGRATION COMPANIES

Since 1992, systems integration has been the most rapidly growing component of the computer industry. RTI conducted informal interviews with industry experts to investigate the types of research activities performed in systems integration. RTI conducted 10 interviews with nine systems integration services firms (see Table C-4), including large and small corporations.

The CSTB (2000) states that total revenues for custom integrated system design and custom programming services rose from $34 billion in

Table C-4. Organizations Interviewed Related to Systems Integration Services

Company Name	Position
Carolina Advanced Digital Inc.	President and Chief Scientist
Computer Science Corporation	Practice Manager of IT Strategy and Architecture
Computer Service Partners	Inside Account Manager
Concurrent Technologies Corporation	Director of Systems Integration
EMC Corporation	Chief Information Officer
Infosystems Technology Inc. (ITI)	Founder and President
Integrian Inc.	Business Development
IBM	Systems Integration Project Manager
IBM	Vice President of Assets Innovation
PeopleSoft	Project Manager

1990 to $76 billion in 1997. Systems integration services facilitate the intersection of hardware, software, and pragmatic industry knowledge that provide the foundation of IT systems. The CSTB defines systems integration as “the ‘wiring’ together, via hardware and frequently very complex software, of the often already existing islands of computer applications into a coordinated enterprise-wide distributed network system.” Systems integration includes more than just physically allowing incompatible components to communicate. It is the synthesis of application domains such as finance, manufacturing, transportation, and retail and the supporting information infrastructure including databases, operating systems, architectures, networks, communications devices, and security measures (CSTB, 2000).

The remainder of this appendix is based on the findings from the interviews and discusses the innovation process for developing systems integration products and services and the activities that are typically classified as R&D.

C.4 DESCRIPTION OF SYSTEMS INTEGRATION SERVICES

The market for systems integration services is evolving. This evolution is largely based on how data are managed and communicated internally between different areas’ business operations and externally between other organizations within a supply chain. As supply chains increasingly become virtually vertically integrated, the level of detail and the quantity of data a firm is required to manage are increasing exponentially. Today's systems integration services help client organizations manage data and provide innovative ways to exploit the knowledge nested in the large amounts of data that exist both inside and outside of a firm's business operations. To this end, systems integration services have been evolving over time from the simple task of "wiring" two or more systems together to enabling information transfer across different companies, platforms, and standards protocols.

As this highly competitive industry grows, integration services firms are forced to seek out ways to differentiate their services. In the 1980s and 1990s almost all systems integration activities involved computer programming labor services. Customizing software programs, translation algorithms, and other middleware were commonly needed to interconnect legacy information infrastructures to more modern business software applications. Today's systems integration firms rely less on a set of software programs that were developed traditionally as a unique solution for each project and more on developing and leveraging capital and intellectual assets that can provide a competitive advantage. This can include developing either generic technology solutions that require relatively minor adaptations to individual customer needs or software that is sufficiently flexible to allow the customer to make adaptations.

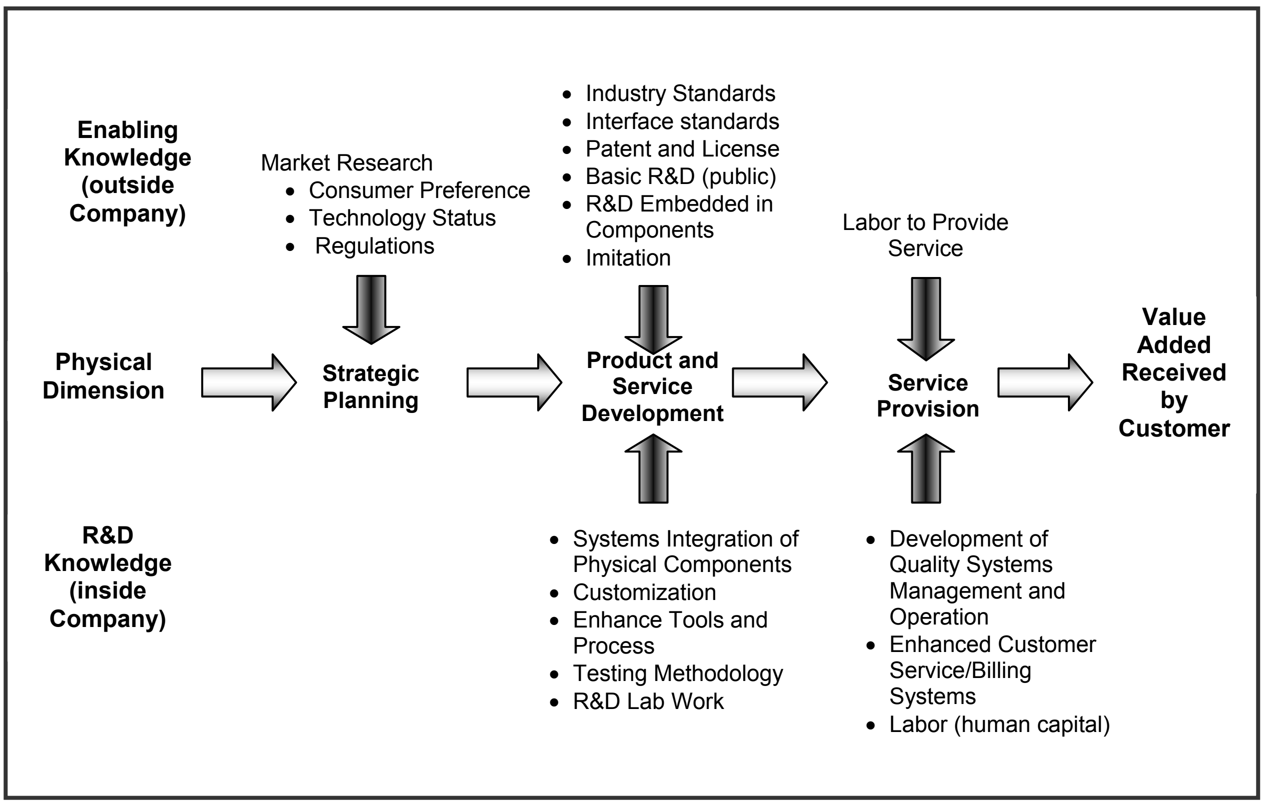
The trend is for an increasing share of systems integration services to be "commoditized." For example, software vendors have begun to specialize in a specific industry or business process software. Over time, the high costs of setting up custom-built systems has motivated the software industry to identify common needs across numerous clients and collapse the commonalities into products that are closer to the concept of "shrink wrapped" software. These packaged applications can then be configured with relatively little additional effort to meet the needs of many firms within a single industry.

As the components of systems integration services become commoditized, leaders in systems integration are differentiating their services from basic labor exercises aimed at linking several systems in a business operation through computer programming. The service provider differentiates its services through "asset innovation," leveraging its internal assets to assist in developing solutions for a client. For example, many companies' strategic plans include accumulating and maintaining industry-specific knowledge in business operation optimization, which is sold to industry as a service. As a result, we are increasingly seeing a distinction between traditional programmers-based service systems integration firms and more diversified companies that also have detailed scientific or industry-specific knowledge that can be bundled with their systems integration services.

C.4.1 Systems Integration Service Development Process

Companies interviewed were asked to describe the process by which they develop the IC underlying their products and services. Figure C-1 illustrates the information flows that characterize innovation for systems integration activities. The center horizontal row represents an average product life cycle and the different stages associated with it.

Figure C-1. Example Illustration of the Information Flows for Systems Integration Activities



The upper horizontal row represents the information flowing into the company's product development from outside the company and/or industry. The lower horizontal row represents R&D that is performed within the company, which is embedded in the product development process. The development stage includes any activity associated with pushing the frontier of knowledge related to each bullet point. It is important to note that in a competitive industry, such as systems integration, developed knowledge is considered a trade secret. As a result, each company in the industry could potentially be required to reinvent existing technology already developed by a competing company to maintain a competitive edge in the market. This is merely an example of the types of activities that could occur in a systems integration company.

C.5 R&D ACTIVITIES

Systems integration companies devote a significant resource to developing and enhancing the skills and knowledge required to provide their services. Many of these innovative activities occur “on the job” as part of software customization or trouble shooting system problems. However, some people disagreed about whether many of these activities met the definition of R&D.

Table C-5 illustrates the diversity of companies providing systems integration services in terms of the variance in their R&D reporting. Service-only firms are generally less likely to report their systems integration activities as R&D expenditures. In contrast, diversified firms such as IBM and Hewlett Packard classify one-quarter to one-half of systems integration activities as R&D; thus, the level of reported R&D spending by diversified service firms is significantly greater than that of service-only firms.

This variance in reported R&D for systems integration is likely due to several factors. As mentioned above, larger systems integration firms differentiate themselves through the IC and assets they offer in conjunction with traditional integration services. This can be in the form of detailed knowledge of the hardware and software products these firms provide or through specific industry knowledge of selected sectors’ IT needs. In these instances, companies introduce products and services with IC developed through strategic R&D initiatives.

For example, IBM conducts research to ensure its hardware and software will interoperate with legacy and competing systems and then promotes this research as part of a strategy to market their systems integration services. In this way it leverages its technical expertise related to its proprietary hardware and software technology.

Table C-5. R&D Investments of Representative Systems Integrators, 1998

Company	Systems Integration Revenues ($ millions)	Percentage Systems Integration R&D
Services-Only Firms		
Accenture Consulting	$8,307	0%
American Management Systems	$1,058	77%
Computer Sciences Corporation	$7,660	0%
Electronic Data Services	$16,891	0%
Keane	$1,076	3.5%
Diversified Firms		
IBM	$28,916	25%
Hewlett Packard	$6,956	50%
Lockheed Martin	$5,212	36%

Source: Computer Science and Technology Board, 2000.

In contrast, smaller service-only systems integration firms are more likely to solve their problems in the field through on-site modification of software programs and development of work-arounds. From this perspective they have no “R&D staff,” and any “research” they might conduct is considered an integral part of the integration service being provided. In addition, it is likely their customized integration services have less potential for reuse (although lessons learned build the IC and capabilities of service-only firms).

Larger firms follow a model of innovation moving from concept stage, where a potentially marketable solution is developed, to proof-of-concept stage, where risk is evaluated in terms of marketability, and finally to pilot project, where risk assessment is continued before moving into mass production. Small firms are more likely to implement existing service integration technology, which involves some development/engineering of a “commodity” service integration approach, but minimal activities related to seeking out novel approaches to integration.

C.5.1 Categories of R&D

Firms generally grouped their research into four categories:

- **Building New Systems** for clients—activities for this category resemble software design and the synthesis of hardware and interface applications. Products developed in this category are one of a kind.

- **Maintenance of Code**—rewriting code is necessary to maintain the system's integrity with respect to its operational environment.
- **Support**—(**applied** research) researching better processes for server maintenance and monitoring and system tracking for trouble shooting.
- **Break/Fix Maintenance**—(**applied** research) research consists of designing better processes and establishing generic protocols across all products.

The large corporations such as Unisys, Electronic Data Systems, IBM, and Computer Science reported that they were undertaking at least some "basic research." These companies maintain large facilities dedicated to noncommercial research programs. Smaller firms consistently reported zero activity in "basic research." Respondents explained that the smaller business model for systems integration was focused primarily in applied research with respect to the overall objective of completing the project.

Directors from large firms identified "applied research" as the area in which their division spent the largest share of time, whereas directors from smaller firms attributed only a small portion of their activities to such research. Identifying practical applications for emerging technology was the primary activity that respondents associated with this category of research.

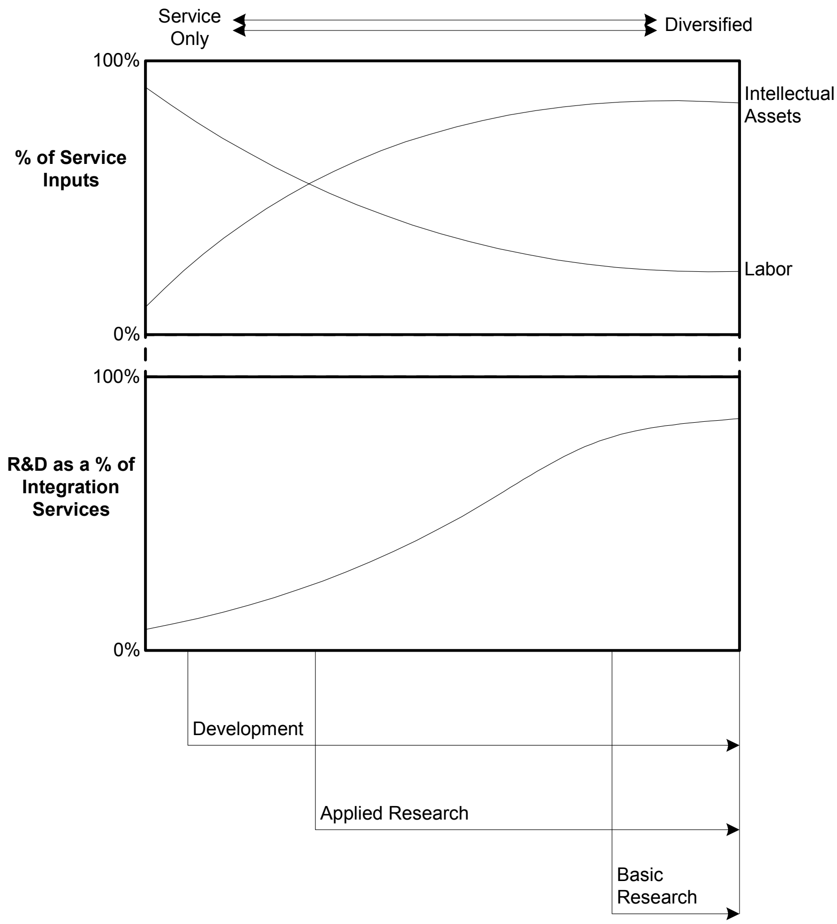
"Development" activities were reported as the second largest share of a systems integrator's time from large firms and the largest share by smaller firms.[1] The types of activities respondents associated with this category of research were writing code, setting up infrastructure, wiring, and "putting the system together." While building systems was a major activity for the larger companies, it was not an activity mentioned by the smaller firms. Over time, the high costs of setting up custom built systems have motivated the computer services industry to identify common needs across numerous clients and collapse the commonalities into a "shrink-wrapped" product.

C.5.2 Labor Versus Intellectual Capital

Conceptually, Figure C-2 highlights the spectrum of systems integration services and the shift between labor and IC as inputs to providing integration services. On the left-hand side, the service-only firm relies

[1]National statistics indicate that development activities are typically the largest component of R&D expenditures. The emphasis on applied research provided by participants interviewed as part of this study highlights the difficulties in distinguishing between basic, applied, and developmental research in the systems integration services sector.

Figure C-2. Spectrum of Systems Integration Service Firms



heavily on basic labor (computer programmers and some managerial workers) to implement a standard set of activities that integrate multiple systems. As one moves from left to right in Figure C-2, the share of the labor versus IC that goes into providing a systems integration service increases. The IC consists of input from skilled scientists (possibly involved in hardware or software development) and industry specialists, in addition to proprietary technologies such as algorithms and other patentable or licensed technology.

R&D intensity increases as intellectual assets become an increasing share of providing integration services. The lower box in Figure C-2 shows this increase in R&D intensity, highlighting the type of R&D potentially conducted as a systems integrator becomes more diversified.

In general, systems integrators are most likely to engage in development, working to enhance or create new service offerings.

As a firm continues across the spectrum and leveraging related technologies becomes more important, the firm may conduct applied research to incorporate these technologies into its service offerings. In the extreme, larger firms may conduct basic research to support systems integration, such as involvement in standards and protocol development, as well as basic research into business organization and communications.

C.6 SERVICE-ONLY VERSUS DIVERSIFIED FIRMS' R&D ACTIVITIES

A distinction can be made between two general types of systems integration firms: service-only and diversified service and product firms. Service-only systems integration firms primarily provide services in computer programming and reconfiguration of packaged software, leveraging experience gained over time from previous (often similar) projects. Diversified systems integration firms (such as IBM) provide hardware and software products as well as integration services that can be bundled. In addition, diversified systems integration firms are typically much larger service firms that acquire and use a pool of technology and intellectual assets that the company can leverage to differentiate their services from those of competitors.

C.6.1 R&D Activities of Service-Only Integrators

From our interviews, service-only firms responded that they engaged in few activities that would be considered R&D. Service-only firms commonly build on business software applications using "open" architecture that allows the integrator to easily configure prepackaged applications purchased from a vendor to meet the needs of the client. Using XML and other open-source networking languages, the integrator brings together various components of a client's business operation.

However, those interviewed in the service-only firms were concerned with protecting and managing their IC, which is largely the ability to engineer commodity software systems. Service-only firms interviewed reported that they were managing the IC developed from years of experience on different projects.

Larger service-only firms often create executive positions known as Chief Knowledge Officers to manage and coordinate the IC developed by the firm. Larger firms, such as Computer Science Corporation (CSC) reported developing formal methodologies for enterprise architecture, product life-cycle management (PLM), enterprise resource management (ERM), and managing operations centers. These methodologies are documented through white papers and in-house presentations at company research conferences.

Service-only firms generally grouped their methodologies and development activities into four categories:

- **Building new systems** for a client—including software design and systems engineering (synthesis of hardware and interface applications). Products developed in this category are one of a kind.
- **Systems configuration**—turning certain options within purchased software applications off or on to maintain the system's integrity as products/systems evolve.
- **Support research**—researching better processes for server maintenance and monitoring and system tracking for trouble shooting (one firm classified this as applied research).
- **Break/fix maintenance**—designing better processes and establishing generic protocols across all products.

In addition, service-only firms also perform scoping exercises to determine the capabilities of future technologies. As part of these exercises, they research the technologies that will be most influential over the next 30 years by scanning the scientific literature and technology news sources. This information is then used to conceptualize how the integrator can create new services or incorporate the capabilities into existing services.

CSC reports that 24 months is a minimum required lead time that an integration firm must have on the emerging technology markets if the firm wants to remain competitive. The optimal lead time is 4 to 5 years. However, this amount of lead time is generally only possible if the integration firm is taking part in the technology development process. Service-only integrators rarely have access to emerging technology at its earliest stages of development.

C.6.2 R&D Activities Cited by Diversified Integrators

In contrast, diversified integrators not only have access to the IC accumulated through experience on previous integration projects, but they also have access to the technology being developed in the design and manufacturing division of their company and to the researchers leading these activities. IBM Global Services reports that they are working with their company's technology experts who design computing equipment to conceptualize how existing equipment or capabilities can generate new service offerings. IBM is creating new services by moving away from the labor exercise that integration has become and attempting to leverage internal and external IC to innovate their integration services.

One example of leveraging IBM equipment technology to innovate integration services is Global Services' new offering called WebFountain. This new service offers clients the ability to harness the power of a super computer to scour the Internet for all the published or online information on a given topic. The service is composed of five servers with over a petabyte of data storage programmed with unique algorithms designed to seek out Web content on specific topics. The amount of data the technology can gather allows the client to examine trends in consumer preference or identify cultural norm differences across society. In its traditional form, this type of research would be very expensive and require several years of research. WebFountain reduces the costs of research in product design and increases revenue by shortening the time required to bring a product to market.

Integration of systems in a business operation setting requires understanding the role that information plays in the business. Global Services is taking this concept one step further to better understand the nature of work within different industries. IBM has anthropologists who specialize in researching the way professionals in different industries use information to maintain large business operations systems. IBM considers their research in this area as a basic research exercise. Although the study of human behavior is a social science area, the end use is to increase the effectiveness of an integration service.

Global Services has also used its engineering staff, which normally specializes in designing super computers and deep computing technology, to develop a cryptographic scheme to code electronic signatures for the French land titling system. The French government wanted to modernize their real estate titling system, converting all hard copies to digital online documents. However, the French government required a guarantee that no technology would emerge that could make the system vulnerable to computer attacks for the next 25 to 30 years. IBM was hired to create a system that met the French government's requirements. The system required a combination of hash and cryptographic schemes. As part of this project IBM Global Services leveraged its deep computing R&D division to develop a scheme that met the government's requirements.

C.7 SUMMARY

Today, business must rely on the efficient and reliable transfer of data internally and externally across an entire supply chain; this includes design, supply logistics, production, distribution, and marketing. Systems integration services require both a stock of IC to understand the hardware and software configuration and more importantly a conceptual understanding of the role the IT infrastructure plays in the client's industry or supply chain.

The firms we interviewed responded that systems integration firms conduct R&D activities in the following areas:

- developing methodologies to improve processes and implementation,
- adopting existing or emerging technologies in equipment and systems, and
- examining how people use information in different industries and business operations.

These examples could apply to any integration service firm. However, service-only firms typically focus on developing ways to improve the efficiency of labor through detailed methodologies that standardize the integration process. Diversified firms are more likely to conduct complex research in technology adoption and tailor their service to industry-specific uses.

C.8 REFERENCES

COMPUSTAT. 2003. American Stock Exchange Database. Contennial, CO: Standard & Poor's, McGraw Hill Companies, Inc.

Computer Science and Telecommunications Board (CSTB). 2000. *Making It Better: Expanding Information Technology Research to Meet Society's Needs*. Washington, DC: National Academy Press.

Marklund, Goran. 2000. "Indicators of Innovation Activities in Services." *Services and the Knowledge Based Economy*, Mark Boden and Ian Miles (eds.), New York: Continuum.

Young, A. 1996. "Measuring R&D in the Services." STI Working Papers. Paris: OECD. <http://www1.oecd.org/dsti/sti/prod/wp_7.htm>.

Appendix D: Research Development and Testing Service Sector

The expansion in service-sector R&D is in large part due to an increasing dependence by large firms on “outsourcing” as the vehicle for accomplishing innovation in products and production (Jankowski, 2001; Amable and Palombarini, 1998; and Howells, 1999; Pilat, 2001). Outsourcing is a common approach for conducting research in areas of interest that require expertise outside of a firm’s core competencies. As of 2000, engineering and scientific contract research accounted for between 5 and 12 percent of industrial R&D in most industrial economies (OECD, 2001).

The literature has yet to agree on a common set of factors that motivate firms to contract out scientific R&D. In general, RD&T services commonly outsourced have traditionally been viewed as “formal, routine, repetitive, and cost based with short time horizons” (Andersen et al., 2000). However, this appears to be changing as RD&T firms are establishing long-term partnerships with client industries and increasingly providing core research functions to support strategic initiatives (Howells, 2000b).

This appendix begins with an overview of the broader RD&T service sector and its R&D activities. This is followed by a more in-depth analysis of R&D activities and the innovation process in the biotechnology industry, which is one of the largest and fastest growing segments of the RD&T service sector.

D.1 RD&T INDUSTRY PROFILE AND R&D STATISTICS

The RD&T sector (NAICS 5471, also referred to as Scientific R&D Services) performs R&D activities in the fields of physical, engineering, life sciences (NAICS 54711), social science, and humanities (NAICS 54712). Most firms classified as RD&T perform R&D by contract or fee for either manufacturing or nonmanufacturing industries.[1]

Table D-1 lists the top 10 RD&T firms by sales based on the COMPUSTAT database. In general, these firms are of modest size with fewer than 5,000 employees. For example, AAI Pharma, employing 1,200 workers, considers itself a specialty pharmaceutical company. The firm acquires branded pharmaceuticals that it believes hold potential for further development and improvement. AAI Pharma also offers pharmaceutical R&D services on a fee-for-service basis. The firm supports R&D activities to formalize categories of "products" (IV nutritional fluid and immunosuppression drugs) and "technologies" (drug delivery systems). They reported net revenue of $141 million in 2001. Their SEC 10K report cites R&D expenditures as 8 percent of net revenues. As a stated goal, the company tries to keep its expenditures on R&D between 8 percent and 10 percent of the budgeted annual net revenues for the following year.

Table D-2 shows a sample of firms with significant R&D expenditures in 2001 based on COMPUSTAT. Most of these firms are engaged in some form of biotechnology research.[2]

Because of the predominance of RD&T firms engaged in biotechnology research (including genetic bioscience research, drug discovery, pharmaceutical testing, etc.), the remainder of this appendix focuses on the biotechnology biopharmaceutical industries and their relationship with RD&T firms (outsourcing of R&D).

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[1]Because social science and humanities research falls outside NSF's definition of R&D, this case study focuses primarily on physical, engineering, and life science research firms—specifically biotechnology firms.

[2] The composition of biotechnology research and definitions of the biotech industry are discussed in Section D.1.2.

Table D-1. Top 10 RD&T Firms by Sales

Name	Employment (thousands)	NAICS	Sales ($ millions)
Covance Inc.	7.2	5417	$856
Charles River Labs International Inc.	4.0	5417	$466
Pharmaceutical Product Development Inc.	4.4	5417	$432
Parexel International Corporation	4.6	5417	$388
Inveresk Research Group-Redh	2.3	5417	$156
Kendle International Inc.	1.8	5417	$154
AAI Pharma Inc.	1.2	5413	$141
Albany Molecular Resh Inc.	0.5	5417	$98
Huntingdon Life Science-ADR	1.3	5417	$95

Source: COMPUSTAT, 2003.

D.2 BIOTECHNOLOGY

The term "biotechnology industry" is widely used by public policy makers as well as the popular press. However, no group of homogeneous firms or organizations (or NAICS code) clearly defines the biotechnology industry (Toole, 2003)[3] because of the rapidly evolving nature of the industry and the diverse set of technologies used to develop applications from bioscience research. The biotechnology industry crosses over many disciplines from agriculture and the environment to health care and industrial applications. However, individual biotech firms typically specialize in and develop core competencies in specific genes and treatments that increase their probability of success.

In general, the biotechnology industry is not identified by a set of common products that are produced by similar techniques, but rather by its applications. Prevezer (1998) defines the biotechnology industry in terms of the following applications:

- therapeutics (drugs)
- diagnostic applications
- chemicals (pesticides, insecticides, and new chemicals)
- agricultural (seed, plant, and animal applications)

[3]Throughout the following discussion, we present statistics and discuss research activities based on similar, but not necessarily identical definitions of the biotechnology industry.

Table D-2. Sample of RD&T Firms with Significant R&D Expenditures Based on COMPUSTAT, 2003

Name	Employment (thousands)	NAICS	Sales ($ millions)	R&D Expenses ($ millions)	Business Description
Exelixis Inc.	0.57	5417	$41	$89	Genomics-based pharmaceuticals company
Curagen Corporation	0.51	5417	$23	$66	Genomics-based pharmaceuticals company
Maxygen Inc.	0.31	5417	$30	$64	Genomics-based pharmaceutical and agriculture
Genaissance Pharmaceuticals	0.16	5417	$5	$46	Genomics-based pharmaceuticals company
Deltagen Inc.	0.30	5417	$10	$45	Genomics-based pharmaceuticals company
Symyx Technologies Inc.	0.20	5417	$60	$39	Genomics-based pharmaceuticals company
Microvision Inc.	0.23	5417	$11	$33	Optical scanning systems
Paradigm Genetics Inc.	0.25	5417	$24	$28	Life sciences in agriculture and human health
Arena Pharmaceuticals Inc.	0.21	5417	$18	$23	Biopharmaceutical company
Exact Sciences Corporation	0.07	5417	$0.05	$14	Applied genomics company

Source: COMPUSTAT, 2003.

- food and cosmetics
- environmental
- energy (biomass)

By all definitions, the biotechnology industry has experienced rapid growth in the past 2 decades. October 2002 marked the 20th anniversary of the first Food and Drug Administration (FDA)-approved biotechnology drug (Biotechnology Industry Organization, 2002). Today, there are 141 biotech-based medicines and vaccines on the market in an industry valued at $198 billion. The biotech industry, which includes 1,457 firms and employs 191,000 people in the United States, spent $15.7 billion on R&D activities in 2001 (Ernst & Young, 2002).

A recent study by the U.S. Department of Commerce (DOC) surveyed 1,031 firms conducting R&D in biotechnology-related applications. A large majority were conducting R&D activities in the area of human health in support of the pharmaceutical and the medical device industries (DOC, 2003). A large number of these biotechnology companies are relatively young, independent firms (established after 1990), employing fewer than 100 researchers. The DOC report states that most small firms conducting human health research focused on applied research and larger firms emphasized product and process development.

Table D-3 provides a list of some of the top biotechnology firms in terms of estimated R&D expenditure in 2002. These firms are increasingly outsourcing R&D activities to RD&T service firms.

Table D-3. Top Biotechnology Firms by R&D Expenditures, 2002

Company	Estimated 2002 R&D ($ millions)	Percentage Change from 2001	R&D as Percentage of 2002 Revenue
Amgen	$967.1	11.8%	19.4%
Genentech	$613.1	16.5%	24.0%
Millenium Pharmaceuticals	$510.0	27.3%	123.4%
Biogen	$365.7	16.2%	30.9%
Chiron	$361.0	4.8%	27.0%
Immunex	$258.6	26.3%	20.0%
Genzyme Corp.	$238.5	27.2%	20.1%
Vertex Pharmaceuticals	$212.0	55.1%	113.9%
Human Genome Sciences	$205.8	40.7%	954.2%
Incyte Genomics	$183.0	–10.0%	116.6%
ICOS	$173.0	54.7%	211.0%
Inhale Therapeutic	$160.0	14.6%	190.5%
Abgenix	$155.0	54.4%	328.7%
Gilead Sciences	$145.0	–21.9%	36.2%
Celera Genomics[a]	$142.4	–31.4%	103.4%
Total R&D Expenditure	$**4,690.2**		

[a]*Celera* was a major contributor to the Human Genome Project and completed a draft of the human genome in June 2000.

Source: Standards & Poor's Biotechnology Industry Survey, May 2002.

Examples of health-related biotechnology R&D include the following:

- **Molecular modeling** is the three-dimensional modeling of nucleic acids and protein structures based on a one-dimensional amino acid sequence; however, researchers are missing a description of the relationships between the one-dimensional sequence and the three-dimensional structure.
- **Genomics** is the study of disease origins at the molecular level, which is then used to inform drug researchers of new potential therapeutic targets.
- **Proteomics** is the identification and understanding of the function and interrelationships among proteins. Proteins are the product of genes following transcription (the transformation of information from DNA sequences into RNA) and translation (the transformation of the information in RNA into proteins). Disease processes become apparent at the protein level of activity.

D.3 BIOPHARMACEUTICAL INDUSTRY

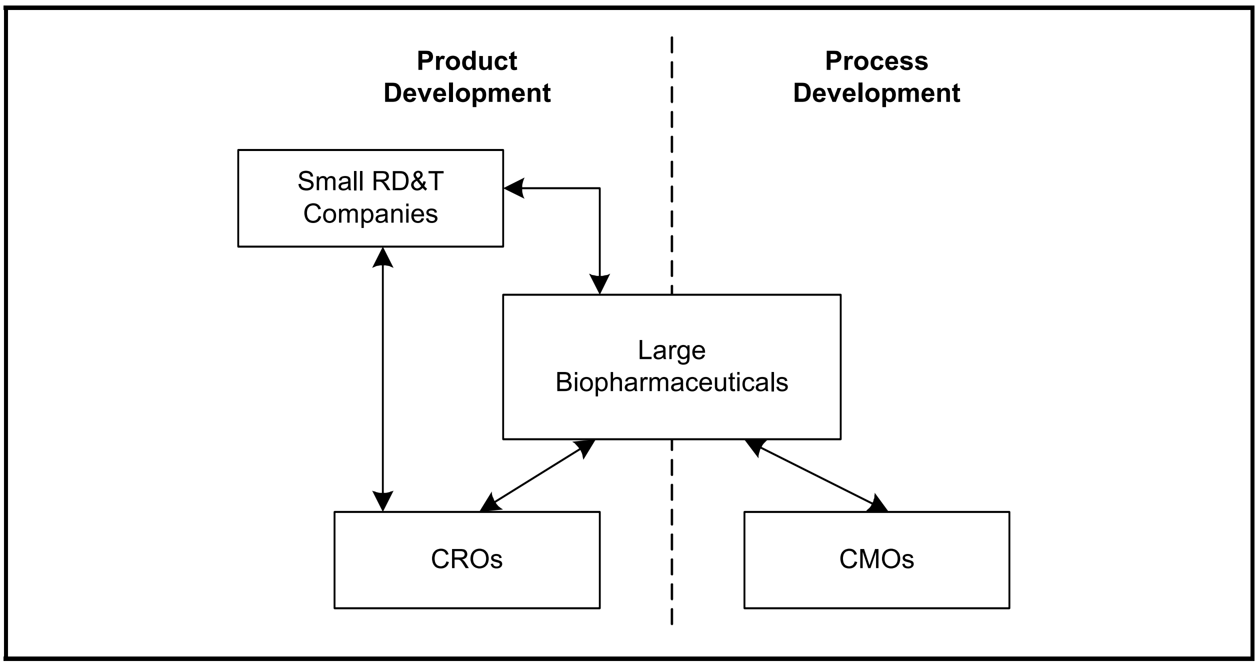
A larger, more encompassing industry description used in professional literature and policy discussions is the term “biopharmaceutical industry.” Biotechnology firms commonly enter into commercialization agreements with large pharmaceutical companies. Large pharmaceutical companies finance the R&D for biotech firms with potential drug targets in exchange for exclusive distributing rights and a royalty fee should the drug survive clinical trials and gain FDA approval.

The term “biopharmaceutical industry” captures all major participants in the drug development supply chain, including identification and discovery, pre- and postclinical trials, and production activities. In addition to large biotechnology pharmaceutical firms, this includes smaller RD&T firms, contract research organizations (CROs), and contract manufacturing organizations (CMOs).

The pharmaceutical industry is rapidly expanding with the advent of biotechnology-related drugs and gene therapies otherwise known as biopharmaceuticals, in addition to efficiency improvements in technologies that analyze potential drugs. As the “new drug” market expands, many companies are focusing their internal resources on drug discovery. As a result, the contract research industry has experienced rapid growth in the past 2 decades and now is extremely diversified in the variety of services and tools offered. The tools and services vary dramatically across the spectrum of R&D activities required to discover and develop a new drug.

Figure D-1 shows the four major players in the supply chain involved in the drug development, identification and discovery, pre- and postclinical trials, and production activities. These include large biopharmaceutical companies, smaller RD&T companies, CROs, and CMOs. RD&T companies and CROs are mostly involved in the product development phase of the supply chain and are typically classified as services providers. CMOs support the process side of drug development. This appendix discusses the drug and therapies development supply chain, focusing on the roles the RD&T companies and CROs play in the development process.

Figure D-1. Drug Development Supply Chain



D.3.1 The Drug Development Process

RD&T biotechnology firms are integrally involved in drug development. Development of a new drug costs on average $800 million for each new drug. A large share of the total R&D dollars by these industries pays for outsourcing development services and process and manufacturing services. Drug discovery and development is a well-documented process that includes several stages, starting with discovery of a potential targeted compound or therapy, followed by FDA-regulated preclinical and clinical trials, and ending with the successful marketing of a new drug or therapy. Assuming the newly discovered compound or therapy clears the FDA approval process, the total time from discovery to market can be 10 to 15 years. This process is both costly and time consuming.

The innovation process for biotechnology-related drug treatment products and processes is closely aligned with that of the pharmaceutical industry's drug development model. Figure D-2 illustrates the innovation process in biopharmaceuticals over several phases of R&D. The model identifies phases required to bring a drug to market in the United States. The arrows indicate the direction for the flow of information. Basic research originating in the information technology, manufacturing, and physical and biological sciences sectors is synthesized by the biotechnology sector and applied to identify possible drug targets. Tools and processes used in the discovery include

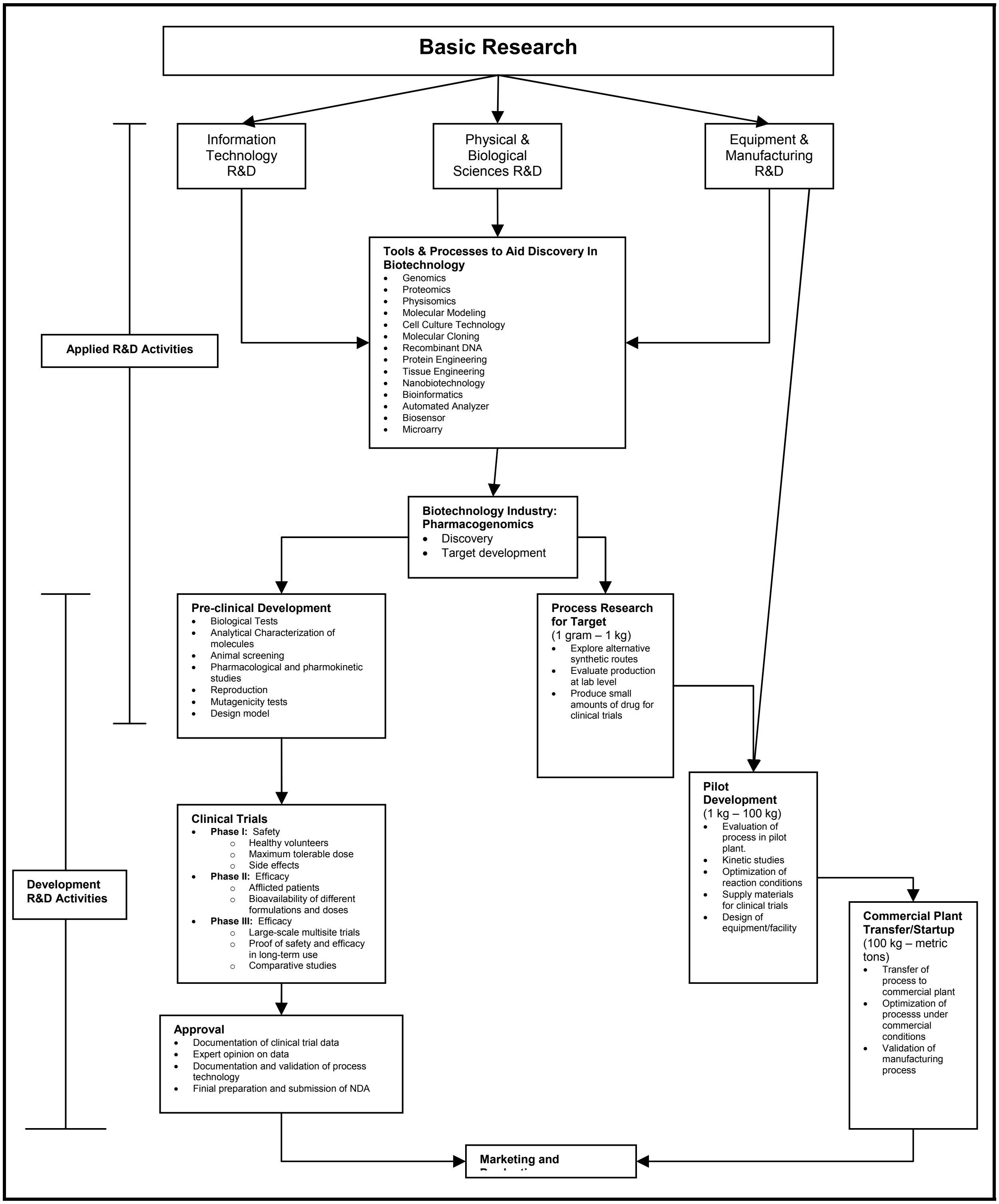
- genomics,
- proteomics,
- molecular cloning,
- recombinant DNA,
- protein engineering,
- bioinformatics,
- automated analyzer, and
- microarray technology.

In most cases, biotechnology firms, like large pharmaceutical firms, are scanning millions of possible compounds or genetic combinations for any variation that may improve human health in some measurable way. Much of this applied research is conducted by small RD&T companies and then transferred (through purchasing or licensing agreements) to larger pharmaceutical firms. Once a compound is discovered, the biopharmaceutical firm must decide where the drug has the greatest potential for market success. Firms will often contract with large CROs that have knowledge of various disease markets in the hopes of tailoring their R&D efforts towards a disease with the highest probability of success both in clinical trials and marketability. Following discovery of a new drug or treatment, the development diverges on two tracks: product and process.

Product Development

On the product side, the drug company is required to demonstrate a drug's efficacy and safety to FDA, evaluated through several years of

Figure D-2. The Innovation Process in Biopharmaceuticals over Several Phases of R&D



clinical trials. Stages in the product development process include preclinical testing; clinical trial Phases I, II, and III; FDA review and approval; and Phase IV postmarket testing. Each stage takes at least 1 year or more to complete. Figure D-3 outlines the various stages in the product development process.

The preclinical testing stage indicates likely safety and efficacy attributes in living organisms through animal testing and toxicology studies. These studies show biological activity of a compound against a targeted disease. Additionally, risk assessment and market viability are established at this stage as well. The type of information that comes out of these studies includes detailed descriptions of

- the new drug's chemical structure,
- how it works in the body,
- any toxic effects, and
- how the drug will be manufactured.

These sets of information are submitted to FDA in an Investigational New Drug (IND) application. The IND specifies the how, where, and by whom the clinical trials will be conducted. The five remaining compounds enter into clinical trials. Over 50 percent of the product development effort is spent in clinical trials. Over the course of 6 years, the drug is tested on real human patients to evaluate the drug's safety and dosage range.

Phase I of clinical trials generally takes about 1 year to complete. These studies enroll about 20 to 80 normal, healthy volunteers to determine how the drug is absorbed, distributed, metabolized, and excreted and the duration of its effects. Phase II uses volunteers that suffer from the targeted disease to study the drug's effectiveness. Phase II usually lasts 2 years. Finally Phase III is a nationwide study enrolling 1,000 to 3,000 real patients in clinics and hospitals around the country. Phase III requires physicians to monitor patients to determine efficacy and adverse effects. Upon successful completion of clinical trials, trial data, expert opinion data, and validation of process manufacturing data are compiled and analyzed.

A New Drug Application (NDA) submitted to FDA includes the final analysis and all the data gathered since the discovery of the new drug compound. The NDA regulatory submissions are typically over 100,000 pages and require an average review period by FDA of 30 months. Following the approval and marketing of the new drug, the drug company

Figure D-3. The Stages in Drug Development

	Preclinical Testing		Clinical Trials Phase I	Phase I	Phase I		FDA	Phase IV
Years	3.5	**File IND at FDA**	1	2	3	**File NDA at FDA**	2.5	
Test Population	Laboratory and animal studies		20 to 80 healthy volunteers	100 to 300 patient volunteers	1,000 to 3,000 patient volunteers		Review Process and Approval	Additional Postmarketing Testing Required by FDA
Purpose	Assess safety and biological activity		Determine safety and dosage	Evaluate effectiveness, look for side effects	Verify effectiveness, monitor adverse reactions from long-term use			
Success Rate	5,000 compounds evaluated		5 compounds enter trials				1 compound approved	

is still required to periodically report any adverse patient reactions and conduct (Phase IV) long-term effect studies on existing patients.

Additionally some drugs are discovered to have additional positive effects that were not specified in the IND submission. One example is Welbutrine; this drug was originally approved as an antidepressant but has been found to mitigate the withdrawal symptoms associated with quitting smoking. To market the existing drug for a new purpose, the drug company must go through the entire FDA approval process again.

Process Development

Process development begins even before preclinical testing. Newly discovered compounds must be manufactured in small amounts and the process for manufacturing must be determined in the IND regulatory submission to FDA. Depending on the size of the drug company, the firm may or may not have the resources and knowledge to efficiently evaluate how best to produce the newly discovered compound. Drug companies with limited resources, especially small biopharmaceutical companies, will outsource the drug manufacturing to a CMO that specializes in chemical or biological manufacturing. Although the CMO provides a service, these firms are generally classified under the industry classification medicinal manufacturing (NAICS 3254).

CMOs, like the traditional pharmaceutical manufacturing company, perform research to determine the availability and affordability of the components for a drug compound. Process research is intent on developing more cost-effective avenues for the drug's production. A team of process engineers, chemists, and/or geneticists is assigned to examine the underlying chemistry behind the new drug or therapy, in the hopes of finding ways to produce the drug on a larger scale in a commercial manufacturing plant. Following the firm's IND with FDA, clinical trials will begin, and additional testing demands larger quantities of the drug to be available.

CMOs also offer services to develop the packaging and labeling for a new drug. This process is generally done in close cooperation with the drug company and the CRO managing clinical trials. Controlled testing requires adherence to a strict protocol in the drug's composition and exterior appearance and packaging. The dosages must look the same for all three phases of clinical trials. Finally the drug's packaging must meet child safety regulations while being used in the clinical trial. Blister packets are one example of packaging services that a CMO might offer.

CMOs perform process engineering, manufacturing, and package and labeling development services on a contract basis with sponsor drug companies. CMOs play a significant role in the supply chain for drug development. Although it is important to highlight the services CMOs provide, they are primarily manufacturing facilities and are classified as such and therefore are not in the scope of this study

D.4 INTERVIEWS WITH RD&T BIOTECHNOLOGY FIRMS

To investigate the R&D in the drug development process, RTI interviewed several small biotechnology RD&T companies and larger CROs. Interviews were conducted with the companies' research directors. The biotech companies were small start-up firms (see Table D-4) conducting contract research for larger pharmaceutical companies or conducting independent research (funded by venture capitalists) with the hope of being bought out or going public once innovations have proven successful. Their activities are characterized as high-risk, high-return research, and risk sharing is one of the "services" they provide. Although their research eventually affects health care services, most of their research activities are in biological sciences similar to those conducted by large pharmaceutical and medicine manufacturing companies found in NAICS 3254.

Table D-4. Small RD&T Biotech Services Organizations Interviewed

Company Name	Contact	Research Activities
BioMachines	Frank Wang Director of R&D	Designs bench-top computer analysis solutions to automate proteomic R&D
Nobex	Robert Soltero Director of R&D	Develops and markets various methods for delivering drugs to a patient (e.g., transdermal patch, time release pills)
Zen-Bio	Renee Lee-Currie Director of R&D	Licenses tissue engineering technology associated with human fat cells (adipocyte)

In addition to small biotechnology organizations, RTI interviewed four of the largest CROs in the United States. Table D-5 lists the names of the companies interviewed. CRO is a generic term used in the pharmaceutical industry to label firms that perform research on a contractual basis for a sponsor pharmaceutical company. The contract

Table D-5. Large Organizations Interviewed Related to RD&T Services

Company Name	Contact	Research Activities
Covance	Dianne Sheehan Client Services Director	Preclinical pharmacological studies, and Phases I through IV clinical trials and postmarketing studies
InGenium Research	Leslie McCriminon Public Relations Directory	Phases II through IV clinical trials
Inveresk	Jon Koch VP Global Commercial Services	Process engineering, data management software, assay development
Quintiles Transnational	Dick Jones Director of Corporate Communications	Preclinical pharmacological studies, and Phases I through IV clinical trials and postmarketing studies

research industry has experienced rapid growth in the past 2 decades, and research performed by CROs spans the preclinical and clinical phases.

Several biotech firms interviewed are developing technologies, such as assays,[1] to support drug discovery and development of new vaccines. These companies either sell the assays directly to biopharmaceutical companies or use them to provide services.

Few of the experts interviewed considered their company a service provider. Most saw their business as a small player in the rapidly growing sector of pharmacogenomics (development of patient-specific therapies based on the individual's genetic makeup). Although most of the experts did not consider their business a service, their research was primarily funded by pharmaceutical companies. They indicated that "big pharma" typically focus on their areas of core competencies and outsource to biotech firms to research unexplored gene therapies. This practice reduces risk while expanding the number of markets in which a pharmaceutical company can compete.

Of those interviewed, none reported performing *basic research*. However, they often partner with local universities to adopt and leverage knowledge as it emerges. In addition, many firms purchase the rights to existing research on a particular compound and continue its development. Respondents reported that basic research is often too costly to perform in house because it "generates little or no revenue."

[1]Assays are in-vitro cells with characteristics similar to a human cell. They are marketed for use in preclinical tests to prove efficacy of a drug before entering costly clinical trials.

The biotech firms interviewed attributed the largest share of their R&D activities to performing highly specialized *applied research* to support the creation of proprietary technology, which in turn can be marketed as a service through licensing or contracting.

Responses varied for *development* activities depending on the firm's area of research and business interest. Following the completion of preclinical trials, biopharmaceutical companies either complete development in house, through CROs, or by allowing larger pharmaceutical firms to take over development. Firms specializing in assay design reported their largest share of R&D was spent in development.

D.4.1 Small RD&T Biotechnology Research Activities

The biotechnology industry crosses over many disciplines from agriculture and the environment to health care and industrial applications. However, smaller individual biotech firms typically specialize and develop core competencies in specific genes and treatments that increase their probability of success in discovering a new marketable compound, therapy, or process.

These smaller biopharmaceutical companies want to rapidly bring compounds to market using as few internal resources as possible. Outsourcing by small R&D companies to CROs is becoming increasingly more common for achieving this goal. Preclinical testing is normally kept in house to ensure proprietary information is kept confidential. However, given very few resources to spare, smaller biopharmaceutical companies will often outsource some of the more time-consuming studies to a CRO. Examples include bioavailability, drug optimization, and toxicology. In summary, the biotechnology service firms we spoke with had little problem classifying their activities as R&D and were familiar with the distinction between basic, applied, and developmental research. However, even though many were conducting contract research for larger biotech or pharmaceutical companies, none of the companies we contacted consider themselves a "service" firm.

Although many research projects fail, the small biotech firms that encounter a successful outcome from their applied research are frequently purchased by a large pharmaceutical company; transfer all or part of the IP to a partner through a licensing of the proprietary technology; or create a third jointly owned entity. Such business models may be supported by the RD&T service sector just as independent biotechnology firms use these services.

However, in recent years, many smaller biotech companies have become more independent because of increases in capital availability. Standard & Poor's (S&P's) industry profile reports that from 1999 to 2002 the biotech industry raised approximately $60 billion through a variety of public and private financing sources, whereas only $15 billion were raised from 1996 to 1998. Nevertheless, the huge total cost of bringing a new drug to market necessitates both hybrid organizational strategies and the extensive use of efficiency-enhancing RD&T service firms.

Even though small biotechnology firms conduct R&D activities in a wide range of areas (including human health, animal health, agriculture and aquaculture, marine and terrestrial microbial applications, industrial and agricultural processing, environmental remediation, and natural resource recovery), their research activities fall into several common categories. The DOC reports R&D activities performed by biotechnology firms can generally be classified as follows (DOC, 2003):

- DNA based
  - gene probes, DNA markers
  - bioinformatics
  - genomics, pharmacogenetics
  - DNA sequencing/synthesis/amplification, genetic engine
- Biochemistry/immunology
  - vaccines/immune stimulants
  - drug design and delivery
  - synthesis/sequencing of proteins and peptides
  - cell receptors/signaling, structural biology
  - combinatorial chemistry, 3-D molecular modeling
  - biomaterials
  - microbiology, virology, microbial ecology
- Bioprocessing based
  - culturing/manipulation of cells, tissues, and embryos
  - extractions, purifications, and separations
  - fermentation, bioprocessing, and biotransformation
- Environmental
  - bioleaching, biopulping, biobleaching, and biodesulfurization
  - bioremediation and biofiltration

D.5 CRO R&D ACTIVITIES

Outsourcing by both large and small pharmaceutical companies is generally done when the drug company believes that it is overburdened by work relating to the drug development process or believes that a CRO may have expertise that allows it to conduct aspects of the process more efficiently. CROs work with their sponsor client to develop trial protocols, standardize their methods for data analysis and regulatory submissions, and create a seamless interchange of communication and data exchange.

CROs specialize in every aspect of drug development, including medicinal chemistry, preclinical testing, clinical trials, sales and marketing, and postmarket testing. Of those we interviewed, none reported performing *basic research*. CROs leverage technology emerging from universities and software vendors to supply their clients with the most efficient tools and processes to conduct the studies they have been contracted to perform.

The CROs interviewed described the small share of their R&D activities directed at *applied research* to be targeted at the creation of proprietary technology, which in turn can be marketed as a service through licensing or contracting. This research is centered in process engineering with a focus on assay development and testing techniques.

The CROs interviewed attributed the largest share of their R&D to performing *development activities*. CROs adopt existing technologies from various industries and convert the technology to meet their business needs. Much of the development is aimed at streamlining the information flows between the sponsor and the CRO and improving the speed and accuracy at which the data can be acquired and analyzed.

Following the completion of preclinical testing and the submission of an IND to FDA, biopharmaceutical companies will most likely contract with a leading CRO that can conduct the clinical trials and efficiently process and analyze data from the field to maximize the speed at which the new drug moves through the FDA approval process. As discussed earlier, many types of CROs specialize in one or all of the services a biopharmaceutical company may need. However, the core mission is always the same—provide efficient and accurate methods and tools to ensure timely completion of the clinical trials and regulatory submissions.

From RTI's interviews, we found that some of the largest CROs in the United States were conducting R&D in support of their research services. The most common areas of development were in

- process engineering in service delivery and
- software development in data acquisition, exchange, and security.

Process engineering was cited as an area of constant reworking in the industry. CROs compete on the promise that their firm has the fastest, most efficient, and streamlined system for moving the drug company's IND through clinical trials. As a result, the larger, more competitive CROs spend large sums of money on research to streamline processes in site recruitment, communication with sponsors, and the efficiency and accuracy of data delivery and analysis.

CROs interviewed also mentioned software development as another source of R&D conducted internally to enhance their services. In all cases, this generally included purchasing existing software from third-party vendors such as Oracle that specialize in clinical trial database management applications. Once purchased, CROs modify these applications to meet the needs and specifications that they believe will have the greatest impact on the quality of services they provide. In addition to modifying existing software, the CROs in cooperation with the pharmaceutical industry have recently developed an industry standard for how data are defined across the industry. The Clinical Data Interchange Standards Consortium (CDISC) is the industry organization leading this initiative.

Electronic data capture (EDC) is another area of software development that CROs are working on. Massive quantities of clinical data are generated in each of the three phases of trials. This information was traditionally filled out on a bubble sheet questionnaire by the physician or patient volunteer and then mailed or faxed back to the CRO where the data were entered into a database. In the late 1990s, CROs began to conceive of compiling trial data over the Internet. Today, Web services allow physicians and patients around the world to enter clinical data into laptops, cell phones, or palm devices, which then send the data over the Internet directly to the CRO's database. Security becomes an important issue as EDC technologies are developed. CROs are forced to comply with the sponsor's strict confidentiality requirements while transferring data and must develop security protocols that ensure that the data will not be captured during transmission from the field to the CRO.

D.6 CMO R&D ACTIVITIES

Biopharmaceutical drug development also requires some special research on the manufacturing side as well. CMOs research the most efficient process for manufacturing large quantities of the new drug. For this reason CMOs adopt many of the same technologies the biopharmaceutical company used to discover the drug. The following tools are used to perform basic and applied research that will ultimately lead to the discovery of a novel pharmaceutical application or gene therapy, new medical diagnostic device or method, or a preventative vaccine. These technologies can also inform and facilitate the product and process development activities conducted at CMOs further down the pipeline. Other examples include the following:

- Bioprocessing technology—uses single-cell microorganisms to catalyze biochemical reactions that in turn produce new products. This technology is used to create insulin, biodegradable plastics, and vaccines for various blood-borne pathogens.
- Cell culture—growing living cells outside of living organisms.
- Recombinant DNA technology—the preferential genetic selection and expression. This technology is used in combination with cloning or protein engineering to achieve new genetic properties in existing cells or proteins.
- Cloning—the production of genetically identical copies of a molecule, cell, or animal allows researchers to study genetic diseases and processes and discover potential drugs and therapies.
- Protein engineering—technology is used to improve the chemical structure of proteins and enzymes to be used in drug development, food processing, and industrial manufacturing.
- Biosensors—attaches biological components to transducers to measure extremely low concentrations of certain substances. This technology allows for the development of products that measure nutritional value of food or allows physicians to measure the levels of vital blood components.
- Nanobiotechnology—is the combination of nanotechnology with microbiology to discover stable micro-structures that can be employed to create nanoprocessors to channel electronic signals.
- Microarrays—are used to study gene structure and function at the DNA or protein molecular level. Arrays are used to monitor and detect mutations in genes and diagnose infectious diseases. These arrays also support the drug discovery and development of new vaccines.

D.7 REFERENCES

Amable, Bruno, and Stefano Palombarini. 1998. Technical Change and Incorporated R&D in the Service Sector. OECD. <http://netec.mcc.ac.uk/WoPEc/data/Papers/ cpmcepmap9808.html>.

Andersen, Birgitte, Jeremy Howells, Richard Hull, Ian Miles, and Joanne Roberts (eds.). 2000. *Knowledge and Innovation in the New Service Economy.* North Hampton, MA: Edward Elgar Publishing Ltd.

Biotechnology Industry Organization (BIO). 2002. Biotechnology Industry Organization. 2004. The Editors' and Reporters' Guide to Biotechnology. Washington, DC: Biotechnology Industry Organization. <http://www.bio.org/speeches/pubs/er/ BiotechGuide.pdf>. As obtained on July 19, 2004.

COMPUSTAT. 2003. American Stock Exchange Database. Contennial, CO: Standard & Poor's, McGraw Hill Companies, Inc.

Ernst & Young. 2002. "Convergence: Ernst & Young's Biotechnology Industry Report Millenium Edition." <http://www.ey.com/global/ download.nsf/US/Convergence_Biotechnology_Millennium_ Report/$file/ConvergenceBiotechnologyRpt.pdf>.

Howells, Jeremy. 1999. "Research and Technology Outsourcing." *Technology Analysis & Strategic Management* 26(1):17-29.

Howells, Jeremy. 2000b. "Understanding the New Service Economy." In Birgitte Andersen, et al. (eds.), *Knowledge and Innovation In the New Service Economy.* Northampton, MA: Edward Elgar Publishing Inc.

Jankowski, John E. 2001. "Measurement and Growth of R&D Within the Service Economy." *Journal of Technology Transfer* 26:323-336.

Organisation for Economic Co-operation and Development (OECD). 2001. *Research and Development Expenditure in Industry 1987-1999*. Paris: OECD Publication Service. Pilat, Dirk. 2001. "Innovation and Productivity in Services: State of the Art." In *Innovation and Productivity in Services*, pp. 17-58. Paris: Organisation for Economic Co-operation and Development (OECD).

Prevezer, M. 1998. "Clustering in Biotechnology in the USA." In *The Dynamics of Industry Clustering*, M. Prevzer and D. Stout (eds.), Oxford: Oxford University Press.

Standard & Poor's. Standards & Poor's Biotechnology Industry Survey. May 2002.

Toole, A.A. 2003. "Understanding Entrepreneurship in the U.S. Biotechnology Industry." In *The Emergence of Entrepreneurship Policy: Governance, Start-Ups, and Growth in the U.S. Knowledge Economy*, D.M. Hart (ed.), Cambridge: Cambridge University Press.

U.S. Department of Commerce (DOC), Technology Administration and Bureau of Industry and Security. 2003. "A Survey of the Use of Biotechnology in U.S. Industry." Washington, DC: U.S. Department of Commerce. <http://www.technology.gov/reports/Biotechnology/CD120a_0310.pdf>. As obtained on July 19, 2004.

Appendix E: Definitions of R&D

Most U.S. agencies and many foreign agencies follow NSF's definition of R&D. However, R&D is defined slightly differently across different U.S. and international agencies. This appendix describes and contrasts R&D definitions used by NSF, OECD, and U.S. R&D tax credit codes.

E.1 NATIONAL SCIENCE FOUNDATION'S DEFINITION OF R&D

The NSF was created in 1950 by the National Science Foundation Act. This act directs the NSF to collect, interpret, and analyze data on the availability and need of scientific and technical resources. The NSF Act also instructs the agency to provide a source of information for policy formulation for other federal agencies. Since 1953, NSF's Division of Science Resources has sponsored and managed a survey of industrial R&D. This survey is the method by which NSF collects R&D data from manufacturing and service industries. From 1953 to 1956, the Bureau of Labor Statistics (BLS) in the U.S. Department of Labor conducted the R&D survey. Since 1957, the Bureau of the Census in the U.S. Department of Commerce has conducted the survey.

NSF has adopted a widely accepted definition of R&D that comprises three general categories of research: basic, applied, and development. These categories are distinguishing between R&D-related activities and all other activities, as stated clearly at the beginning of the survey. These categories are defined as follows:

- Basic research is research directed toward increases in the knowledge or understanding of fundamental aspects of phenomena and of observable facts without specific application toward processes or products. This type of research is limited to the federal, university, and nonprofit sectors.

- Applied research is research directed toward gaining knowledge that will meet a specific need. This includes research for specific commercial objectives.
- Development is the systematic use of knowledge directed toward the production of a product, service, or method. This includes the design and development of prototypes and processes. However, it excludes quality control, routine product testing, and production.

Based on NSF's definition, an activity is considered R&D if it is related to one or more of the following goals:

- Pursue a planned search for new knowledge whether or not the search has reference to a specific application.
- Apply existing knowledge to problems involved in creating a new product or process, including work required to evaluate possible uses.
- Apply existing knowledge to problems involved in improving a present product or process.

R&D includes the activities described above, whether assigned to separate R&D organizational units of the company or carried out by company laboratories and technical groups not part of an R&D organization.

NSF's definition specifically excludes the following:

- R&D from acquired companies prior to acquisition;
- amortization above actual cost of property and equipment related to R&D activities;
- test and evaluation once a prototype becomes a production model;
- routine product testing;
- geological and geophysical exploration activities;
- technical services such as
  - quality and quantity control,
  - technical plant sanitation control, and
  - trouble-shooting in connection with breakdowns in full-scale production;
- advertising programs to promote or demonstrate new products or processes;
- assistance in preparing speeches and publications for persons not engaged in R&D; and

- social science R&D, which is defined to encompass those activities devoted to further understanding the behavior of groups of human beings or of individuals as members of groups. Some of the topics include the following:
  - personnel R&D
  - economic R&D
  - artificial intelligence and expert systems R&D
  - consumer, market, and opinion R&D
  - engineering, psychology R&D
  - management and organization R&D
  - actuarial and demographic R&D
  - educational processes and applications R&D
  - R&D in law

E.2 FRASCATI MANUAL

In 1963, the OECD produced the first draft of *The Proposed Standard Practice for Surveys of Research and Experimental Development*, or the Frascati Manual. This manual is part of the OECD series, "The Measurement of Scientific and Technological Activities." The Frascati Manual attempts to measure the R&D of OECD member countries that have similar economic systems. The OECD designed the manual for the experts who collect and issue national R&D estimates.

The Frascati Manual defines R&D as comprising "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD, 1994b, p. 7). R&D is a term covering three research activities: basic research, applied research, and experimental development. Those activities are defined in the Frascati Manual as follows:

- Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. Basic research analyzes properties, structures, and relationships with a view to formulating and testing hypotheses, theories, or laws. The results of basic research are not generally sold but are usually published in scientific journals or circulated to peers. Occasionally, basic research may be kept confidential for security reasons.
- Applied research is also original investigation undertaken to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. The results of applied research are intended primarily to apply to a single or

limited number of products, operations, methods, or systems. Applied research develops ideas into operational form. The knowledge or information derived from it is often patented but may also be kept confidential.

- Experimental development is systematic work, drawing on existing knowledge gained from research and practical experience that is directed to producing new materials, products, and devices; to installing new processes, systems, and services; or to improving substantially those already produced or installed.

The basic criterion for distinguishing R&D from related activities is the element of novelty and the resolution of scientific and/or technological uncertainty. Institutions and firms whose principal activity is R&D often have secondary, non-R&D activities (e.g., scientific and technical information, testing, quality control, and analysis). If the secondary activity is undertaken primarily in the interests of R&D, it is included in R&D activities. However, if the secondary activity is designed essentially to meet needs other than R&D, it is excluded from R&D.

The Frascati Manual specifically excludes a number of related innovation activities from its definition of R&D. These include the following activities:

- education and training.
- other related scientific and technological activities.
- other industrial activities.
- administration and other supporting activities.
- scientific and technical information services (collecting, coding, recording, classifying, disseminating, translating, analyzing, evaluating services, technical personnel, bibliographic services, patent services, scientific and technical information extension and advisory services, and scientific conferences), except where conducted solely or primarily for the purpose of R&D support.
- general-purpose data collection to record natural, biological, or social phenomena that are of general public interest or that only the government has the resources to record (routine topographical mapping; routine geological, hydrological, oceanographic, and meteorological surveying; astronomical observations; and marketing surveys).
- testing and standardization. This refers to maintaining national standards, calibrating secondary standards and routine testing and analyzing materials, components, products, processes, soils, atmosphere, etc.
- feasibility studies. Investigation of proposed engineering projects using existing techniques to provide additional information before deciding on implementation. In the social sciences, feasibility studies are investigations of the

socioeconomic characteristics and implications of specific situations (e.g., a study of the viability of a petrochemical complex in a certain region). However, feasibility studies on research projects are part of R&D.

- specialized medical care. Refers to routine investigation and normal application of specialized medical knowledge. There may, however, be an element of R&D in what is usually called “advanced medical care,” carried out, for example, in university hospitals. Usually such advanced medical care is not considered R&D, and all medical care not directly linked to a specific R&D project should be excluded from the R&D statistics.
- patent and license work. All administrative and legal work connected with patents and licenses. However, patent work connected directly with R&D projects is R&D.

The activities that are a part of the innovation process, but rarely involve any R&D (patent filing and licensing, market research, manufacturing start-up, tooling up and redesign for the manufacturing process), are excluded from the R&D estimates. However, some activities, such as tooling up, process development, design, and prototype construction, may contain an appreciable element of R&D. This makes it difficult to identify what should or should not be defined as R&D. One of the greatest sources of error in measuring R&D lies in the difficulty of locating the cut-off point between experimental development and the related activities.

E.3 R&D TAX CREDIT—DEFINITION OF R&D

Congress enacted the R&D tax credit in 1981. It is important to understand the tax credit definition of R&D because it may influence a company’s internal tracking of R&D expenditures. The tax credit definition of R&D is more exclusive than NSF’s or Frascati’s. Tax credits are awarded to firms or individuals who engage in “qualified research.” Since its inception, the bill has been extended eight times.

Qualified research is defined as

- ***Research*** undertaken for the purpose of discovering information
  - that is technological in nature and
  - whose application is intended to be useful in developing a new or improved business component of the tax payer.
    - Business component is defined as any product, process, computer software, technique, formula, or invention that is
      - held for sale, lease, or license; or

      - used by the taxpayer in trade or business of the taxpayer.
  - Special rule for production processes:
    - Any plant process, machinery, or technique for commercial production of a business component shall be treated as a separate business component (and not as part of the business component being produced).
  - Substantially all activities of which constitute elements of a process of experimentation for a purpose (listed below).
- Purposes for which research may qualify for credit:
  - In general, research shall be treated as conducted for the purpose of
    - developing a new or improved function,
    - performance, or
    - reliability or quality.

Qualified research excludes the following:

- *Research after* commercial production of the business component.
- *Adaptation of existing business components* and any research related to adapting an existing business component to a particular customer's requirement or need.
- *Duplication of existing business component;* that is, any research related to reproducing an existing business component (in whole or in part) from a physical examination of the business component itself or from plans, blueprints, detailed specification, or publicly available information with respect to such business component.
- Surveys, studies, etc.
  - efficiency survey
  - activity relating to management function or technique
  - market research, testing, or development (including advertising or promotions)
  - routine data collection
  - routine or ordinary testing or inspection for quality control
- *Computer software*, except to the extent that provided in regulations, any research with respect to computer software that is developed by (or for the benefit of) the taxpayer primarily for internal use by the taxpayer, other than for use in
  - an activity that constitutes qualified research or
  - a production process with respect to which the requirements of qualified research (criteria) are met.
- *Foreign research*—any research conducted outside the United States.

- *Social sciences, etc.*—any research in the social sciences, arts, or humanities.
- *Funded research*—any research to the extent funded by any grant, contract, or otherwise by another person (or governmental entity).

E.4 SUMMARY OF R&D DEFINITIONS

Table E-1 summarizes the three different definitions of R&D described above and presents them side by side to illustrate their similarities and differences. NSF identifies *basic research, applied research,* and *development* as the three types of activities classified as R&D for reporting purposes. All three activities require either the creation of new knowledge or a novel application of existing knowledge. Once a production model is established, all activities associated with further development are not considered R&D. Furthermore, NSF omits all social science research from its definition of R&D activities.

The Frascati Manual classifies R&D activities into the same three general categories: *basic research, applied research,* and *experimental development,* where all activities classified as R&D must be in the pursuit of new knowledge or the discovery of new applications for existing knowledge, product, or process. The Frascati definition lists fewer disqualifying criteria for R&D activities, compared to the R&D tax credit and NSF's definition.

The R&D tax credit bill uses the term "qualified research" to identify activities aimed at creating new information or product and new applications of existing knowledge as applied to existing products. The tax credit bill addresses the issue of modification or adaptation, omitted by the other two institutional definitions. The bill says that modification or adaptation of existing products to meet a client's needs is not considered R&D.

Table E-1. Summary of R&D Definitions

NSF	Frascati	Tax Credit Bill
	Included in the definition of R&D	
Basic research: Pursue **new knowledge** whether or not the search has reference to a specific application **Limited** to federal, university, and nonprofit organizations	**Basic research** is work done to acquire new knowledge, without any particular application or use in view	**Research** that is undertaken to discover information technical in nature, and holds applications useful in developing a new or improved business component[a] of the taxpayer
Applied research: Apply **existing knowledge** to problems involved in the **creation of a new product or process**	**Applied research** is original investigation to acquire new knowledge directed towards a practical objective or a single product, operation, method, or system	**Research** that seeks a new or improved function performance, reliability, or quality
Development: Apply **existing knowledge** to problems involved in the **improvement of an existing product or process**	**Experimental development** is systematic work, drawing on existing knowledge aimed at producing new, or to improving substantially, existing products	Not specified
	Not included in the definition of R&D	
Not specified	Not specified	**Adaptation of existing business components** to fit a particular customer's requirements
R&D from acquired companies prior to acquisition	Not specified	Not specified
Amortization above actual cost of property and equipment related to firm R&D	Not specified	Not specified
Test and evaluation once a prototype becomes a production model	Not specified	**Research after** commercial production of the business component
• Routine product testing • Consumer, market, and opinion R&D • Advertising new products or processes	• Routine product testing • General purpose data collection	• Market research, testing, or development (including advertising or promotions) • Routine data collection
Geological and geophysical exploration activities	Analysis of soils and atmosphere	Not specified
Quality and quantity control	Not specified	Routine or ordinary testing or inspection for quality control
Trouble-shooting for breakdowns in production	Scientific and technical information assistance	Scientific and technical information assistance

(continued)

Table E-1. Summary of R&D Definitions (continued)

NSF	Frascati	Tax Credit Bill
	Not included in the definition of R&D (continued)	
Social sciences, etc.: any research in the social sciences, arts, or humanities	**Social sciences, etc.**: any research in the social sciences, arts, or humanities	**Social sciences, etc.**: any research in the social sciences, arts, or humanities
Not specified	**Feasibility studies**: (e.g., a study of the viability of a petrochemical complex in a certain region)	Efficiency survey
Management and organization R&D	Administration and other supporting activities	Activity relating to management function or technique

[a]**Business component** is defined as any product, process, computer software, technique, formula, or invention that is held for sale, lease, or license or used by the taxpayer in trade or business.

E.5 REFERENCES

Organisation for Economic Co-operation and Development (OECD). 1994b. *Proposed Standard Practice for Surveys of Research and Experimental Development.* Frascati Manual 1993, Paris. Organisation for Economic Co-operation and Development (OECD).

Appendix F: 2003 Survey Instructions and Instrument

U.S. DEPARTMENT OF COMMERCE
Economics and Statistics Administration
U.S. CENSUS BUREAU

2003 Survey of Industrial Research and Development

Form RD-1

Instructions

Page

2003 Survey of Industrial Research and Development
Form RD-1
General Instructions

Changes from 2002 to 2003 R&D survey year

1) Some item headings and numbers have changed. The five mandatory items are now as follows:
   - Question 2, line A
   - Question 2, line B
   - Question 4D, column 1
   - Question 4D, column 3
   - Question 11
2) The categories for energy in Question 12 are changed so that conservation and utilization are now reported under "All other energy."

How this information is used

Information about corporate research and development (R&D) activities is important in assessing our nation's scientific and technological resources. Your survey answers help us to provide national data on industrial R&D. This information is not available from any other source. Your participation is appreciated so that we can produce timely and comprehensive data.

Who fills out this survey?

U.S. publicly traded and privately owned, nonfarm business firms

This survey does ***not*** include:

- Operations owned by Federal, state, or local governments
- Nonprofit organizations
- Trust or pension plans performing only investments

If you received this form in error, please explain in the Remarks section on page 10 of the survey form and return the form.

Which company operations should you include in your survey answers?

Report all domestic operations of your ***entire consolidated domestic enterprise***, including all U.S. subsidiaries, affiliates, and branches.

Report all parts of the company located in the 50 United States and the District of Columbia (D.C.), except where indicated differently.

For holding companies, report for all U.S. subsidiaries, affiliates, and branches under the ownership and control of the holding company.

EXCEPTION: If you report separately for a component of this company based upon an arrangement with the Census Bureau, please continue to do so.

Reporting period for your survey answers

Please provide calendar year 2003 information, if possible. If not, please use your fiscal year ending between September 2003 and March 2004

Comparing your 2002 and 2003 responses

If your company reported for 2002, entries from that form are preprinted on this form. (If you would like to correct these figures, please do so.) If your answers for 2003 are substantially higher or lower than your 2002 answers, you may comment on the reasons in the Remarks section on page 10 of the survey form." Such reasons may include new government contracts, a revised accounting method, or an R&D unit that was acquired or disposed of during 2002 or 2003.

How to report tax incentives for R&D

The Federal government and many states offer incentives for research and development activity. For purposes of this survey, please report your total R&D expenditures regardless of any tax incentives.

For further information on the Federal research tax credit please go to:

http://www.irs.gov/businesses/

For further information on state tax incentives, please contact the Comptroller of the Treasury in your state.

To request more time to complete your form or additional copies of the form

Please provide your 11-digit identification number (ID) as printed on the form above your address when you contact us.

For more time, call the Census Touchtone Data Entry System: 1-800-851-2014.

For official copies of the form, call (812) 218-3331.

OR

Write: U.S. Census Bureau
1201 East 10th Street
Jeffersonville, IN 47132-0001

To obtain a sample copy of the form, please visit the following web site. However, that sample copy cannot be used to submit your survey response because it lacks the appropriate labeling.

http://help.econ.census.gov/econhelp/rd/

For answers to your questions regarding this form

Write:

U.S. Census Bureau, Manufacturing and Construction Division
ATTN: Special Studies Branch
Room 2135/4
Washington, DC 20233–6900

Phone:

1 –800-851-2014 (option "0")

Use our web site at **http://help.econ.census.gov/econhelp/rd/**

- Submit e-mail via our secure server to encrypt your message and to keep your survey participation confidential
- See answers to frequently asked questions

Electronic alternative for reporting

An electronic questionnaire may be used to report your responses. This electronic alternative potentially saves time for you and helps us to reduce processing costs. If you use the electronic alternative, please do ***not*** mail in the paper form. For questions about installing or using the electronic questionnaire, please call the Electronic Reporting Staff at 800–838–2640.

System Requirements

1. Microsoft Windows 98 or higher.

2. Microsoft Internet Explorer or Netscape Navigator 4.0 or above (128-bit encryption).

3. If you set your screen display for 16-bit color or higher, the forms will be easier to read. The forms are harder to read with 256-color display.

Have your username (UID) and password (PW) handy. ***The username and password are case sensitive.***

1. Go to the following Business Help Site at: **www.census.gov/econhelp/rd**
2. Click on Electronic Reporting
3. Follow the instructions for downloading software.

Transmitting your data

You may transmit you completed data to the Census Bureau electronically via Internet, or by mail.

Burden hour estimate

Public reporting burden for this collection of information is estimated to average 18 hours per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimates or any other aspects of this collection of information, including suggestions for reducing this burden, to:

Suzanne H. Plimpton
National Science Foundation
4201 Wilson Boulevard, Room 485
Arlington, VA 22230.

Survey Definitions of R&D

R&D includes the following:

- the planned, systematic pursuit of new knowledge or understanding toward general application (basic research);
- the acquisition of knowledge or understanding to meet a specific, recognized need (applied research); and
- the application of knowledge or understanding toward the production or improvement of a product, service, process, or method (development).

This survey covers industrial R&D performed by people who are

1) trained—either formally or by experience—in engineering or in the physical, biological, mathematical, statistical, or computer sciences, and
2) employed by a publicly or privately owned firm engaged in for-profit activity in the 50 U.S. states or D.C. (This also includes R&D they may perform ***outside*** of the 50 states and D.C.)

This survey specifically ***excludes*** quality control, routine product testing, market research, sales promotion, sales service, and other nontechnological activities; routine technical services; and research in the social sciences or psychology.

This survey defines basic research, applied research, and development as follows:

Basic research is the pursuit of new scientific knowledge or understanding that does not have specific immediate commercial objectives, although it may be in fields of present or potential commercial interest.

Applied research applies the findings of basic research or other existing knowledge toward discovering new scientific knowledge that has specific commercial objectives with respect to new products, services, processes, or methods.

Development is the systematic use of the knowledge or understanding gained from research or practical experience directed toward the production or significant improvement of useful products, services, processes, or methods, including the design and development of prototypes, materials, devices, and systems.

Survey Definitions of R&D *(continued)*

Types of R&D activities to consider for this survey

INCLUDE:	EXCLUDE:
• Activities that incorporate: – Basic and applied research in the sciences and engineering – Design and development of new products and processes – Enhancement of existing products and processes • Activities carried on by persons trained, either formally or by experience, in: – Biological sciences (e.g., medicine) – Computer science – Engineering – Mathematical and statistical sciences – Physical sciences (e.g., chemistry and physics) • Activities that take place in: – Separate R&D organizational units of the company – Company laboratories – Technical groups not part of an R&D organization.	• R&D from acquired companies prior to acquisition (in-process R&D) • Amortization above the actual cost of property and equipment related to your R&D activities • Test and evaluation once a prototype becomes a production model • Routine product testing • Geological and geophysical exploration activities • Technical services such as: – Quality and quantity control – Technical plant sanitation control – Troubleshooting in connection with breakdowns in full-scale production • Advertising programs to promote or demonstrate new products or processes • Assistance in preparation of speeches and publications for persons not engaged in R&D • Social science R&D including: – Personnel R&D – Economic R&D – Artificial intelligence and expert systems R&D – Consumer, market, and opinion R&D – Engineering psychology R&D – Management and organization R&D – Actuarial and demographic R&D – Educational processes and applications R&D – R&D in law

Question-by-Question Instructions

Question 1

Question 1 asks about your company's ownership as of December 31, 2003.

If "yes," your company was owned or controlled by another company on December 31, 2003, follow the instructions below:

Your situation	Action to take
Your company was purchased by another company after March 31, 2003	Note the new owner and purchase date under the Remarks section on page 10 of the form. Complete the rest of the form for the months ***prior*** to the purchase of your company.
Your company was purchased by another company on or prior to March 31, 2003	Note the new owner and purchase date under the Remarks section on page 10 of the form and return the form without completing the rest of it.

If you have questions, please call the R&D Survey staff at 1-800-851-2014 (option "0") to determine whether you are required to complete the form.

Question 2A

Question 2A covers domestic company sales. Report only the parts of your company located ***within*** the 50 United States or D.C.

INCLUDE:	EXCLUDE:
• Sales, operating receipts, and revenues from all domestic operations of the company, ***net of returns and allowances*** • Receipts from sales of products and services provided to other companies, individuals, U.S. Government agencies, and foreign countries • Net selling value of shipments, f.o.b. plant, after discounts and allowances minus freight charges and excise taxes • Revenue from investments, rents, and royalties only if it is the principal business of the company • Interest, dividends, commissions, and rental income as part of revenues ***only*** if you are a finance, insurance, or real estate company • Value of assets sold under a capital lease agreement • Export transfers to your foreign subsidiaries, affiliates, and branches.	• Sales and other taxes collected and paid directly to government taxing agencies • Domestic intracompany transfers • Receipts from sale of products and services provided by your foreign subsidiaries, affiliates, and branches. • Receipts from sale of products and services provided by your subsidiaries, affiliates, and branches in Puerto Rico and other U.S. territories ***outside*** the 50 United States and D.C. • Income from interest, dividends, and commissions (Exception: Companies in the finance, insurance, and real estate industries) • Other nonoperating income (e.g., royalties)

Question 2B

Question 2B covers domestic company employment. Report only the parts of your company located ***within*** the 50 states or D.C.

INCLUDE:
• Full- and part-time employees of the company as defined on Treasury Form 941, Employer's Quarterly Federal Tax Return, and Circular E, Employer's Tax Guide, if filed for the entire company • Number of employees in all activities ***within*** the 50 United States or D.C. during the pay period that includes March 12, 2003 • Persons on paid sick leave, paid holidays, and paid vacations during the pay period that includes March 12, 2003.

Question 3

Question 3 covers the scientists and engineers who are employees of your company and perform R&D activities. It asks for the number of full-time equivalent (FTE) scientists and engineers who work on your company's R&D ***within*** the 50 United States or D.C.

There are two steps to calculate the number of FTEs for R&D scientists and engineers:

1. For company laboratories performing only research and development, count the number of scientists and engineers employed in January 2004.

2. For employees whose activities are not solely devoted to R&D, use the proportion of their time that is devoted to R&D to compute the number of full-time equivalent R&D scientists and engineers. For example, if a company had 60 scientists and engineers in January 2004 and one-fourth of their time was charged to R&D projects, then that company would have 15 full-time equivalent R&D scientists and engineers. Add these full-time equivalents to the count from the previous step.

INCLUDE:
• All persons engaged in scientific or engineering work at a level that requires knowledge of physical or life sciences or engineering or mathematics • Persons with experience equivalent to completion of a 4-year college course with majors in these fields, regardless of whether they actually hold degrees in the fields

Question 4

Question 4 covers the R&D that is performed both (1) ***within*** your company and (2) ***within*** the 50 United States or D.C.

How to decide which expenditures to include as R&D costs

INCLUDE:	EXCLUDE:
• Wages, salaries, and related costs • Materials and supplies consumed • R&D depreciation • Cost of computer software used in R&D activities • Utilities, such as telephone, telex, electricity, water, and gas • Travel costs and professional dues • Property taxes and other taxes (except income taxes) incurred on account of the R&D organization or the facilities they use • Insurance expenses • Maintenance and repair, including maintenance of buildings and grounds • Company overhead including: personnel, accounting, procurement and inventory, and salaries of research executives not on the payroll of the R&D organization	• R&D from acquired companies prior to acquisition (in-process R&D) • Capital expenditures • Test and evaluation once a prototype becomes a production model • Patent expenses • Income taxes and interest

Question 4 *(continued)*

How to decide which category of R&D

<table>
<tr><td>1. Basic research</td><td colspan="2">Projects that pursue new scientific knowledge or understanding that does not have specific immediate commercial objectives, although it may be in fields of present or potential commercial interest</td></tr>
<tr><td>2. Applied research</td><td colspan="2">Projects that apply the findings of basic research or other existing knowledge toward discovering new scientific knowledge that has specific commercial objectives with respect to new products, services, processes, or methods</td></tr>
<tr><td rowspan="3">3. Development</td><td colspan="2">Projects that are directed toward the systematic use of the knowledge or understanding gained from research or practical experience directed toward the production or significant improvement of useful products, services, processes, or methods, including the design and development of prototypes, materials, devices, and systems</td></tr>
<tr><td>INCLUDE:</td><td>EXCLUDE:</td></tr>
<tr><td>• Expenditures for designing and conducting clinical trials of drugs, pharmaceuticals, or other products that have not been marketed
• Software development
– Designing and/or adapting software if the application has commercial value (exclude software development for internal use)
– Beta version of software being developed that has potential commercial application
– Design and operation of pilot plants and semiwork plants
• Engineering activity required to advance the design of a product or process so it meets specific functional and economic requirements
• Design, construction, and testing of prototypes and models including test models for defense contracts
• Designs for special manufacturing equipment and tools
• Preparation of reports, drawings, formulas, specifications, standard practice instructions, or operating manuals</td><td>• Software development intended for within company use only
• •Routine technical services to customers
• Tool making and tool tryout
• Production of detailed construction drawings and manufacturing blueprints</td></tr>
</table>

Question 4 *(continued)*

How to decide which category to use for sources of R&D funding

Source of R&D	INCLUDE:	EXCLUDE:
Federal funds	• Federally funded R&D performed ***within*** the company. Include only the amount of work done on Federal R&D contracts or subcontracts in the current year. • R&D portion of procurement contracts or subcontracts	• Federally funded R&D contracted or subcontracted to or otherwise performed by others ***outside*** of your company. (Report such funds in Question 6, line A.) • Expenditures for independent research and development (IR&D). (Report in column 2, Company funds.)
Company and other	• R&D from company and other nonfederal sources that is performed ***within*** the company. NOTE that "**company and other funds**" and "**company funded**" are used interchangeably in the Form RD-1. • R&D your company performs under contracts you have with non-Federal sources • Costs for independent research and development (IR&D). We define IR&D funds as R&D performed by the company for which you anticipate reimbursement by the government through indirect charges for the purchase of products or services. Qualified projects usually have potential interest to the Department of Defense or other agencies of the Federal government. These IR&D funds are excluded from federal funds received for federally sponsored research and development contracts.	• R&D from nonfederal sources that is contracted to or otherwise performed by others ***outside*** of your company (Report such funds in Question 6, line A.)

Question 5

Question 5 asks for an estimate or projection of the cost of R&D your company expects to perform in 2004 in the 50 United States or D.C. that will be funded by company and other non-Federal sources.

Question 6A

Question 6A covers the R&D that was ***both*** performed for your company (1) by ***others outside your company*** such as contractors, and (2) ***within*** the 50 United States or D.C.

Include payments for R&D projects, contracts, or services performed for your company by contractors, suppliers, educational institutions, or other organizations.

Question 6B

Question 6B asks for the type of organizations that performed the portion of your answer to question 6A for company and other nonfederal sources of R&D funding.

Definitions for types of organizations	
For-profit companies	A company that is organized to pursue profit
Universities and colleges	A degree-granting institution of higher learning, having facilities for teaching and research
Other nonprofit organizations	An organization that is not organized to pursue profit. However, universities and colleges are reported in another category.

Question 7A

Question 7A covers R&D performed ***outside*** the 50 United States and D.C. including R&D performed in Puerto Rico.

For Question 7A, line 1, report payments for R&D projects, contracts, or services performed for your company by contractors, suppliers, educational institutions, or other organizations.

Question 7B

Question 7B provides more detail for your answer to Question 7A, line 4. If a country is not listed, please include the R&D in the “Other” category.

Question 8

Question 8 covers domestic federally funded R&D by agency.

Question 9

Question 9 covers R&D by type of expense

A. Wages and salaries of R&D personnel

INCLUDE:	EXCLUDE:
• Gross earnings paid in calendar year 2003 to employees engaged in R&D (follow the definition of salaries and wages that is used for calculating withholding tax) • Salaries of officers in the research establishment(s) of a corporation	• Payments to proprietor or partners if an unincorporated concern • Employee fringe benefits (Report under "B. Fringe benefits.")

B. Fringe benefits of R&D personnel

A **fringe benefit** is an employment benefit granted by an employer that has monetary value but does not affect basic wage rates. It includes any benefits given in addition to wages.

INCLUDE:
• Disability benefits • Life and medical insurance • Paid holidays • Retirement benefits, pension, and social security contributions • Stock options • Time-off benefits • Vacation, annual, sick, and maternity leave

C. Materials and supplies consumed

Report the delivered cost for all purchased materials consumed.

INCLUDE:	EXCLUDE:
• Materials and supplies that were: – Received from other companies – Withdrawn from inventory – Received from other establishments of this company • All work done for your laboratories and other technical units by noncompany organizations; for example: Model construction by a non-company model shop	• Purchases from other R&D organizations

Question 9 *(continued)*

D. Depreciation on R&D property and equipment

INCLUDE:
• Depreciation and amortization charged during the year against property and equipment related to your R&D activities • Depreciation and amortization against property and equipment acquired since the beginning of the year that was ***sold or retired*** during the year and not in service at the end of the year • Depreciated amounts no higher than the actual cost of property and equipment

E. All other R&D expenses

INCLUDE:
• Books and periodicals • Company overhead • Property and other taxes • Utilities

Question 10A

Question 10A covers R&D by selected technology area.

A. Biotechnology

Definition of biotechnology for this survey:

Biotechnology is the application of science and technology to living organisms, as well as parts, products, and models thereof, to alter living or nonliving materials for the production of knowledge, goods, and services.

INCLUDE:

- DNA technologies such as:
  - Genetics
  - Pharmacogenetics
  - Gene probes
  - DNA sequencing/synthesis/simplification
  - Genetic engineering
- Protein and molecular technologies such as:
  - Protein/peptide sequencing/synthesis
  - Lipid/protein glycoengineering
  - Proteomics
  - Hormones
  - Growth factors
  - Cell receptors/signaling/pheromonics
- Cell and tissue culture and engineering including:
  - Cell/tissue culture
  - Tissue engineering
  - Hybridization
  - Cellular fusion
  - Vaccine/immune stimulants
  - Embryo manipulation
- Process biotechnologies such as:
  - Bioreactors
  - Fermentation
  - Bioprocessing
  - Bioleaching
  - Biopulping
  - Biobleaching
  - Biodesulphurization
  - Bioremediation
  - Biofiltration
- Subcellular organism research including:
  - Gene therapy
  - Viral vectors
- Other biotechnology areas such as:
  - Bioinformatics
  - Nanobiotechnologies

Question 10A *(continued)*

B. Software development

INCLUDE:	EXCLUDE:
• Application development tools and environments • Applications software • Computer-aided design tools and methods • Computer systems software	• Software programming or engineering used exclusively for internal company operations such as financial management or human resources

C. Materials synthesis and processing

Formulation and manipulation of new or improved materials using the data and techniques of science and engineering

INCLUDE:
• Advanced structural materials in the industrial machinery, medical, building, and construction industries • Higher performance semiconductors and photonic devices in the semiconductor industry • Ceramics and alloys designed to withstand extreme temperatures and stresses for use in engine and structural parts in the aerospace and automotive industries • Composite materials for use in sporting goods • New and significantly improved synthesis and production techniques for existing materials

D. Other areas

Report the remainder of R&D costs so that the total for this question matches Question 4, line D, column 3.

Question 10B

Question 10B asks for the nanotechnology proportion of the R&D expenditures provided in Question 10A.

For example, if about a fourth of your biotechnology R&D expenditures was devoted to nanotechnology projects, report 25% in Question 10B.

Nanotechnology is the creation and utilization of materials, devices, and systems through the control of matter on the nanometer-length scale, that is, at the level of atoms and molecules in the range of 1 to 100 nanometers.

INCLUDE:
• Materials and systems that exhibit novel and significantly improved physical, chemical, and biological properties; phenomena; and processes because of their size

Question 11

Question 11 covers R&D for each state location where your company has research and development laboratories or facilities.

It is not necessary to calculate separately individual assignments made outside the home state of a particular research staff.

Question 12

Question 12 covers R&D by type of energy source.

The types of R&D projects that are included:

INCLUDE:
• R&D to increase energy resources or capabilities • Development of energy equipment • Products and processes for exploration, extraction, transportation, processing, storage, generation (including conversion), distribution, conservation • Present, new, or improved forms of energy

How to estimate if the project is for joint or multiple purposes

Estimate the portion of the cost incurred for energy purposes.

Include the total cost of the R&D energy spending if the primary purpose of the project is energy R&D and costs cannot be apportioned.

Exclude costs if the project is not primarily for energy research and development and the costs cannot be apportioned.

Question 12 *(continued)*

What is included for each type of energy:

Type of energy	INCLUDE:
Nuclear	• Fission and fusion
Fossil fuels	• Oil • Gas • Shale • Coal – Including synthetic fuels designed to convert coal to gaseous and liquid products – Including equipment and techniques to improve the productivity and recovery rates of coal mining
Geothermal and solar	• Geothermal heat pumps • Geothermal power plant generators • Photovoltaic technology • Solar water-heating systems
All other energy sources	• Conservation and utilization R&D to reduce consumption either at the point of energy use or in the transmission, transportation, storage, and conversion of energy including such activities as: – Reduce fuel consumption in manufacturing – Improve the efficiency of transportation of energy products – Produce an end product that is more efficient in energy consumption • Wind, waste, hydroelectric • Other energy R&D that cannot be classified above

Question 13

Question 13 covers your share of R&D expenditures funded by company and other nonfederal sources for collaborative R&D by type of R&D partner. These joint activities may or may not be organized as alliances, partnerships, or joint ventures.

INCLUDE:	EXCLUDE:
• Activities performed jointly with other organizations including legally distinct business units, universities, government agencies, or nonprofit organizations • Alliances • Partnerships • Joint ventures	• Purchasing, funding, or financing relationships that do not involve joint or collaborative R&D

Definitions of types of R&D partners

For-profit companies	A company that is organized to pursue profit
Federal laboratories	An organization of the U.S. government
Universities and colleges	A degree-granting institution of higher learning, having facilities for teaching and research
Other nonprofit organizations	An organization that is not organized to pursue profit. However, universities and colleges are reported in another category.

Question 14

Question 14 asks for information on the time period that your survey responses cover. It also asks about your company organization.

Question 15

Question 15 provides space for your contact information. Please give the name and telephone number of the person in your company to contact regarding this report.

Remarks

The Remarks section provides space for your comments and explanations.

WARNING CONCERNING ELECTRONIC MAIL: The Internet is not a secure means of transmitting information unless it is encrypted. If you choose to communicate with the Census Bureau via electronic mail, the Census Bureau cannot guarantee the privacy of the information while transmitted, but will safeguard it in accordance with Title 13. Be advised that making inquiries regarding this survey via electronic mail may divulge your participation in this survey.

U.S. DEPARTMENT OF COMMERCE
Economics and Statistics Administration
U.S. CENSUS BUREAU

FORM **RD-1** (02-13-2004)

2003 SURVEY OF INDUSTRIAL RESEARCH AND DEVELOPMENT

OMB No. 3145-0027: Approval Expires 01/31/2005

Mail your completed form to ▶ **U.S. CENSUS BUREAU**
1201 East 10th Street
Jeffersonville, IN 47132-0001

Please read the accompanying instructions before answering the questions.

Need help or have questions about filling out this form?

Visit our Web site at **www.census.gov/econhelp/rd**

To speak with an analyst, call 1-800-851-2014, option "0" between 8:00 a.m. and 5:00 p.m., Eastern time, Monday through Friday.

- OR -

Write to the address above. Include your 11-digit Identification Number (ID) printed in the mailing address.

YOUR RESPONSE IS REQUIRED BY LAW. Title 13, United States Code, requires businesses and other organizations that receive this questionnaire to answer the questions and return the report to the U. S. Census Bureau. By the same law, **YOUR CENSUS REPORT IS CONFIDENTIAL.** It may be seen only by persons sworn to uphold the confidentiality of Census Bureau information and may be used only for statistical purposes. Further, copies retained in respondents' files are immune from legal process.

You will satisfy the mandatory reporting requirements for this survey if you answer ❷, lines A and B; ❹, line D, columns (1) and (3); and ⓫, columns (1) and (2).

Name of person who supplied 2002 data

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(Please correct any errors in this mailing address.)

Except as noted, this report covers your entire consolidated domestic enterprise, including all U.S. subsidiaries, affiliates, and branches. Reasonable estimates are acceptable.

❶ Was this company owned or controlled by another company on December 31, 2003?

001 ☐ Yes - *See instructions.* ☐ No - *Go to* ❷.

HOW TO REPORT DOLLAR FIGURES ▶ Dollar figures should be **rounded** to **thousands** of dollars.

If a figure is **$1,025,628.79:** ***Report*** ⟶

2003		
$ Bil.	Mil.	Thou.
	1	0 2 6

❷

		2003 $ Bil.	2003 Mil.	2003 Thou.	2002 $ Thou.
A. What was the amount of your company's domestic sales, shipments, operating receipts, or revenues, net of returns and allowances? *(EXCLUDE domestic intracompany transfers and sales by foreign subsidiaries. INCLUDE receipts for sales of products and services provided to other companies, individuals, U.S. Government agencies, and foreign countries.)*	102				
		Number			Number
B. How many employees worked in the United States for your company on March 12, 2003? *(Include number of full- and part-time employees whose payroll was reported on Internal Revenue Service Form 941, Employer's Quarterly Federal Tax Return.)*	112				

CONTINUE ON PAGE 2

3 What was the number of full-time equivalent (FTE) scientists and engineers employed by your company as of January 1, 2004 who worked on the following types of R&D?

(See instructions for the definition of FTE scientists and engineers.)

		January 1, 2004	January 1, 2003
		Number of FTEs	Number of FTEs
A. Federally-funded R&D	204		
B. Nonfederal R&D funded by your company and other nonfederal sources	205		
C. **TOTAL** *(Sum lines A and B)*	206		

4 What was the cost of R&D performed within your company in the 50 United States and D.C.?

(Please report R&D performed for each source of funding.)

	2003									2002		
	Federal funds (1)			Company and other (2)			Total (Columns (1)+(2)) (3)			Federal funds (4)	Company and other (5)	Total (Columns (4)+(5)) (6)
	$ Bil.	Mil.	Thou.	$ Bil.	Mil.	Thou.	$ Bil.	Mil.	Thou.	$ Thou.	$ Thou.	$ Thou.
A. Basic research (Research for the advancement of scientific knowledge without specific immediate commercial objectives.)	304			305			306					
B. Applied research (Research directed primarily towards a specific commercial or practical objective.)	314			315			316					
C. Development (Activity translating research into new or improved goods, services or processes.)	324			325			326					
D. **TOTAL** *(Sum lines A through C)*	344			345			346					

5 For 2004 what is your projected cost for company-funded R&D performed by your company in the 50 United States and D.C.?

*(Comparable to the 2003 figure reported in **4**, line D, column (2).)*

		2004		
		$ Bil.	Mil.	Thou.
	401			

INFORMATION COPY
DO NOT USE TO REPORT

CONTINUE ON PAGE 3

If not shown, please enter your 11-digit Identification Number (ID) from the mailing address.

6 **A.** What was the cost of R&D performed by others for your company in the 50 United States and D.C.?

(Please report R&D performed for each source of funding.) . . . .

2003									2002		
Federal funds (1)			Company and other (2)			Total (Columns (1)+(2)) (3)			Federal funds (4)	Company and other (5)	Total (Columns (4)+(5)) (6)
$ Bil.	Mil.	Thou.	$ Bil.	Mil.	Thou.	$ Bil.	Mil.	Thou.	$ Thou.	$ Thou.	$ Thou.
354			355			356					

B. What was the cost of company-funded R&D performed by others for your company in the 50 United States and D.C. by the following types of organizations?

	Key code 8	2003 (1) $ Bil.	Mil.	Thou.	2002 (2) $ Thou.
1. For-profit companies	11				
2. Universities or colleges	21				
3. Other nonprofit organizations	31				
4. TOTAL *(Sum lines 1 through 3. The sum should equal the total reported in line A, column (2).)*	41				

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7 **A.** What was the cost of your company-funded R&D performed outside of the 50 United States and D.C. by your subsidiaries, affiliates, or branches, or by other organizations in which your company owns the following percentages of voting stock or equivalent interest?

		2003 Company and other (2)			2002 Company and other (5)
		$ Bil.	Mil.	Thou.	$ Thou.
1. 0%	363				
2. More than 0% but less than 10%	364				
3. 10%-50%	365				
4. More than 50%	366				
5. **TOTAL** *(Sum lines 1 through 4.)*	369				

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B. What was the cost of your company-funded R&D that was performed outside the 50 United States and D.C. by your subsidiaries, affiliates, or branches, or by other organizations in which your company owns more than 50% of the voting stock or equivalent interest in the following countries and Puerto Rico?

	Key code	2003 (1)			2002 (2)
	12	$ Bil.	Mil.	Thou.	$ Thou.
1. Canada	01				
2. Germany	02				
3. France	03				
4. Japan	04				
5. United Kingdom	05				
6. Puerto Rico	06				
7. Other - *Specify* 1209	07				
8. **TOTAL** *(Sum lines 1 through 7. The sum should equal the amount reported in line A4.)*	10				

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If not shown, please enter your 11-digit Identification Number (ID) from the mailing address.

8 What was the cost of the Federally-funded R&D your company performed in the 50 United States and D.C. for each of these Federal agencies?

	Key code	2003 (1)			2002 (2)
	5	$ Bil.	Mil.	Thou.	$ Thou.
A. Department of Defense (DoD).	11				
B. National Aeronautics and Space Administration (NASA) . . .	21				
C. Department of Energy (DOE)	31				
D. Other Federal agencies.	41				
E. TOTAL *(Sum lines A through D. The sum should equal the total reported in ❹, line D, column (1).)*	51				

9 What was the cost relating to the total R&D performed within your company in the 50 United States and D.C. for the following types of expenses?

	Key code	2003 (1)			2002 (2)
	6	$ Bil.	Mil.	Thou.	$ Thou.
A. Wages and salaries of R&D personnel *(Include scientists and engineers, technicians, secretaries, and other personnel.)*	11				
B. Fringe benefits of R&D personnel *(Include taxable and nontaxable benefits, 401K plans, employers' contribution to health plans.)*	21				
C. Materials and supplies consumed *(Include the cost of all purchased materials consumed.)* . . .	31				
D. Depreciation on R&D property and equipment *(Include depreciation and amortization costs for property and equipment used for R&D during the year.).*	41				
E. All other R&D expenses *(Include R&Ds share of company overhead and other expenses such as utilities, books and periodicals, and property and other taxes.)*	51				
F. TOTAL *(Sum lines A through E. The sum should equal the total reported in ❹, line D, column (3).)*	61				

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10 **A.** What was the cost relating to total R&D performed within your company in the 50 United States and D.C. for the following types of technologies?

	Key code	2003 (1)			2002 (3)
	7	$ Bil.	Mil.	Thou.	$ Thou.
1. Biotechnology (The use of scientific and engineering data and techniques for the study and solution of problems concerning living organisms.)	11				
2. Software development (The formulation of programs, applications, routines, etc., for computers, excluding those used exclusively for internal company operations.)	21				
3. Materials synthesis and processing (The use of scientific and engineering data and techniques for the formulation and manipulation of new materials.).	31				
4. Other areas	41				
5. **TOTAL** *(Sum lines 1 through 4. The sum should equal the total reported in* **4***, line D, column (3).)*	51				

B. What percentage of the R&D costs reported in **10**A are attributable to nanotechnology for each of the following types of technologies?

(Nanotechnology is defined as the creation and utilization of materials, devices, and systems through the control of matter on the nanometer scale, at the level of atoms and molecules in the range of 1 to 100 nanometers.)

	Key code	2003 (2)		2002 (4)	
	7	Whole percents		Whole percents	
1. Biotechnology (The use of scientific and engineering data and techniques for the study and solution of problems concerning living organisms.)	11		%		%
2. Software development (The formulation of programs, applications, routines, etc., for computers, excluding those used exclusively for internal company operations.) .	21		%		%
3. Materials synthesis and processing (The use of scientific and engineering data and techniques for the formulation and manipulation of new materials.).	31		%		%
4. Other areas	41		%		%

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If not shown, please enter your 11-digit Identification Number (ID) from the mailing address.

11 What was the cost of the R&D your company performed in each of the fifty States and the District of Columbia?

(Please report R&D performed for each source of funding.)

Key code 9	State	2003 Federal funds (1)			2003 Total funds (2)			2002 Federal funds (3)	2002 Total funds (4)	Key code 9	State	2003 Federal funds (1)			2003 Total funds (2)			2002 Federal funds (3)	2002 Total funds (4)
		$ Bil.	Mil.	Thou.	$ Bil.	Mil.	Thou.	$ Thou.	$ Thou.			$ Bil.	Mil.	Thou.	$ Bil.	Mil.	Thou.	$ Thou.	$ Thou.
01	AL									19	LA								
02	AK									20	ME								
03	AZ									21	MD								
04	AR									22	MA								
05	CA									23	MI								
06	CO									24	MN								
07	CT									25	MS								
08	DE									26	MO								
09	DC									27	MT								
10	FL									28	NE								
11	GA									29	NV								
12	HI									30	NH								
13	ID									31	NJ								
14	IL									32	NM								
15	IN									33	NY								
16	IA									34	NC								
17	KS									35	ND								
18	KY									36	OH								

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11 What was the cost of the R&D your company performed in each of the fifty States and the District of Columbia?

(Please report R&D performed for each source of funding.) - Continued

Key code 9	State	2003 Federal funds (1) $ Bil.	Mil.	Thou.	2003 Total funds (2) $ Bil.	Mil.	Thou.	2002 Federal funds (3) $ Thou.	2002 Total funds (4) $ Thou.
37	OK								
38	OR								
39	PA								
40	RI								
41	SC								
42	SD								
43	TN								
44	TX								
45	UT								
46	VT								
47	VA								
48	WA								
49	WV								
50	WI								
51	WY								
954	**TOTAL** *(Sum of lines 1 through 51. The sum should equal the totals reported in* 4*, line D, columns (1) and (3).)*								

12 What was the cost of the energy-related R&D your company performed in the 50 United States and D.C. during 2003?

(Include the portion of project cost incurred for the purpose of increasing energy resources or capabilities for each source of funding. These expenditures should also be included as part of the information reported in 4*, line D, columns (1) and (3).)*

	Key code 10	2003 Federal funds (1) $ Bil.	Mil.	Thou.	2003 Total funds (2) $ Bil.	Mil.	Thou.	2002 Federal funds (3) $ Thou.	2002 Total funds (4) $ Thou.
A. Nuclear	11								
B. Fossil fuels	21								
C. Geothermal and solar	31								
D. All other energy sources	41								
E. TOTAL *(Sum lines A through D)*	51								

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If not shown, please enter your 11-digit Identification Number (ID) from the mailing address.

13 What was the cost of the R&D performed by your company in the 50 United States and D.C. company-funded in collaboration with the type of R&D partner listed below?
(These expenditures should also be included as part of the information reported in ❹, line D, column (2).)

	Key code	2003 (1)			2002 (2)
	11	$ Bil.	Mil.	Thou.	$ Thou.
A. For-profit companies	01				
B. Federal laboratories	02				
C. Universities or colleges	03				
D. Other nonprofit organizations	04				
E. **TOTAL** *(Sum lines A through D)*	10				

14 **A.** Do the R&D expenditures reported on this form cover the entire fully consolidated enterprise, including all subsidiaries, affiliates, or branches located in the 50 United States and D.C.? *(Mark "X" only ONE box.)*

1301 ☐ Yes
☐ No - *Please explain in the "REMARKS" section.*

B. Was your company publicly or privately owned? *(Mark "X" only ONE box.)*

1302 ☐ Publicly owned
☐ Privately owned

C. Other than the parent company, how many subsidiaries, affiliates, or branches located in the 50 United States and D.C. owned or controlled by your company (by means of voting stock or other equivalent interest) are included in this report? *(Mark "X" only ONE box.)*

1303 ☐ None
1304 ☐ 1
1305 ☐ 2-5
1306 ☐ More than 5

D. Other than the parent company, how many subsidiaries, affiliates, or branches located outside the 50 United States and D.C. owned or controlled by your company (by means of voting stock or other equivalent interest) are included in this report? *(Mark "X" only ONE box.)*

1307 ☐ None
1308 ☐ 1
1309 ☐ 2-5
1310 ☐ More than 5

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14 **E.** What percent of your company was owned or controlled (by means of voting stock or other equivalent interest) by one or more companies located in the 50 United States and D.C.? *(Mark "X" only ONE box.)*

- 1311 ☐ 0%
- 1312 ☐ More than 0% but less than 10%
- 1313 ☐ 10%-50%
- 1314 ☐ More than 50%

F. What percent of your company was owned or controlled (by means of voting stock or other equivalent interest) by one or more companies located outside the 50 United States and D.C.? *(Mark "X" only ONE box.)*

- 1315 ☐ 0%
- 1316 ☐ More than 0% but less than 10%
- 1317 ☐ 10%-50%
- 1318 ☐ More than 50%

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15 CONTACT INFORMATION

Is the time period covered by this report a calendar year?

0078 ☐ Yes 0079 ☐ No - *Enter time period covered* →

	Month	Year
FROM 0070		
TO 0071		

0072 Name of person to contact regarding this report

0073 Title

	Area code	Number	Extension
Telephone 0074		-	
Fax 0075		-	

0076 Internet e-mail address

	Month	Day	Year
Date completed 0069			

REMARKS *(Please use this space for any explanations that may help us in understanding your reported data.)*

Thank you for completing your 2003 SURVEY OF INDUSTRIAL RESEARCH AND DEVELOPMENT form.

PLEASE PHOTOCOPY THIS FORM FOR YOUR RECORDS AND RETURN THE ORIGINAL.